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**GALWAY HARBOUR EXTENSION ORAL
HEARING: BRIEF OF EVIDENCE OF DR
TOM GITTINGS**

Tom Gittings BSc, PhD, MCIEEM
Ecological Consultant
3 Coastguard Cottages
Roches Point
Whitegate
CO. CORK
www.gittings.ie

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INTRODUCTION

1. My name is Tom Gittings. I have a BSc (Hons) in Ecology from the University of East Anglia and a PhD in Ecology from University College Cork. I am a member of the Chartered Institute of Ecology and Environmental Management (CIEEM). I have over 19 years' experience as a professional ecologist. From 1995-2001, I worked fulltime as an ecological consultant with RPS Group in their Cork office. From 2001-2009, I was employed as a postdoctoral researcher in the Department of Zoology, Ecology and Plant Science, University College Cork where I carried out research into biodiversity and land use. I now work as an independent ecological consultant.
2. I have been carrying out professional bird survey and assessment work since 1989 and have carried out academic research and consultancy work on a wide range of bird species and their habitats. Since 2010, I have been working on a variety of projects for the Marine Institute relating to the Appropriate Assessment of aquaculture and shellfisheries in coastal SPAs. This has included developing and implementing research programmes studying the interactions between waterbirds and aquaculture and fisheries activities in coastal SPAs to provide the information base required for the assessments. As part of this work, I have also written Appropriate Assessment reports for six coastal SPAs, including Inner Galway Bay.
3. My role in this project was to:
 - review the ornithological content of the EIS and NIS;
 - review the bird monitoring data collected by Dr Chris Peppiatt;
 - review the issues raised in the NPWS submissions to An Bord Pleanála and in the Further Information Request from An Bord Pleanála; and
 - prepare site and species-specific assessments of the potential impacts of the Galway Harbour Extension project on the Special Conservation Interest (SCI) species of the Inner Galway Bay SPA.
4. This brief of evidence addresses the potential impacts of the project on Special Conservation Interest (SCI) species of the Inner Galway Bay SPA.
5. This brief of evidence is based on my report *Galway Harbour Extension: Special Conservation Interests Species Assessments*, which is included as Appendix 3.4 in the NIS Addendum/Errata. All information in this brief of evidence is derived from this report, unless otherwise stated.
6. My assessment included the following SCI species: Light-bellied Brent Goose, Wigeon, Red-breasted Merganser, Great Northern Diver, Cormorant, Grey Heron, Bar-tailed Godwit, Curlew, Redshank, Turnstone, Black-headed Gull, Common Gull, Sandwich Tern and Common Tern. Cormorant is listed for its breeding and non-breeding populations, Sandwich Tern and Common Tern for their breeding populations, and the other species for their non-breeding populations.
7. The remaining six SCI species (Teal, Shoveler, Ringed Plover, Golden Plover, Lapwing and Dunlin) have never, or only very rarely been recorded within the development site, and it is considered that the habitat conditions within the site are unsuitable for these species. They have only been recorded irregularly and in very small numbers (if at all) in adjacent areas, so any potential disturbance impacts will not be significant.
8. In this brief of evidence, I consider the breeding and non-breeding populations separately. This reflects differences in: the conservation objectives specified for these populations; the nature of the data available for these populations; and the nature of some of the potential impacts affecting these populations.
9. In this brief of evidence, I refer to the following areas (see Figure 1 in Appendix 3.4 of the NIS Addendum Errata):
 - GHE development site - the area subject to permanent development work.
 - GHE site - the GHE development site and the area subject to maintenance dredging.

- GHE count area - the area covered by the waterbird monitoring counts.
 - Nimmo's Pier-South Park Shore - the intertidal and shallow subtidal habitat between Nimmo's Pier and the Mutton Island causeway.
 - Renmore Beach - the intertidal and shallow subtidal habitat between the GHE development site and the small headland approximately 250 m to the east.
10. In my impact assessment, potential displacement impacts are often expressed as decimal fractions (e.g., 0.3 birds). Clearly, only whole birds can be physically displaced. However, the displacement impact from a site reflects both the numbers occurring within the site and the amount of time they use the site. Therefore, a displacement impact of 0.3 can be interpreted as the displacement of one bird that uses the site for 30% of the time, or two birds that used the site 15% of the time, etc.

DATA SOURCES

11. The main data sources used for my assessment were:
- Analyses of waterbird species habitat usage and distribution patterns in Inner Galway Bay (Appendix 1 in Appendix 3.4 of the NIS Addendum Errata).
 - Waterbird monitoring data of the area around the GHE site collected by Dr Chris Peppiatt (Appendix 2.7 in the NIS Addendum Errata).
 - Irish Wetland Bird Survey (I-WeBS) data for Inner Galway Bay for the winters of 2011/12 and 2012/13 (included in Appendix 1 of this brief).
 - Reviews of the occurrence and distribution of species within Inner Galway Bay generally, and in the vicinity of the development site, and their sensitivities to potential impacts, included within the species profiles reports prepared by Dr Chris Peppiatt (Appendix 2.8 in the NIS Addendum Errata).
12. It should be noted that the area covered in the waterbird monitoring counts (the GHE count area) covered a much larger area of subtidal habitat than will actually be affected by either direct habitat loss, or habitat degradation, from the proposed development (see Figure 1 in Appendix 3.4 of the NIS Addendum Errata).
13. The analyses of waterbird species habitat usage and distribution patterns, included examination of whether species showed predictable patterns of distribution between subsites in relationship to habitat availability.
14. My assessment was also informed by a literature review, which included: the sensitivity of the species to displacement impacts; the effects of construction disturbance on waterbirds; and the species escape distances (the distance at which birds respond to disturbance by taking evasive action).
15. As detailed in the evidence of Dr Chris Peppiatt, the data available for this assessment included detailed waterbird monitoring data for the GHE site and adjacent areas over two full winters (2011/12 and 2012/13) and two full summers (2011 and 2014). I consider that this dataset is sufficient to characterise the waterbird occurrence within the GHE site, and within the area of subtidal habitat around the GHE site potentially affected by habitat degradation and/or disturbance effects. The dataset for waterbird occurrence in adjacent intertidal areas is more limited. However, in combination with information from the scientific literature on species responses to potential disturbance impacts, there is sufficient information available to make an assessment of the likely impacts.
16. The I-WeBS counts only cover around 54% of the subtidal habitat within the SPA (see Figure 1 in Appendix 3.4 of the NIS Addendum Errata). However, as the key species associated with subtidal habitat show predictable patterns of association between their distributions and the availability of suitable habitat (identified from the analyses detailed in paragraph 13 above), there is sufficient information to assess the potential displacement impacts to these species.

KEY ASPECTS OF THE PROPOSED DEVELOPMENT

17. The proposed development will involve the removal of 2.1 ha of intertidal habitat (0.1% of the intertidal habitat within the SPA) and 24.8 ha of subtidal habitat (0.2% of the subtidal habitat within the SPA). This will cause a small reduction in the area of habitat available to waterbirds.
18. The proposed development will also involve temporary construction/dredging disturbance (including maintenance dredging of the turning circle) to an additional 51.8 ha of subtidal habitat. This may reduce the suitability of the habitat for waterbirds.
19. Construction work (particularly blasting/piling), and shipping/boating traffic and activity within the harbour during the operational phase, may cause disturbance impacts to birds in adjacent areas of intertidal and subtidal habitat.

CONSERVATION OBJECTIVES AND THEIR INTERPRETATION

20. The conservation objectives for the Inner Galway Bay SPA, and the attributes and targets specified for these objectives, as defined by NPWS, provide the framework for this assessment.

NON-BREEDING POPULATIONS

21. The conservation objectives for all the waterbird species listed as Special Conservation Interests (SCIs) of the Inner Galway Bay SPA for their non-breeding populations are to maintain their "favourable conservation condition". The favourable conservation conditions of these populations are defined by two attributes, and their associated targets:
 - Population trend - Long term population trend stable or increasing.
 - Distribution - No significant decrease in the range, timing or intensity of use of areas by ... [the SCI species] ... other than that occurring from natural patterns of variation.
22. Displacement impacts can be considered as a type of early-warning indicator: developments that affect population trends will usually first cause significant displacement impacts, and these will then translate into impacts on population trends over a period of years.
23. Assessments of displacement impacts that assume that all displaced birds emigrate or die represent a conservative form of assessment: the population-level consequences of displacement will depend upon the extent to which the remaining habitat is available (i.e., whether the site is at carrying capacity). Some of the displaced birds will be able to find suitable alternative habitat and survive in good condition.
24. My assessment of the impact of habitat loss and degradation, and some aspects of disturbance impacts, on the non-breeding SCI populations focuses on the potential displacement impact. Where significant displacement impacts are predicted to occur, the next step would be to assess the potential impact on the long-term population trend (but this step was not necessary in the case of the present assessment as no significant displacement impacts were identified).
25. The conservation objectives do not specify any criteria for the assessing the level of decrease in the numbers or range (distribution) of areas that is considered significant.
26. The only reasonable scientific interpretation is that displacement impacts are significant when they have population-level consequences. Such consequences can only occur if the site is at its effective carrying capacity prior to the development, or if the displacement impact causes the site to reach its effective carrying capacity. In this situation, the displaced birds will have to compete with birds elsewhere in the site for food and density-dependent reductions in survivorship and/or body condition may occur.
27. Density-dependent reductions in survivorship means that survival rates decrease as population density increases. Loss of body condition in overwintering bird populations may result in reduced survivorship on spring migration.

BREEDING POPULATIONS

28. The conservation objectives for all the waterbird species listed as Special Conservation Interests (SCIs) of the Inner Galway Bay SPA for their breeding populations are to maintain their "favourable conservation condition". The favourable conservation conditions of these populations are defined by a number of attributes, and their associated targets, referring to specific aspects of their breeding biology: breeding population abundance; productivity rate; distribution (breeding colonies); prey biomass available; barriers to connectivity; and disturbance at breeding site.
29. The potential impacts of the Galway Harbour Extension were assessed against the above attributes for each of the SCIs listed for their breeding populations.

HABITAT LOSS AND DEGRADATION (NON-BREEDING POPULATIONS)

30. The potential displacement impact on SCI species listed for their non-breeding populations was calculated using the mean September-March GHE development site count divided by the mean I-WeBS counts for the relevant two winters (2011/12 and 2012/13), with correction factors for the subtidal species to account for the fact that only a proportion of the area counted will be affected by habitat loss and degradation.
31. The predicted displacement due to habitat loss was 0.3%, or less, of the mean I-WeBS count, with the exception of Turnstone (2.1%). The predicted displacement due to habitat loss combined with a worst-case scenario of habitat degradation (i.e., assuming complete exclusion) was 1.0% for Great Northern Diver, 0.7% for Cormorant and 0.1-0.2% for the remaining species.
32. As discussed above, the area covered by the I-WeBS counts only includes around 54% of the subtidal habitat within the SPA. Therefore, the percentage displacement figures for Red-breasted Merganser, Great Northern Diver and Cormorant, and, to a lesser extent, Black-headed Gull and Common Gull, will be significant over-estimates. In addition, as discussed in the species profiles report prepared by Dr Chris Peppiatt (Appendix 2.8 in the NIS Addendum Errata), the much more intensive survey effort involved in the GHE counts will have over-recorded certain species compared to the I-WeBS counts. This will be particularly the case for species that occur offshore (Red-breasted Merganser, Great Northern Diver and Cormorant) and for cryptic species (Turnstone).
33. All the predicted displacement impacts involve very small numbers of birds, and very small percentages of the overall Inner Galway Bay population. Therefore, these displacement impacts will only have consequences at the site population-level, if the population is at, or near, the effective carrying capacity of the site.
34. The Inner Galway Bay Light-bellied Brent Goose population has shown a sustained strongly increasing population trend, indicating that the population is not at, or close to, the effective carrying capacity.
35. The analyses of waterbird distribution patterns in Inner Galway Bay (Appendix 1 in Appendix 3.4 of the NIS Addendum Errata) indicate that Red-breasted Merganser, Great Northern Diver, Cormorant, Grey Heron, Curlew and Redshank occur at relatively uniform densities across suitable habitat within Inner Galway Bay and, therefore, any displaced birds would be evenly distributed across the remaining habitat, rather than concentrated in one area. For these species, the displacement is predicted to cause an increase in overall density of less than 0.1 bird per 100 ha, or, in percentage terms, an increase in overall density of around 1% or less.
36. The predicted displacement impact to Wigeon is 1.6 birds, or 0.1% of the Inner Galway Bay population. Wigeon have low site fidelity, are not sensitive to interference effects, and have some potential ability to use alternative terrestrial habitats in the vicinity of Inner Galway Bay.

37. The predicted displacement impact to Turnstone is 5.9 birds, or around 2.1% of the Inner Galway Bay population. Turnstone has a high potential sensitivity to displacement impacts, due to its high site fidelity, its sensitivity to interference effects and the limited potential for displaced birds to use alternative habitats. However, the predicted displacement impact is likely to be a substantial overestimate of the true displacement impact due to differences in the survey intensity between the GHE and I-WeBS counts. It is also possible that Turnstone will be able to use structures within the completed development: the use of textured construction material has been proposed, which will enhance settlement by algae and invertebrates, potentially creating suitable foraging habitat for Turnstone. Therefore, the actual displacement impact is likely to be very minor.
38. The predicted displacement impact to Black-headed and Common Gull from combined habitat loss and a worst-case habitat degradation scenario, is 1.1-1.4 birds or 0.1% of the Inner Galway Bay population. Any displaced birds would have a very high potential ability to use alternative terrestrial habitats in the vicinity of Inner Galway Bay.
39. Therefore, for the reasons detailed above, for all of the SCI species listed for their non-breeding populations, it is reasonable to conclude that sufficient area and diversity of habitats will be maintained for the species, and that the very minor displacement impacts will not cause any population-level consequences, and the conservation status of the species within the SPA will not be adversely affected by the proposed development.

HABITAT LOSS AND DEGRADATION (BREEDING POPULATIONS)

40. The Cormorant breeding colony is located at Deer Island around 8.5 km from the GHE site. The mean summer GHE count is around 1% of the adult breeding population. This would equate to a potential displacement impact of less than 0.1%, due to habitat loss, and 0.25%, from combined habitat loss and a worst-case habitat degradation scenario. However, this will overestimate the potential displacement impact due to the presence of non-breeding birds. In any case, following the argument for the non-breeding population above, it is reasonable to conclude that this very minor displacement impact will not cause any population-level consequences.
41. The Sandwich Tern breeding colony is located at Illaunnaguroge in Corranroo Bay around 12 km from the GHE site. The distance of the GHE development site from the Sandwich Tern colony suggests that it is unlikely that the site provides important foraging resources for the colony. Therefore, loss and degradation of habitat within the GHE site is unlikely to cause any population-level consequences.
42. In recent years, the main Common Tern colony has been at Rabbit Island. In 2014, this site was abandoned and the main Common Tern colony had moved back to Mutton Island (which had been the site of the main colony in the early-2000s). However, the proximity of the Mutton Island colony to the GHE count area does not mean that the latter is necessarily a particularly important foraging area, and the count data indicates that the GHE count area does not provide crucial food resources for a large proportion of the Mutton Island colony. Furthermore, the mobile nature of the prey, and their lack of dependence on benthic habitats, mean that habitat loss and degradation of a very small amount of the marine habitat within Inner Galway Bay will not significantly affect the prey resources for Common Terns. Therefore, it can be reasonably concluded that there will be no population-level impacts on Common Terns in Inner Galway Bay.

DISTURBANCE (NON-BREEDING POPULATIONS)

43. The potential disturbance zones are the GHE count area¹, for the subtidal species, and Nimmo's Pier-South Park Shore (eastern end) and Renmore Beach, for the intertidal/shallow subtidal species. In addition there is potential for disturbance to high tide roosts on Mutton Island, Hare Island and the rocks on the eastern side of the landward end of the Mutton Island causeway.
44. In the case of the Nimmo's Pier-South Park Shore, it should be noted that this area is separated from the development site by a tidal channel and this will significantly reduce the perceived disturbance experienced by birds in this area from activity within the development site.
45. Disturbance impacts can affect bird populations in two ways. If disturbance levels are intense enough, birds may completely abandon an area and the disturbance impact is, therefore, analogous to habitat loss. At lower disturbance intensities, birds may continue to use an area but may suffer energetic impacts due to loss of foraging time and energy expended in evasive behaviour.
46. For disturbance to cause displacement impacts, the disturbance pressure will have to operate over a wide area (relative to the size of the site) and be more or less continuous. For disturbance to cause significant energetic impacts, birds must be disturbed with sufficient frequency, and/or forced to engage in energetically expensive evasive behaviour (e.g., long flights, or extended interruption of feeding). Various modelling studies have indicated that multiple disturbance events per daylight hour are required to cause impacts on wader survival rates.

CONSTRUCTION DISTURBANCE

47. Disturbance pressures from major construction works can be expected to be generally rather constant, as activities will not change over short periods of time. Therefore, the pattern of disturbance is likely to involve a low frequency of displacement events with birds moving out of the area affected and avoiding it while the disturbance pressure continues. Therefore, the energetic impacts of responding to disturbance (loss of foraging time and energy expended in evasive behaviour) will generally be low, and the following assessment focuses on the potential displacement impacts.
48. Studies of noise impacts on waterbirds, reviewed in my report, indicate that displacement impacts may occur at levels of around 70-85 dBA, while behavioural responses may occur at levels of around 50-55 dBA. 55 dB(A) has been used as a threshold noise level for assessing potential impacts in various assessments of potential impacts to waterbirds from development projects.
49. Figures 10.4.1-10.4.4 in the noise chapter in the EIS shows that no noise impact in excess of 84 dB(A) is predicted for any of the construction activities, while noise impacts greater than 70 dB(A) will be limited to a small area around the immediate vicinity of the construction work. Noise impacts greater than 55 dB(A) will affect significant areas within the subtidal zone of the GHE count area during pile driving and dredging. Noise impacts greater than 55 dB(A) will affect Renmore Beach and most of the Nimmo's Pier-South Park Shore during the backhoe dredging and pile driving. These impacts could also affect high tide roosts on Mutton Island and Hare Island.
50. The species using subtidal habitat might be expected to be potentially the most affected by construction disturbance, as they will occur in the closest proximity to the works. In the case of Red-breasted Merganser, Great Northern Diver and Cormorant, under the worst-case

¹ Note, that there is a typographical error in Section 4.3.1 (page 20) of my species assessment report, which refers to the potential disturbance zone as the GHE site. This does not affect the assessment and the figures in Table 11 are based on the GHE count area, not the GHE site.

scenario of complete displacement from the entire GHE count area, the increase in density in the remaining habitat would be 0.04-0.11 birds/100 ha. Therefore, it is reasonable to conclude that such very minor displacement impacts (which are an overestimate of the actual likely impact) will not cause any population-level consequences. While similar density calculations cannot be made for Black-headed Gull and Common Gull, given the very low percentage displacements for these species (from subtidal habitat), it is also reasonable to conclude that any displacement impacts to these species would be very minor and will not cause any population-level consequences.

51. Most SCl species occurred in very low numbers in, or were absent from, the areas of intertidal habitat counted at Renmore Beach and the Nimmo's Pier-South Park Shore. While the counted areas do not include the entire potential disturbance zone (as indicated by the noise modelling), overall numbers of these species within these zones were unlikely to be very high, given these very low counts. Moreover, the counted areas will be the areas subject to the highest potential displacement. Given evidence from the literature reviewed in my report, which indicates that construction disturbance does not cause complete displacement, and the actual disturbance zone is likely to be quite limited, it is reasonable to conclude that any displacement impacts that occur will be very minor, and these very minor displacement impacts will not cause any population-level consequences.
52. Bar-tailed Godwit occurred in relatively high numbers in the area counted at the eastern end of the Nimmo's Pier-South Park Shore. Bar-tailed Godwit population trend data indicate that the Inner Galway Bay population may have reached the effective carrying capacity of the site and the attributes of the species indicate a moderate/high sensitivity to displacement impacts. Therefore, it is theoretically possible that complete displacement due to construction disturbance could cause a non-negligible short-term increase in mortality rates. However, as discussed above, there is no evidence for construction disturbance causing complete displacement. Furthermore, Nimmo's Pier-South Park Shore already experiences a high level of disturbance, so birds using the area must be habituated to a certain level of disturbance, and the noise levels generated by the construction work will only just exceed the levels where any behavioural responses are likely. While disturbance from a major construction project is likely to cause greater disturbance impacts than the level to which the birds are habituated, the evidence from the waterbird monitoring carried during the construction of the Mutton Island WWTP indicates that Bar-tailed Godwits in this area of Inner Galway Bay have a low sensitivity to construction disturbance (Nairn, 2005). The GHE development will be spatially separated from the Nimmo's Pier-South Park Shore by a deep tidal channel, which will reduce the perceived disturbance impact to birds using the intertidal habitat in the latter area. Therefore, given all the available evidence, it is reasonable to conclude that construction disturbance from the GHE development will not cause significant displacement impacts to this species.
53. Black-headed Gull occurred in relatively high numbers in the area counted at the eastern end of the Nimmo's Pier-South Park Shore. This species has a low potential sensitivity to displacement impacts, due to its very high potential ability to use alternative terrestrial habitats in the vicinity of Inner Galway Bay, and is also relatively tolerant of disturbance. Therefore, it is unlikely that displacement due to construction disturbance could cause a non-negligible increase in mortality rates.
54. The high tide roost on Mutton Island is within the predicted 55-60 dB(A) noise contour from the Backhoe Dredging Noise Model (Figure 10.4.3 in the EIS), while the high tide roost at Hare Island is within the predicted 55-60 dB(A) noise contour from the Pile Driving Noise Model (Figure 10.4.4 in the EIS). The high tide roost on the rocks on the eastern side of the landward end of the Mutton Island causeway is outside the predicted 55-60 dB(A) for any of the construction activities (Figure 10.4.1-10.4.4 in the EIS). However, the construction of the Mutton Island WWTP, which obviously involved major construction works in much closer proximity to the Mutton Island roost than will occur in the GHE development, did not cause any detectable adverse impacts to the Mutton Island high tide roost (Nairn, 2005). Therefore,

it is reasonable to conclude that the GHE development will not cause significant disturbance to the Mutton Island and Hare Island high tide roosts.

OPERATIONAL DISTURBANCE

55. The disturbance pressures to adjacent subtidal habitat will not be of sufficient intensity to cause complete displacement. Within the subtidal habitat, ship and boat traffic will not be continuous and will follow fixed routes. Any birds disturbed will be able to move short distances into adjacent areas of undisturbed habitat, and return to the area, when the disturbance pressure has passed. Similarly, as disturbance impacts are likely to be of low frequency, and birds will not have to move far, birds will not incur significant energetic expenditure avoiding the impacts.
56. Disturbance from activity within the GHE site will only affect Renmore Beach, and the eastern end of the Nimmo's Pier-South Park Shore, where the intertidal zone is at its narrowest. The only species that occurred in significant numbers in these areas were Bar-tailed Godwit and Black-headed Gull in the eastern end of the Nimmo's Pier-South Park Shore.
57. The GHE development site, at its nearest point, is around 160 m from the intertidal habitat at the eastern end of Nimmo's Pier-South Park Shore. This is within the range where Bar-tailed Godwits have been reported to show disturbance responses in undisturbed, open tidal flats, but outside the range for Black-headed Gulls. In reality, both species will tolerate much closer approaches at the eastern end of Nimmo's Pier-South Park Shore, due to habituation, while the separation of the GHE development site from the Nimmo's Pier-South Park Shore intertidal habitat by a deep tidal channel will also act to reduce the birds' sensitivity to disturbance from land-based activity within the GHE site.

DISTURBANCE FROM SHIPPING AND BOATING TRAFFIC

58. The disturbance sensitivity of subtidal species to shipping and boat traffic is reviewed in the relevant species profiles (Appendix 2.8 in the NIS Addendum Errata). In particular, the review in the species profile for Great Northern Diver demonstrates that the figure that has been quoted in the submission by the Department of Arts, Heritage and the Gaeltacht of this species being disturbed by shipping traffic at distances of more than 1 km has no evidential basis in the scientific literature, while the species is known to tolerate close approach from shipping in inshore Irish waters.
59. Disturbance impacts from shipping traffic approaching/within the harbour are dealt with above (paragraph 55). Outside the harbour area, the shipping traffic will follow the existing shipping lane in the middle of the bay. This shipping channel, and the adjacent subtidal habitat, runs through deep subtidal habitat (> 5 m deep), and will only, therefore, potentially affect species associated with such habitat. The assessment of the impact of shipping traffic within the GHE site (paragraph 55) will also apply to the impact of shipping traffic in the shipping lane outside the GHE site.
60. A twofold increase in overall levels of recreational boat activity within Inner Galway Bay may also be generated². It is anticipated that most of the extra marina traffic will follow established routes from the harbour to the South and West, since many of the areas at the eastern end of the bay can be dangerously shallow, even for small boats. Disturbance from this boat traffic will only affect species associated with moderately deep and deep subtidal habitat, as the boats are not likely to travel into the shallow subtidal habitat. Of these species, the gulls and terns will not be sensitive to such disturbance impacts. Red-breasted Merganser, Great Northern Diver and Cormorant may show avoidance reactions to such boat traffic. However, given the more or less uniform very low densities at which these species occur in Inner Galway Bay (2-5 birds per 100 ha), and the fact that highest intensity of recreational boat

² Note that the NIS Addendum Errata incorrectly referred to a tenfold increase in recreational boat traffic.

traffic will be in the summer, outside the main season of occurrence of these populations, it is unlikely that the increased recreational boat traffic will cause significant disturbance impacts.

DISTURBANCE (BREEDING POPULATIONS)

61. The Cormorant breeding colony is 8.5 km from the development site and well away from the main shipping route. Therefore, there will be no direct disturbance impacts to the breeding colony. The percentage occurrence of Cormorant within the GHE site during the breeding season is similar to its occurrence there during the non-breeding season. Therefore, the assessment of no significant impacts from disturbance to the non-breeding population, also applies to the breeding population (with the exception that the highest intensity of recreational boat traffic will overlap with the main season of occurrence of this population).
62. The Sandwich Tern breeding colony is 12 km from the development site and well away from the main shipping route. Therefore, there will be no direct disturbance impacts to the breeding colony.
63. The Mutton Island Common Tern colony is 1 km from the construction area and 300 m from the dredging area. These distances are sufficient to prevent any direct disturbance to the breeding colony from construction or operational activities within the GHE site.
64. Blasting and piling will not be carried out during the tern breeding season, while foraging Sandwich and Common Terns are generally tolerant of human disturbance.

OTHER ISSUES

65. Blasting and piling will not be carried out during the tern breeding season. A RIB will quarter over and around the blast site immediately prior to blasting with the intention that any birds present will be scared away from the danger zone. Blasting will be delayed/postponed if sensitive species are seen in the area when blasting is scheduled.
66. Collision risk is a potential issue with very large structures, such as wind turbines, situated on flight paths or within the foraging ranges of potentially sensitive species. However, there is no evidence to suggest that collisions with built structures (of the types proposed in this development) in developed coastal areas, such as ports and harbours, pose any significant collision risk.
67. Extreme weather can, potentially, cause the local population to reach, or exceed, the effective carrying capacity of the site, and cause increased mortality rates due to density-dependent processes. In addition, birds may be more susceptible to disturbance impacts in extreme weather. With reference to the GHE development, there is no evidence that any of the above factors is a significant issue. The levels of displacement that will be caused by the GHE development are so small that it is not reasonable to suppose that such displacement will significantly increase densities in the remaining habitat to the extent that would be required for this displacement to contribute to increased mortality rates in extreme weather. The area around the GHE development site is already subject to high levels of disturbance, and birds using these areas will be habituated to some degree to disturbance impacts. Therefore, it can be stated with reasonable scientific certainty that the birds will not be so sensitive to disturbance impacts that there will be significant increases in energetic costs/loss of feeding time in extreme weather.

IN-COMBINATION EFFECTS

GALWAY HARBOUR ENTERPRISE PARK

68. Historical habitat loss from the development of the Galway Harbour Enterprise Park (GHEP) is estimated to have involved the loss of 8.6 ha of intertidal sediments and another 7.7 ha of saltmarsh and *Scirpus maritimus* habitat. This development mainly took place in the late-1990s.

69. The intertidal habitat lost from the development of the GHEP is considered to have been mainly a habitat classified as fucoid-dominated (a hard-substrate habitat with high levels of seaweed cover). This would have been very suitable foraging habitat for Turnstone and, in combination with the 2.1 ha remaining within the GHE site, would have amounted to 10.7 ha of foraging habitat (around 1% of the total area of fucoid-dominated biotope within the SPA). This may have provided a sufficient area for birds to remain foraging throughout the low tide period and, therefore, the potential usage of this habitat may have been significantly greater than would be implied by a simple pro-rata calculation from the numbers using the remaining habitat. However, population trend data indicates that the Inner Galway Bay Turnstone population did not reach the effective carrying capacity during the period of the development of the GHEP. Therefore, any displacement impact caused by the development of the GHEP would not have had population-level consequences.
70. It is possible that the historical habitat loss from the development of the Galway Harbour Enterprise Park caused a measurable level of displacement to Light-bellied Brent Goose and Wigeon. However, as the GHE development is not predicted to cause measurable displacement impacts to these species, there will be no cumulative impact from habitat loss due to the GHE development in combination with the historical habitat loss from the development of the Galway Harbour Enterprise Park.
71. For the other species considered in this assessment, based on their pattern of occurrence in adjacent areas, and/or their habitat preferences, it is unlikely that the habitat lost from the development of the Galway Harbour Enterprise Park held significant numbers of the species.

MUSSEL BOTTOM CULTURE

72. The *Inner Galway Bay SPA: Appropriate Assessment of Aquaculture and Shellfisheries & Fisheries Risk Assessment* identified that there was a potential risk of impact to Sandwich Terns and Common Terns, due to mussel bottom culture in Rinville Bay, which is within the likely core foraging range of their colonies, and occurs partly within shallow water zones where benthic fish prey would be accessible to terns. As the GHE development is not considered likely to have measurable impacts on foraging resources for the Sandwich Tern colony, there is no potential for cumulative impacts in-combination with impacts from mussel bottom culture for this species. In the case of the Common Tern, the GHE development could possibly have a measurable, but not significant, impact, so, the assessment in the aquaculture AA, raises the possibility for significant cumulative impacts in-combination with impacts from mussel bottom culture for this species.
73. The aquaculture AA reviewed the biotope characteristics of the mussel bottom culture plots in Rinville Bay in relation to fish survey data from Kinvarra Bay and concluded that the plots could contain suitable benthic prey resources for terns. However, this conclusion was not informed by local knowledge of the area. More specific information on Rinville Bay indicates that, in fact, the area is not likely to provide important benthic prey resources for feeding terns:

Rinville Bay is of minor value as a feeding resource for terns as the sea bed is anoxic and benthic production is therefore low. This is due to the fact that water exchange with Galway Bay is restricted due to the narrow and shallow opening to the open sea. It behaves more like a mill pond than an open mouthed bay - the tide rises and falls quite passively giving rise to low current speeds. It also acts as a sink for suspended sediments - these fall out to the sea bed at slack high water and are not exported on the following ebb tide as bottom velocities are not high enough to re-mobilise them. However, there is no reason why juvenile fish (including sand eels) cannot enter the bay giving rise to at least some source of prey items for fish-eating birds. (Brendan O'Connor, pers. comm.)

74. The potential impact of bottom mussel culture to prey resources to terns is limited to impacts on benthic prey. Therefore, in light of the further assessment, it can be concluded that the

precautionary assessment in the aquaculture AA is incorrect and that, beyond reasonable scientific doubt, there will not be any significant impact from bottom mussel culture on benthic prey resources for terns. Therefore, no potential cumulative impacts from the GHE development in-combination with impacts from mussel bottom culture arise.

CONCLUSIONS

75. As a result of this assessment it can be stated beyond reasonable scientific doubt that none of the potential impacts arising from the proposed development will be likely to cause population-level consequences to any of the SCI populations of the Inner Galway Bay SPA.
76. Further it can be stated as a result of this assessment that, beyond reasonable scientific doubt, there will be no potential cumulative impacts from habitat loss due to the GHE development in combination with the historical habitat loss from the development of the Galway Harbour Enterprise Park which could cause population-level consequences to any of the SCI populations of the Inner Galway Bay SPA.
77. Further assessment, presented here, has shown that will not be any significant impact from bottom mussel culture on benthic prey resources for terns. Therefore, no potential cumulative impacts from the GHE development in-combination with impacts from mussel bottom culture arise.

REFERENCES

78. Nairn, R.G.W. (2005). Use of a high tide roost by waders during engineering work in Galway Bay, Ireland. *Irish Birds*, 7, 489–496.

Appendix 1 Response to the submission from the Department of Arts, Heritage and the Gaeltacht

79. This is a response to the submission from the Department of Arts, Heritage and the Gaeltacht, dated 05 December 2014.
80. This response deals with issues raised under the heading *Inner Galway Bay Special Protection Area* on pages 8-11 of the submission, and under the heading *Assessment in combination with other projects and plans* on page 12 of the submission.

ASSESSMENT IN VIEW OF THE CONSERVATION OBJECTIVES

Conservation objectives (breeding species)

81. The conservation objectives list seven attributes that define the favourable conservation condition of the breeding Cormorant, Sandwich Tern and Common Tern populations: breeding population abundance, productivity rate, distribution of breeding colonies, prey biomass availability, barriers to connectivity and disturbance at breeding site.
82. The following text summarises the results of my assessment in relation to these attributes.
83. The productivity rate depends upon the ability of the population to find sufficient suitable food resources, which could be negatively affected by displacement from important feeding areas and/or reductions in foraging efficiency due to disturbance. My assessment has concluded that there will not be any significant displacement or disturbance impacts to the breeding populations of these species. Therefore, there will be no significant impact to the productivity rate attribute.
84. Displacement impacts can be considered as a surrogate measure of prey availability: i.e., if an area supports a high level of prey biomass it will attract a high number of birds and, therefore, significant degradation of the habitat, or complete loss of the area, would result in a large displacement impact. Therefore, the absence of any significant predicted displacement impacts indicates that there will be no significant impact to the prey biomass availability attribute.
85. My assessment has concluded that there will not be any disturbance impacts to the breeding colonies of these species. Therefore, there will be no impact to the disturbance at breeding site attribute.
86. The development will not create a barrier between the breeding colonies of the species and important foraging areas. Therefore, it will not have any impact on the barriers to connectivity attribute.
87. The breeding population abundance and distribution of breeding colonies attributes are higher-level attributes, which represent the cumulative influence of the other attributes. Therefore, as there will not be any significant impacts to any of the other attributes, there will be no significant impacts to the breeding population abundance or distribution of breeding colonies attributes.

Conservation objectives (non-breeding species)

88. The conservation objectives list two attributes that define the favourable conservation condition of the non-breeding Light-bellied Brent Goose, Wigeon, Red-breasted Merganser, Great Northern Diver, Cormorant, Grey Heron, Bar-tailed Godwit, Curlew, Redshank, Turnstone, Black-headed Gull and Common Gull populations: population trend and distribution.

89. In the conservation objectives, the distribution attribute is measured by the "number and range of areas used" with a target of "no significant decrease in the range, timing and intensity of use of areas ... other than that occurring from natural patterns of variation"³.
90. The population trend attribute is a higher-level attribute that represents the cumulative influence of displacement and disturbance impacts. There are also other possible impacts that could contribute to the population trend attribute (e.g., reduced prey biomass due to fishing) but these are not relevant to the GHE project. Furthermore, the population trend attribute may also reflect ex-situ factors, such as impacts on the breeding grounds, or changes in migratory patterns.
91. Impacts to the population trend attribute will only become apparent over a period of many years (due to the natural degree of variation in population sizes that would occur in the absence of any overall trend). However, impacts to the distribution attribute can be detected within a single winter. Therefore, the distribution attribute can be viewed as an "early-warning" indicator of pressures that may ultimately result in impacts to the population trend attribute.
92. I note that the DAHG's own assessment of the conservation condition of the SCI species in Inner Galway Bay (as contained within the SPA Conservation Objectives Supporting Document) is based purely on the population trend attribute, with no reference to the distribution attribute, indicating that the population trend attribute is considered to be the ultimate measure of conservation condition.

Interpretation of the distribution attribute

93. As the target for the distribution attribute is "no significant decrease", not "no decrease", it is necessary to establish criteria against which any projected decrease can be assessed to determine whether or not it is significant.
94. My interpretation of this attribute is based upon an extensive review of the scientific literature on the impacts of displacement due to disturbance and/or habitat loss on waterbird populations. The consensus in the literature is that the potential impact of displacement should be assessed in terms of whether the displacement will result in density-dependent mortality and/or loss of body condition. Therefore, my assessment has explicitly focussed on this question.
95. My interpretation of the distribution attribute is criticised in the DAHG submission on the grounds that, as it is linked to population-level consequences, it is ultimately assessing the population trend attribute and, therefore, there has been no separate assessment of the distribution attribute.
96. The DAHG submission states that "the proposed development should be assessed against each of the attributes separately". However, it is not clear how objective scientific criteria could be used to assess the distribution attribute without having some linkage to population-level consequences.

Assessment against the conservation objectives

97. My assessment has concluded that there will be no significant displacement impacts from habitat loss or modification, or disturbance for any of the non-breeding SCI populations. Therefore, there will be no significant impacts to the distribution attribute.
98. As there will not be any significant displacement impacts, and my assessment also concluded that there will not be any significant non-displacement disturbance impacts, and there are not any other possible impacts that could affect the population trend, there will be no significant impacts to the population trend attribute of the non-breeding SCI populations.

³ For the non-breeding Cormorant population, the target is "no significant decrease in the numbers or range of areas ..."

TURNSTONE

99. My assessment concluded that the construction of the GHEP did not cause a significant displacement impact. In fact, because the population showed a strong sustained increase for several winters after the intertidal reclamation was completed, any displacement impact from the GHEP did not push the population close to its effective carrying capacity. Therefore, for a significant cumulative impact to arise from the construction of the GHEP, in-combination with the proposed development of the GHE, a large displacement impact would be required from the latter (so that the combined impact would push the population close to/over its effective carrying capacity).
100. The predicted displacement impact, based on the count data from the 2011/12 and 2012/13 winters, is 5.9 birds. This represents 2.1% of the mean I-WeBS count for those winters. However, for a cryptic species like Turnstone, the intensive survey effort involved in the GHE monitoring counts will have recorded significantly larger numbers, compared to the numbers that would have been recorded by a similar survey effort to that used for the I-WeBS counts. There are two reasons for this: the duration of the counts, and the size of the area covered.
101. The 3-8 hour duration of each of the GHE monitoring count days allowed transient birds that may have only been present within the site for a short period to be counted. This is illustrated by comparing the maximum and mean counts for each count day (Table 1). In an I-WeBS count, each counter has to cover a large area and will only be present at any one vantage point for a short period of time. Therefore, I-WeBS counts have a low probability of detecting transient birds that are only present for a short period of time.
102. There is only a small area of intertidal habitat within the GHE count area and the configuration of this habitat means that there was a high probability of detecting any Turnstone using the habitat. The I-WeBS subsites can cover several kilometres of shoreline. Each I-WeBS subsite is counted from a few vantage points, with long stretches of shoreline counted at each vantage point. Due to the nature of the habitat used by Turnstone, and their cryptic plumage, there is a low probability of detecting birds more than a few hundred metres distant from a vantage point.
103. For the above reasons, the I-WeBS counts will significantly underestimate the total Turnstone population of the SPA, and the true population size is likely to be much larger than the numbers counted. Therefore, the percentage displacement impact calculated using the mean I-WeBS count as the denominator will significantly overestimate the true displacement impact. Even with this overestimation, the calculated displacement impact was only 2.1%. Therefore, my assessment concluded that the true displacement impact from the GHE will be very minor and not significant.
104. As the GHEP development did not push the Turnstone population close to its effective carrying capacity, and as the GHE development will only have a very minor displacement impact, it can be concluded that the cumulative impact on the distribution attribute of the conservation objectives is not significant.
105. Therefore, as the cumulative displacement impact is not significant, and there are no other potential impacts, the cumulative impact on the population trend attribute of the conservation objectives is not significant.

Table 1. Hourly count data for Turnstone from the GHE monitoring counts, 2011/12 and 2012/13.

Date	Hourly counts								Max	Mean
	1	2	3	4	5	6	7	8		
26/09/2011	5	5	6						6	5.3
12/10/2011	3	4	11						11	6.0
11/11/2011	0	5	2						5	2.3
29/12/2011	0	0	1						1	0.3
13/01/2012			0	0	1	0	0		1	0.2
20/01/2012	0	6							6	3.0
05/02/2012	0	0	10						10	3.3
28/02/2012			0	13	0	3	19	11	19	7.7
06/03/2012	1	16	7						16	8.0
25/03/2012			0	0	10	0	0		10	2.0
30/10/2012	1	0	0	1					1	0.5
16/11/2012		0	0	7	1	1			7	1.8
27/11/2012	0	0	0	0	0				0	0.0
27/12/2012	0	0	1	4	3				4	1.6
22/01/2013	0	0							0	0.0
02/02/2013					0	3	7	4	7	3.5
22/02/2013	5	0							5	2.5
25/02/2013	2	2	0	1					2	1.3
04/03/2013					2	6	1	0	6	2.3
14/03/2013		1	1	0	0	1			1	0.6

Only includes counts within 2.5 hours of low tide (corresponding to the period of time when Turnstone mainly occurred within the GHE site).

NATURE, TIMING AND EXTENT OF THE INCREASED ACTIVITY

Commercial shipping traffic

106. The figures presented in Appendix 3.4 in the NIS Addendum Errata for the increase in shipping traffic are incorrect. The number of ships which entered the docks in 2014 was 177. In the future once the port is fully operational the average annual is forecast as 210 which will be a 25% increase (although catering for increased tonnage). All this shipping traffic will keep to the commercial shipping lane, which is shown on Tobin Consulting Engineers Drawing No. 2139-2103. Given the low intensity of this shipping traffic (on average 1.2 ship movements per day) and its spatial restriction to the shipping channel, sufficient detail was available to allow for a properly informed assessment of the likely impacts associated with such movements.

Recreational boat traffic

107. The existing level of boating activity across the whole of the Inner Galway Bay SPA is as follows, based on information supplied by Tobin Consulting Engineers. During the winter (October-March), there is an average of 8 fishing boats and 2 recreational boats on the water on any one day. In addition, yacht races take place on Sundays with an average of 22 boats involved. During the summer (April-September), there is an average of 8 fishing boats and 5 recreational boats on the water on any one day giving a total of 13. However when shoals of mackerel come into the inner bay the number of fishing/recreational vessels on the sea increases temporarily to an average of 16. In addition, yacht races take place on Wednesdays with the same average of 22 boats involved.

108. In the winter period of 2009/10, the National Parks and Wildlife Service carried out five waterbird counts across Inner Galway Bay. These counts also systematically recorded all potential disturbance-generating activities encountered. There were only five instances of potentially disturbing activity classified as "Powered watercraft (jet-skis, motorboats, etc.)" across all five counts. Non-powered watercraft were not recorded as a separate activity, but would presumably have been classified under "Other" or "Other vehicles", and there was a combined total of six instances of such activities across the five counts. While offshore areas

only had limited coverage during these counts, the NPWS data indicates a similar level of boat activity to the figures provided by Tobin Consulting Engineers.

109. The total numbers of recreational boats moored in Galway Bay are estimated to be in the order of 150 motorised vessels and 100 sailing vessels (Section 10.5.3.1.4 of the EIS). The development of the GHE will increase the number of recreational boats in Galway Harbour from around 70 to 300 (100 in the inner harbour and ultimately 200 in the new marina). This would increase the overall number of recreational boats in Galway Bay from 250-500. Therefore, there would be an approximately sixfold increase in the number of boats operating out of Galway Harbour and a twofold increase in the overall number of recreational boats in Galway Bay⁴. Based on the existing usage patterns (see above), the average number of boats (recreational boats and fishing boats) on the water per day would increase from around 10 to 12 in the winter months, and from 13 to 18 in the summer months. Virtually all recreational boat activity would be expected to take place during daylight hours.

GREAT NORTHERN DIVER

March-May counts

110. The DAHG submission refers to "relatively high counts" during the March-May period of 2011 and 2014.
111. In my assessment, I used count data from the September-March periods of 2011/12 and 2012/13 (24 counts), to allow comparison with I-WeBS data. This produced a mean count for Great Northern Diver of 4.1 birds.
112. If the dataset is extended to include all counts in the September-May periods, across all winters (30 counts), the mean count rises to 4.5 birds. This would equate to an increased displacement impact under the worst-case habitat loss and degradation scenario of 0.1 bird. This would not have any material effect on the conclusions of my assessment.

Mean versus maximum counts and sample sizes

113. The DAHG submission queries the use of mean counts on the basis of the "low" sample sizes. The submission also refers to the high level of statistical processing and questions "how the relatively small sample sizes may have influenced the results".
114. The number of counts used in the analyses in my assessment was 24, which were carried out on 24 separate days (count days). I do not consider this to be a low sample size.
115. These counts were distributed across two winters. Within each winter, the count days were spread out, with a mean separation between consecutive count days of 15 days.
116. Each count day was either a three hour watch (counts up to 01/01/2012) or an eight hour watch (counts from 13/01/2012), with maximum counts recorded every 60 minutes (2011-2013), or every 30 minutes (2014). The counts included in my analyses were the maximum counts across all of the 3-16 counts from each count day.
117. This sampling effort is comparable to sampling efforts used in other similar assessments in Ireland. For example:
- 28 counts across two winters for the assessment of the proposed extension of the Port of Cork (but with counts carried out on consecutive count days).
 - 18 counts on 13 days between January and March in one winter for the assessment of intertidal aquaculture at Dungarvan Harbour.
118. This sampling effort is also comparable to sampling efforts used in many peer-reviewed publications on the spatial ecology of waterbirds in Ireland and elsewhere. For example:
- 29-32 counts across 5 days between October and February in one winter in Murphy et al. (2006).

⁴ Note that the figure cited in Appendix 3.4 in the NIS Addendum Errata of a tenfold increase is incorrect.

- 27 counts across six winters in Lewis and Kelly (2012).
- 26 counts across two winters in Alves et al. (2010).

119. The publications cited above include complex statistical analyses.
120. I also note that the population trend analysis included in the SPA Conservation Objectives Supporting Document uses a statistical method which effectively represents a mean count for each winter (not a maximum count), with these being based on only three counts per winter.
121. Therefore, I do not consider that the sample size is low and, for the reasons explained in Section 3.1.2 of Appendix 3.4 in the NIS Addendum Errata, I consider that the mean count is a more appropriate measure than the maximum count.

Type I errors

122. The DAHG submission questions “why post hoc tests were not employed to reduce the possibility of Type I errors when undertaking multiple correlations”. This presumably refers to the analyses of the relationships between species distributions across subsites and habitat availability included in Appendix 1 of Appendix 3.4 in the NIS Addendum Errata.
123. A Type I error refers to the rejection of the null hypothesis when it is true. Bonferroni-type corrections can be used to reduce the possibility of a Type I error by adjusting the p-value to reflect the number of comparisons made. However, the use of Bonferroni-type corrections is controversial and there is disagreement within the scientific community about when they should be used, or whether they should be used at all.
124. Bonferroni-type corrections are most useful when a large number of exploratory analyses (without a clear hypothesis in mind) are carried out with the same response variable. An example would be carrying out separate correlations of the distribution of Great Northern Diver across Galway Bay against 20 different environmental variables.
125. However, the analyses in Appendix 1 of Appendix 3.4 in the NIS Addendum Errata were carefully targeted. Each species was only analysed in relation to one or two explanatory variables, with the explanatory variables selected on the basis that they represented habitat parameters that were known to be likely to influence the distribution of the species concerned. Where two explanatory variables were tested, these were variants of the same broad environmental parameter (e.g., shallow/moderately deep subtidal habitat and all subtidal habitat).
126. A recent review of the use of Bonferroni-type corrections concluded that no corrections should be made “if the study is restricted to a small number of planned comparisons” (Armstrong, 2014). This describes precisely the nature of the analyses in Appendix 1 of Appendix 3.4 in the NIS Addendum Errata.
127. Due to the small number of tests, and the high significance of the correlations, most of the correlations reported in Appendix 3.4 in the NIS Addendum Errata would remain significant after applying a Bonferroni-type correction. However, my scientific opinion is that Bonferroni-type corrections would not be appropriate for these analyses.

Disturbance distances

128. This is addressed in the response from Dr Chris Peppiatt.

Distribution of Great Northern Diver in Inner Galway Bay

129. The DAHG submission expresses concern about the apparent lack of data “on the numbers and distribution of Great Northern Diver using the middle part of the bay”.
130. The analysis of Great Northern Diver distribution across subsites presented in Appendix 1 of Appendix 3.4 in the NIS Addendum Errata indicates that the species is more or less uniformly distributed throughout suitable subtidal habitat in Inner Galway Bay.

131. There are no unusual habitat features in the middle of the bay that would attract high concentrations of divers. If anything, densities might be expected to be lower, due to the more exposed nature of the area.

132. Therefore, there is no scientific reason to expect densities of Great Northern Diver to be significantly higher in the middle of the bay.

Recreational boat traffic

133. Further details of the projected increase in recreational boat traffic are provided in paragraphs 107-109 above.

134. The projected increase in number of boats on the water during the winter is 2 boats. Given the size of Inner Galway Bay, the low density of the Great Northern Diver population, and the nature of the disturbance response of Great Northern Diver, it is not plausible to suggest that this level of increased boat activity will cause any measurable impacts.

Commercial shipping traffic

135. The shipping traffic will involve an average of 1.2 ship movements per day. Given the size of Inner Galway Bay, the low density of the Great Northern Diver population, and the nature of the disturbance response of Great Northern Diver, it is not plausible to suggest that this level of shipping traffic will cause any measurable impacts.

136. Note also that the shipping lane, and adjoining habitat, is in waters of more than 5 m depth, which are unsuitable habitat for Red-breasted Merganser.

ASSESSMENT IN-COMBINATION WITH OTHER PROJECTS AND PLANS

137. The assessment of any potential for cumulative impacts from the GHE development in combination with impacts from mussel bottom culture is dealt with in paragraphs 72-74 above.

REFERENCES

- Alves, J.A., Sutherland, W.J. & Gill, J.A. (2012) Will improving wastewater treatment impact shorebirds? Effects of sewage discharges on estuarine invertebrates and birds. *Animal Conservation*, 15, 44–52.
- Armstrong, R.A. (2014) When to use the Bonferroni correction. *Ophthalmic and Physiological Optics*, 34, 502–508. <http://onlinelibrary.wiley.com/doi/10.1111/opo.12131/pdf>.
- Lewis, L.J. & Kelly, T.C. (2012) Aspects of the spatial ecology of waders along an estuarine gradient. *Irish Birds*, 9, 375–384.
- Murphy, S., Lewis, L.J. & Kelly, T.C. (2006) The spatial ecology of wildfowl in Courtmacherry Bay, southern Ireland with particular reference to Shelduck *Tadorna tadorna*. *Irish Birds*, 8, 51–58.

Appendix 2 Response to the submission from BirdWatch Ireland

138. This is a response to the submission from the BirdWatch Ireland, dated 05 December 2014.

139. This response deals with all the matters raised in the submission, except issues relating to Lough Corrib, mitigation measures and sea-level rise and storm surge events.

USE OF I-WEBS DATA

140. The BWI submission states that I-WeBS data is “not designed to assess potential impacts or relative importance and habitat usage across a given site”.

141. In my assessment, the I-WeBS data was used for two purposes: to provide overall estimates for the total Inner Galway Bay populations of the SCI species; and, in conjunction with data from the NPWS Baseline Waterbird Survey, to carry out analyses of species distribution across subsites.

142. The use of I-WeBS data to provide overall population estimates is an established use of I-WeBS data. Indeed, I-WeBS data was used by NPWS to derive population estimates and population trends in the SPA Conservation Objectives Supporting Document for Inner Galway Bay.

143. The analyses of species distribution across subsites was initially carried out using just the data from the NPWS Baseline Waterbird Survey. This data was specifically collected to provide information on species distribution between subsites. However, because the data was collected from a single year only, and could be criticised for not being sufficiently representative, I extended the analyses by incorporating I-WeBS data from the most recent five seasons available at that stage. The analyses of the data from the NPWS Baseline Waterbird Survey alone, and the combined NPWS Baseline Waterbird Survey/I-WeBS dataset, produced very similar results. Therefore, only the latter were reported (as is convention in scientific publications).

144. For species where these analyses showed consistent relationships between subsite distribution and relevant habitat parameters (indicating that the species tend to be relatively evenly distributed throughout suitable habitat in Inner Galway Bay), the percentage occurrence in subsites adjoining the GHE site (as calculated in the above analyses) were used to inform the assessment of historical habitat loss due to the development of the GHEP.

145. It is my scientific opinion that the above is an appropriate use of I-WeBS data and I note that the BWI submission does not make any detailed scientific criticism of the analyses.

SITE COUNT DATA

146. The BWI submission states that “count data from across two winters at the site from a total of 13 counts (with no specific dates listed) is insufficient for measuring the likely variability in site usage over time”.

147. In fact, the assessment of displacement impacts used a dataset of 24 counts across two winters. I consider this sufficient to make an adequate assessment and note that this level of sampling effort is comparable to other similar assessments and scientific studies (see paragraphs 114-121 in my response to the DAHG submission).

148. The 13 counts referred to is to the dataset of counts used to assess potential disturbance impacts to adjacent intertidal areas at Renmore Beach and Nimmo’s Pier-South Park Shore.

SALTMARSH HABITAT

149. The BWI submission states that "the assessment of saltmarsh habitat as a potential roosting site for birds was inadequate".
150. This presumably refers to the discussion of the potential use of the saltmarsh that was lost in the GHEP development as a roosting habitat by Curlew, Redshank, Black-headed Gull and Common Gull.
151. The submission does not state in what way the assessment was inadequate. In any event it is my opinion that the assessment of saltmarsh habitat is accurate and appropriate.
152. The fragmented nature of the saltmarsh habitat in the GHEP site means that it would not have been very suitable as roosting habitat. In addition, the fact that this area was never included in the regular waterbird counts that have been carried out since the early 1980s indicates that it was not regularly used by significant numbers of waterbirds.

ECOLOGICAL NEEDS

153. The BWI submission criticises the "lack of consideration of ecological needs of species particularly in extreme weather and potential impacts of the proposed development".
154. The issue of extreme weather is dealt with in Section 7.4 of the Response to the Request for Further Information. While it is difficult in the absence of any specific complaint to know precisely the complaint being suggested here, it is my view that all relevant aspects of the "ecological needs of species" and "potential impacts of the proposed development" have been dealt with in the Response to the Request for Further Information.

LOCATION OF THE DEVELOPMENT

155. The BWI submission criticises the alleged "clear lack of rationale for determining the relative importance of the specific location in question".
156. The assessment of potential displacement impacts, as a percentage of the overall SPA population, in Appendix 3.4 in the NIS Addendum Errata is, in effect, a detailed analysis of the relative importance of the development site for each of the SCI species: i.e., for each species, the size of the potential displacement impact indicates the relative importance of the development site for that species.

DISTURBANCE

157. The BWI submission states that "the likely development impacts will extend far beyond the footprint of the planned development area".
158. This is correct and Appendix 3.4 in the NIS Addendum Errata includes detailed analysis of the potential disturbance impacts extending well outside the development footprint.
159. No specific scientific criticism is made of my assessment of disturbance impacts.

INTEGRITY

160. The BWI submission states that the "direct loss of habitat should be fully assessed in terms of habitat type and prey availability, and knowledge about the tidal sediment regime at this location to determine whether any change in the regime would result in adverse effects on the integrity of the site as a whole".
161. The EIS, NIS and RFI contain detailed assessments of the potential impacts of the development on the tidal sediment regime and the conclusions of these assessments informed my decision on the likely extent and severity of habitat degradation impacts that were considered in my assessment.

CUMULATIVE IMPACTS

162. The BWI submission refers to “concerns regarding the possible significant cumulative impacts from habitat loss in combination with impacts on waterbird populations of the Inner Galway Bay SPA from other pressures, such as increased disturbance, mussel bottom culture ...”
163. Section 4.3 of Appendix 3.4 in the NIS Addendum Errata includes a detailed analyses of potential disturbance impacts, including potential impacts arising from construction work, operational activities within the development site and shipping and boating traffic associated with the development.
164. The potential cumulative impacts from the GHE development in-combination with impacts from mussel bottom culture is dealt with in paragraphs 72-74 above.

Appendix 3 Irish Wetland Bird Survey (I-WeBS) count data for Inner Galway Bay for the winters of 2011/12 and 2012/13

165. The following data were supplied by Dr Chris Peppiatt.

Species	2011/12			2012/13		
	12 Nov	14 Jan	10 Mar	03 Nov	13 Jan	16 Mar
Light-bellied Brent Goose	957	1373	1936	612	1160	1234
Wigeon	1256	3564	1090	767	1325	865
Red-breasted Merganser	248	178	170	124	223	162
Great Northern Diver	146	102	70	25	111	157
Cormorant	194	92	166	151	290	77
Grey Heron	136	65	57	77	118	44
Bar-tailed Godwit	328	590	448	103	585	284
Curlew	672	611	381	275	409	234
Redshank	902	385	452	459	451	340
Turnstone	393	277	176	281	393	154
Black-headed Gull	1213	2115	998	1579	2360	1012
Common Gull	1016	1717	412	392	1697	199

Appendix 4 Errata

166. The following are corrections to information presented in my species assessment report (Appendix 3.4 in the NIS Addendum/Errata).
167. There is a typographical error in Section 4.3.1 (page 20) of my report, which refers to the potential disturbance zone as the GHE site. This does not affect the assessment and the figures in Table 11 are based on the GHE count area, not the GHE site.
168. The figures presented in Section 4.2.5 of my report for the increase in shipping traffic are incorrect. The number of ships which entered the docks in 2014 was 177. In the future once the port is fully operational the average annual is forecast as 210 which will be a 25% increase (although catering for increased tonnage). All this shipping traffic will keep to the commercial shipping lane, which is shown on Tobin Consulting Engineers Drawing No. 2139-2103.
169. Section 4.2.5 of my report incorrectly refers to a tenfold increase in recreational boat traffic. In fact, there will be an approximately sixfold increase in the number of boats operating out of Galway Harbour and a twofold increase in the overall number of recreational boats in Galway Bay. Based on the existing usage patterns, the average number of boats (recreational boats and fishing boats) on the water per day would increase from around 10 to 12 in the winter months, and from 13 to 18 in the summer months. Virtually all recreational boat activity would be expected to take place during daylight hours.

10

Will improving wastewater treatment impact shorebirds? Effects of sewage discharges on estuarine invertebrates and birds

J. A. Alves¹, W. J. Sutherland² & J. A. Gill¹

¹ School of Biological Sciences, University of East Anglia, Norwich, UK

² Department of Zoology, University of Cambridge, Cambridge, UK

Keywords

coastal systems; conservation; estuarine discharges; estuarine macrozoobenthos; organic loading; shorebirds.

Correspondence

José A. Alves, School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, UK.
Email: j.alves@uea.ac.uk

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Abstract

Human communities often discharge wastewaters into estuaries, influencing their organic and pollutant loading, benthic community and trophic structure. The implementation of the Water Framework Directive has encouraged the treatment of wastewater discharges across European estuaries, but the implications for invertebrate and waterbird communities are poorly understood. We explore the effects of untreated sewage discharges on the distribution and abundance of foraging black-tailed godwits *Limosa limosa* and their main benthic prey (bivalves and polychaetes) on the Tejo estuary in Portugal, a major European Special Protection Area with ongoing wastewater improvements. Patches of mudflat in close proximity to sewage streams (<30 m) can support polychaete densities and biomass that are an order of magnitude higher than more distant sites (>70 m), and godwits foraging in these areas can attain the highest intake rates recorded for the estuary. However, high intake rates can also be attained on bivalve prey, and bivalve biomass and density increase slightly with distance from sewage streams. As the organic input from sewage outfalls influences invertebrate abundance and godwit foraging rates over relatively small areas, the ongoing implementation of a sewage treatment network on the Tejo estuary seems likely to have only a limited impact on the wintering godwit population. The localized effect of untreated sewage discharges on benthic communities suggests that the implications for predatory birds are relatively minor where alternative prey are available, but may be more severe in locations with more depauperate, polychaete-dominated invertebrate communities.

Introduction

Estuaries are highly productive systems offering an abundance of resources to many species. The benthic invertebrate populations of estuaries, in particular, support a wide range of predatory fish and bird species (Van de Kam *et al.*, 2004). However, the area surrounding estuaries also frequently provides favourable conditions for urban developments and consequently anthropogenic pressure at these sites tends to be very high. Human coastal communities frequently discharge wastewaters into estuaries, producing direct effects such as pollution that can affect several levels of the estuarine ecosystem (Diaz & Rosenberg, 1995; Van de Kam *et al.*, 2004).

Wastewater including sewage discharge into estuaries can produce focal points of chemical pollution and organic matter that will influence the benthic community (Pearson & Rosenberg, 1978). Several studies have shown that particular elements of the benthic community, especially common and opportunistic species, increase in abundance and biomass in response to increased organic loading (Weston, 1990;

Beukema, 1991; Cardell, Sardà & Romero, 1999; Savage, Elmgren & Larsson, 2002). However, excessive nutrient enrichment can lead to anoxia, and consequently, to declines in biomass and diversity in the benthic community (Beukema, 1991; Ysebaert *et al.*, 1998; Savage *et al.*, 2002). Species richness among benthic communities therefore tends to increase in relation to both temporal and spatial distance from organic loading sources (Savage *et al.*, 2002; Smith & Shackley, 2006; Wear & Tanner, 2007). For pollution-tolerant and opportunistic macrozoobenthos, such as the ragworm *Hediste diversicolor* (Mucha & Costa, 1999), the supply of organic matter can, however, provide a potential food source (Reise, 1985; Olivier *et al.*, 1995), and thus the rates of growth and recruitment can be high around sewage outfalls (Ait Alla *et al.*, 2006). Reductions in organic loading due to either closure or treatment of raw sewage consequently tend to result in a decrease in the density and biomass of the polychaetes (Ait Alla *et al.*, 2006; Smith & Shackley, 2006).

Untreated sewage outfalls provide direct and indirect food resources to the estuarine bird community (Green, Hill

& Clark, 1993). Several gull species have been observed foraging directly on untreated sewage (Raven & Coulson, 2001), wildfowl can feed on items present in the sewage or on the benthic organisms, capitalizing on the high organic loading (Pounder, 1976; Campbell, 1984), and waders are likely to forage mostly on the abundant macrozoobenthos in nutrient-enriched areas (Van Impe, 1985; Burton & Armistage, 2005; Burton, Fuller & Eaton, 2005). Establishing the link between changes in the macrozoobenthic species due to organic loading and its effects on the estuarine bird community is not straightforward (Van de Kam et al., 2004). Nevertheless, several studies report a reduction in numbers or changes in behaviour or in site use of bird species following the reduction of organic loading in estuaries (Pounder, 1976; Campbell, 1984; Green et al., 1993; Raven & Coulson, 2001; Burton et al., 2005).

Throughout Europe, the implementation of the Water Framework Directive (EC, 2000) has increased efforts to improve wastewater treatment, including reducing nutrient inputs into watercourses and estuaries. The Tejo estuary in west Portugal is one of the most important wetlands in Europe, harbouring in excess of 150 000 waterbirds during winter, and serving as a major stop-over location for several species migrating along the East Atlantic Flyway (Leitão et al., 1998). Areas of the Tejo estuary have been designated as a Nature Reserve since 1976 under national legislation, and as a Special Protection Area since 1988 under the European Union Birds Directive 79/409/EEC. However, the estuary is in the vicinity of the most populated area in Portugal, with c. 2.5 million people (CCDRLVT, 2009) likely to have an impact on this estuary (Gaudêncio & Cabral, 2007). The vast majority of tidal flats are located on the southern and eastern banks of the Tejo estuary and, as recently as 2006, an area-wide development of Sewage Treatment Works (STW) for the residual waters of the southern and east banks of the Tejo estuary was initiated. This involves the construction of a wastewater collection grid, the installation of five new STWs and the improvement of another four of the current seven STWs around the estuary. All 12 STWs on the Tejo are predicted to be fully functional by the end of 2010 (SIMARSUL, 2009). Before the installation of this system of STWs, the vast majority of sewage was discharged raw and directly into the estuarine sediments, producing focal points of organic matter loading that are likely to have resulted in the middle sectors of estuary (where most urban development and sewage outfalls are located) having around twice the total organic matter present in the sediments than either upstream and downstream (Gaudêncio & Cabral, 2007). Although seven of the proposed 12 STWs are in operation on the Tejo, deficiencies in the collection grid for wastewaters mean that many outfalls are still discharging untreated sewage directly into the estuary. The levels of total organic matter found in the sediments of the Tejo estuary (c. 3–6%; Gaudêncio & Cabral, 2007) are likely to create focal areas of reduced diversity in the benthic community, but also to be advantageous to opportunistic species such as the ragworm. The improvement of the water treatment system will reduce the quantities of untreated sewage and

thus the organic loading currently being discharged into the estuarine sediments. This is likely to have important implications for the benthic community and, as a consequence, for the birds that prey on these species. However, the extent to which these changes may affect the bird community is currently unknown.

In this study, we explore the effect of the untreated sewage (hereafter termed sewage) currently being discharged into the Tejo estuary on the density and biomass of the two main benthic prey species of a migratory shorebird, the black-tailed godwit *Limosa limosa* currently classified as near threatened (IUCN, 2009). Several estuaries in western Europe support internationally important populations of black-tailed godwits (Gunnarsson et al., 2005; Delany et al., 2009), and the Tejo estuary is particularly important because it supports black-tailed godwits from breeding populations in both Iceland and mainland Europe (Alves et al., 2010). Black-tailed godwits (hereafter termed godwits) forage mainly on the bivalve *Scrobicularia plana* and the polychaete *H. diversicolor* (Moreira, 1994; Gill, Sutherland & Norris, 2001). As these two invertebrate species comprise a substantial proportion of the invertebrate community on intertidal mudflats in western Europe, and of the diet of many shorebird species (Goss-Custard et al., 2006), godwits are an ideal species in which to identify the potential consequences of changes in prey abundance and distribution following changes in nutrient inputs to mudflats. Here, we assess whether the biomass and size distribution of *S. plana* and *H. diversicolor* vary in relation to distance from sewage streams and whether this influences the distribution and foraging rates of godwits. We conclude by discussing the implications of future improvements in water treatment on the Tejo estuary and elsewhere for benthic invertebrates and shorebirds.

Methods

Prey abundance and biomass

The abundance and biomass of invertebrates were sampled monthly at six locations on the Tejo estuary between October 2006 and March 2007 (Fig. 1). These sites are all regularly used by foraging godwits (Moreira, 1993) and vary in distance (between 70 and 243 m) from the closest sewage outfall. The sewage outfall forms streams that meander across the mudflats (Fig. 1), and the six locations varied in distance from the closest sewage stream by between 16 and 86 m. At each sampling location, six to 12 random points were selected and a sediment core 9 cm in diameter and 15 cm in depth (the maximum probing depth of a godwit) was extracted from each point. More cores were extracted from sites for which we had no prior knowledge of invertebrate densities, in order to ensure that adequate estimates were achieved in all sites. The sediment was sieved *in situ* through a 1 mm mesh and all macrozoobenthos collected were transported to the laboratory for identification and measurement. Given that godwits foraging on estuarine mudflats prey almost exclusively on bivalves (mostly *S. plana*) and polychaetes (mostly *H. diversicolor*) (Moreira,

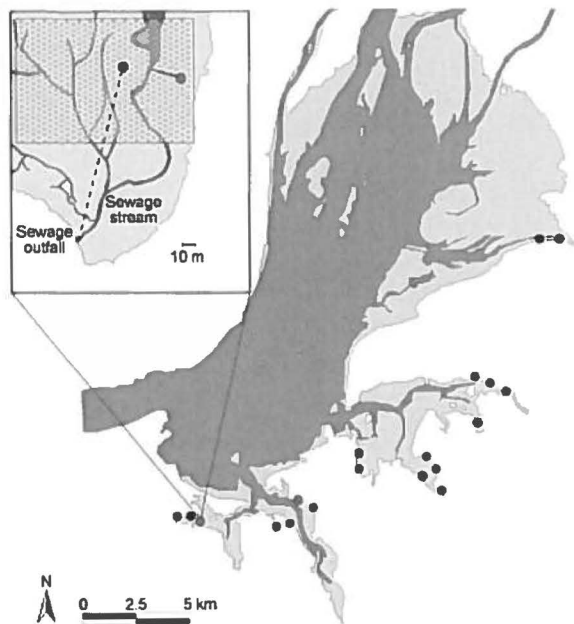


Figure 1 The estuarine mudflats at high (light grey) and low water (dark grey) of the Tejo estuary, and the location of sites used for measurements of black-tailed godwit *Limosa limosa* foraging behaviour (all circles) and prey sampling (grey circles). The inset illustrates the measurements of distances from prey sampling points (grey) to the nearest sewage stream (solid line), and the distance from most frequently used patch (black) within the godwit foraging area (stippled) to the nearest sewage outfall (dashed line).

1994; Gill *et al.*, 2001), the analysis was thus restricted to these two prey items, which were classified into the following size categories: small (3–5.5 mm bivalves; 3–9.9 mm polychaetes); medium (5.6–9.5 mm bivalves; 10–19.9 mm polychaetes); large (9.6–14.5 mm bivalves; 20–49.9 mm polychaetes); very large (14.6–20 mm bivalves; > 50 mm polychaetes). The mean body length of consumed *H. diversicolor* for each size class was reconstructed from the distribution of mandible lengths (following Moreira, 1994) attained from godwit faeces collected at two roosting sites on the Tejo: small ($n = 8$), medium ($n = 27$), large ($n = 105$) and very large ($n = 7$). No measurable *S. plana* fragments (i.e. the cardinal tooth) were found in the faeces and thus the mean lengths of individuals within each size class were calculated from the bivalves collected during prey sampling and for which body length was measured: small ($n = 466$), medium ($n = 217$), large ($n = 68$) and very large ($n = 60$). Prey biomass was then calculated using published formulae relating body length to ash-free dry mass established for these species in the Tejo estuary (Moreira, 1994).

Black-tailed godwit foraging behaviour

During the winters of 2006–2007 and 2007–2008, a total of 19 sites, distributed across all areas where godwits are

known to forage along the south-east bank of the Tejo estuary (Moreira, 1993), were surveyed every fortnight between October and March for flocks of foraging godwits (Fig. 1). These sites included the six sites used for prey sampling and were all located within 800 m of a sewage outfall. On each site, foraging flocks were counted and focal individuals were randomly selected and observed for the time taken to complete ten paces while foraging. Within this time, each successful peck or probe, the identity of the prey (bivalve or polychaete) and its size class were recorded. The foraging techniques used to capture bivalves and polychaetes differ, and the great majority of foraging bouts consist of one prey type only; thus, prey types can be easily distinguished. All observations were carried out by JAA using a $\times 20$ –60 telescope. The size category of each ingested prey item was estimated visually as one of four categories (small, medium, large or very large, corresponding to the size ranges for each prey type described above), and the number of each prey type and size class was multiplied by the average ash-free dry mass of prey in that size class to provide an estimate of the mean biomass intake rate for each site and prey type. Intake rates were pooled for each prey type separately (mean number of observations per site of godwits foraging on polychaetes = 197, range = 30–824, and on bivalves = 178, range = 31–637). The location of the foraging patch used during intake rate measurements was mapped using fixed landmarks and the most frequently used patch at each site was selected as the point from which the distance to the nearest sewage outfall was measured (Fig. 1).

Distances to sewage outfall and sewage streams

The location of each prey sampling site and the location of all sewage outfall sites along the south and east sections of the estuary were recorded using GPS (model eTrex, Garmin Ltd., Southampton, UK). These locations were imported into Google Earth (version 4.3) and the linear distance from each prey sampling site to the nearest sewage outfall or stream was measured using the software ruler tool (Fig. 1). As sewage discharges into streams that meander across the mudflats, the distance between each prey sampling location and the closest point of the sewage stream was measured in order to capture the direct effect of sewage on the macro-zoobenthos for each site (Fig. 1). Sewage flow within streams is independent of tidal action and thus distance to sewage stream is likely to directly influence the local macro-zoobenthos. However, as foraging godwit flocks typically move across the entire mudflat, usually following the tide edge (Dias *et al.*, 2006), the distance between the outfall discharge point and the most frequently used foraging patch within each mudflat area was also measured (Fig. 1). Sewage outfall is likely to be spread across mudflats by the action of the tide, and foraging areas can encompass and be influenced by multiple sewage streams; hence, the distance between the most frequently used foraging patch and the nearest sewage outfall was used in order to capture the effects of the sewage loading over the entire foraging area.

Sediment penetrability

To assess whether sediment type varied in relation to distance from sewage stream, sediment penetrability was measured on nine sites ranging in distance between 16 and 86 m, by recording the maximum depth (in cm) of a 20 cm length metal rod dropped from a height of 90 cm within a PVC cylinder (Jones, Reynolds & Raffaelli, 2006). At each site, 30–33 depth measurements were recorded at random points.

Results

Effects of sewage on macrozoobenthic prey

Across six sites ranging from 16 to 86 m from the nearest sewage stream, the abundance and biomass of polychaetes declined by an order of magnitude (Fig. 2). In contrast, bivalve density and biomass did not vary significantly with distance from the sewage stream (Fig. 2). The biomass of polychaetes in all size classes declined significantly with distance from the nearest sewage stream (Fig. 3a), while the biomass of all bivalve size classes increased with distance from the nearest sewage stream, although this pattern was only statistically significant for very large bivalves (Fig. 3b).

No seasonal changes in the density of either polychaetes or bivalves was evident at any of the sites, regardless of distance from the nearest sewage stream (Fig. 4, polychaetes: overall variation between months: $F_{1,137} = 0.006$, $P = 0.94$; month $\times$ distance from nearest outfall: $F_{1,137} =$

0.012, $P = 0.92$; bivalves: overall variation between months: $F_{1,137} = 0.13$, $P = 0.72$; month $\times$ distance from nearest outfall: $F_{1,137} = 0.81$, $P = 0.37$). Despite the foraging activities of the very large numbers of predatory birds on the Tejo during winter, polychaete densities on sites within 30 m of sewage streams were between 700 and 3000 ind m^{-2} in all months but were only between 30 and 600 ind m^{-2} at sites further from sewage streams (Fig. 4). In contrast, bivalve densities were typically 50–200 ind m^{-2} within 30 m of sewage streams but densities in excess of 500 ind m^{-2} were regularly recorded at sites further than 80 m from sewage streams (Fig. 4). Sediment penetrability did not vary in relation to distance from the nearest sewage stream ($F_{1,7} = 0.56$, $r^2 = 0.075$, $P = 0.48$).

Effects of sewage outfalls on intake rates

For godwits foraging on polychaetes, prey intake rates were significantly higher at sites that are closer to sewage outfalls (Fig. 5a). For godwits foraging on bivalves, there was no apparent change in prey intake rates with distance to sewage outfall (Fig. 5b). Across all sites, prey intake rates for godwits foraging on bivalves are $c 0.5 \text{ mg AFDM s}^{-1}$ (range 0.2–0.7 mg AFDM s^{-1}), whereas intake rates on polychaetes

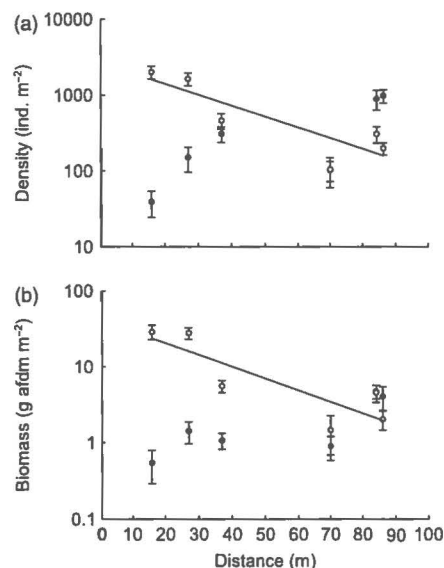


Figure 2 Changes in the mean ($\pm$ se) (a) density and (b) biomass of polychaetes (open circles) and bivalves (filled circles) with distance from the nearest sewage stream. Solid lines indicate significant relationships ($\log_{10}$ polychaete density = $-0.014 \times \text{distance} + 3.43$, $r^2 = 0.74$, $P = 0.029$; and $\log_{10}$ polychaete biomass = $-0.016 \times \text{distance} + 1.58$, $r^2 = 0.73$, $P = 0.030$).

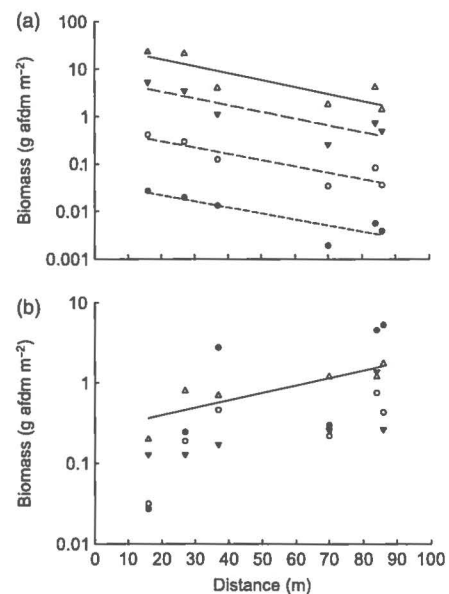


Figure 3 Changes in biomass of (a) polychaetes and (b) bivalves of each size class: small (filled circles), medium (open circles), large (filled triangles) and very large (open triangles), with distance from the nearest sewage stream. Lines indicate significant regressions: for polychaetes (short dashed line, $\log_{10}$ small biomass = $-0.013 \times \text{distance} - 1.41$, $r^2 = 0.75$, $P = 0.025$; medium dashed line, $\log_{10}$ medium biomass = $-0.013 \times \text{distance} - 0.26$, $r^2 = 0.80$, $P = 0.016$; long dashed line, $\log_{10}$ large biomass = $-0.014 \times \text{distance} + 0.81$, $r^2 = 0.74$, $P = 0.027$; solid line, $\log_{10}$ very large biomass = $-0.015 \times \text{distance} + 1.49$, $r^2 = 0.73$, $P = 0.031$) and bivalves ($\log_{10}$ very large biomass = $0.009 \times \text{distance} - 0.59$, $r^2 = 0.73$, $P = 0.030$).

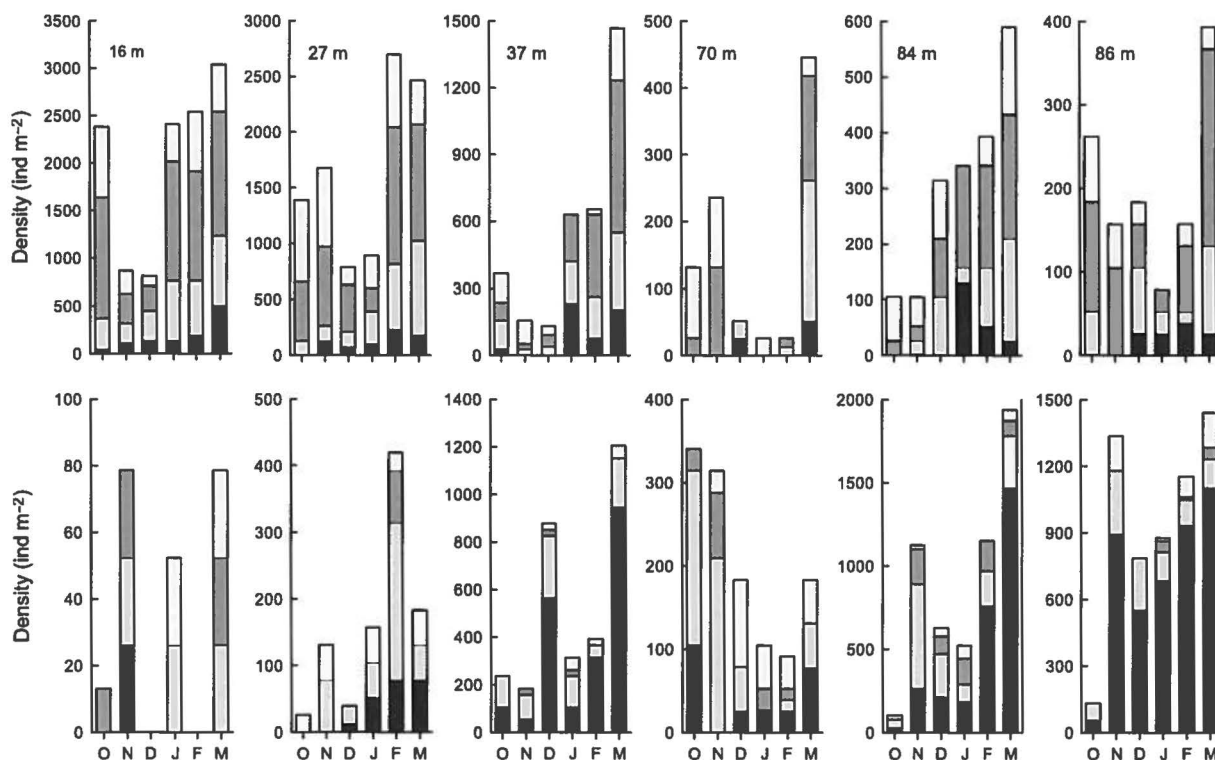


Figure 4 Monthly variation in densities of polychaetes (top row) and bivalves (bottom row) of small (black), medium (grey), large (dark grey) and very large (light grey) size classes from October 2006 to March 2007 at six sites on the Tejo estuary. The distance of each site from the nearest sewage stream is indicated in the upper graphs. Note the different scales on each panel.

range from $c\ 1.6\text{ mg AFDM s}^{-1}$ within 100 m of a sewage outfall to $0.2\text{ mg AFDM s}^{-1}$ at 700 m from an outfall (Fig. 5).

The decline in prey intake rates of godwits foraging on polychaetes with distance to the nearest sewage outfall is primarily a consequence of declines in the proportion of very large polychaetes in the diet (Fig. 6a). Within 200 m of outfalls, very large polychaetes usually constitute $c\ 80\text{--}90\%$ of the biomass intake rate, whereas this typically declines to $c\ 65\%$ beyond 500 m from outfalls (Fig. 6a). The proportion of small, medium and large polychaetes in the godwit diet increases significantly with distance from sewage outfalls, but this is insufficient to maintain the biomass intake rates achieved close to the outfalls (Figs 5a and 6a). For godwits foraging on bivalves, the proportions of each size class do not vary with distance from the nearest sewage outfall, and the relative contribution of each size class to the biomass intake rate is more similar than for polychaetes (Fig 6b).

Across sites, the mean ($\pm\text{SE}$) flock sizes ranged from 21 ± 3.6 to 139 ± 45.0 , but there was no significant change in the mean flock size with distance from the nearest sewage outfall ($F_{1,17} = 0.611$, $r^2 = 0.04$, $P = 0.45$).

Discussion

On the Tejo estuary, areas of mudflat in the immediate vicinity ($c\ 30\text{ m}$) of a sewage stream support polychaete

densities and biomass that are an order of magnitude higher than more distant sites ($> 70\text{ m}$). This in turn allows godwits that forage on polychaetes in these locations to attain the highest intake rates. In contrast, there is little change in the density or biomass of bivalves with distance from sewage streams. However, godwit intake rates are only higher on polychaetes than on bivalves on mudflats that are within $c\ 150\text{ m}$ of a sewage outfall (Fig. 5).

The effect of proximity to sewage stream on polychaete density and biomass is very likely to occur as a consequence of high inputs of organic matter into these sites, providing a rich food supply for *H. diversicolor* (Reise, 1985; Olivier *et al.*, 1995). Invertebrate communities can also vary in relation to sediment type on estuaries (Gaston, 1987; Thrush, 1991), but the lack of any variation in sediment penetrability with distance from sewage outfalls suggests that this is not the driver of the variation in the abundance of polychaetes on the Tejo estuary. Bivalves could also benefit from an increase in the organic load in these locations (but see Matthews & Fairweather, 2008); however, the wastewaters currently being discharged into the Tejo estuary are likely to also contain chemical toxins from factory waste, which might influence bivalve abundance and biomass. High levels of lead in the Tejo estuary have recently led to *S. plana* being declared unfit for human consumption (DR, 2007). The polychaete *H. diversicolor* is generally more tolerant of pollution (Bartels-Hardege &

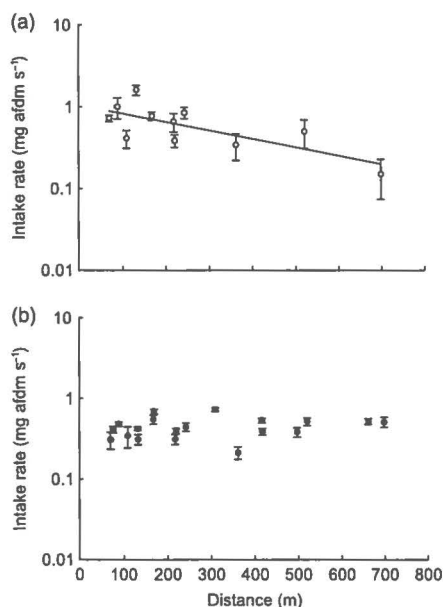


Figure 5 The change in the mean (± se) rate of biomass intake of black-tailed godwits foraging *Limosa limosa* on (a) polychaetes ($\log_{10}$ intake rate = $-0.001 \times \text{distance} - 0.085$, $r^2 = 0.39$, $P = 0.03$) and (b) bivalves with distance from the nearest sewage outfall on the Tejo estuary.

Zeeck, 1990; Saiz-Salinas & Francés-Zubillaga, 1997a,b; Scraps, 2002) and is therefore more likely to be able to take advantage of these high organic loadings (Esselink, 1998).

The high prey intake rates achieved by godwits foraging on polychaetes in close proximity to sewage outfalls (Fig. 5a) are mostly driven by the increased abundance of polychaetes of the very large (> 50 mm) size class (Fig. 6a). Among bivalves and polychaetes of the very large size class, polychaetes exceeding 50 mm length have previously been shown to be the most profitable prey item for godwits (Alves, 2009). However, godwits are sexually size dimorphic (Gunnarsson *et al.*, 2006) and the longer-billed females have been found to forage on polychaetes (particularly of the large and very large size classes) more than the small-billed males (Alves, 2009); thus, the greater burrowing depths of large polychaetes may limit their accessibility to small-billed godwits. As polychaetes of < 50 mm body length are less profitable than bivalves of similar size classes (Alves, 2009), foraging on polychaetes is likely to be of most importance to the longer-billed females that can profit from consuming the large individuals. This may explain why flock sizes are not higher in close proximity to sewage streams; although prey abundances are higher at these sites, these resources may not be available to all individuals.

Conservation implications

The ongoing development of a network of improved sewage treatment on the Tejo estuary is likely to alter the distribution and abundance of polychaetes. In the Oued Souss

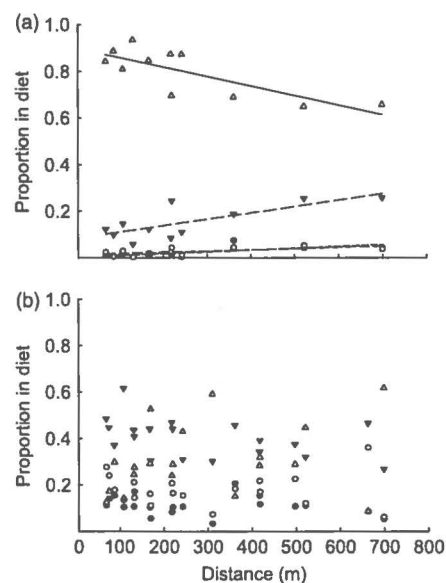


Figure 6 The change in the proportionate contribution of small (filled circles), medium (open circles), large (filled triangles) and very large (open triangles) prey size classes to the biomass intake rate of black-tailed godwits *Limosa limosa* foraging on (a) polychaetes and (b) bivalves with distance to the nearest sewage outfall. Lines indicate significant regressions for polychaetes (short dashed line, small = $7.92 \times 10^{-5} \times \text{distance} + 0.002$, $r^2 = 0.48$, $P = 0.018$; medium dashed line, medium = $5.37 \times 10^{-5} \times \text{distance} + 0.01$, $r^2 = 0.41$, $P = 0.033$; long dashed line, large = $0.001 \times \text{distance} + 0.08$, $r^2 = 0.58$, $P = 0.007$; solid line, very large = $-0.001 \times \text{distance} + 0.90$, $r^2 = 0.62$, $P = 0.004$).

estuary, Morocco, both polychaete density and biomass were significantly reduced after wastewater discharge into the estuary was stopped (Ait Alla *et al.*, 2006). However, declines in polychaete abundance following wastewater treatment are unlikely to greatly influence the numbers of godwits on the Tejo estuary as (1) the current levels of organic loading only produce significant increases in polychaete abundance on sites within c 30 m of sewage streams and c 150 m from sewage outfalls, which comprise only a small proportion (c 8%), of the 34 000 ha of estuarine mudflats available in the Tejo estuary (there are c. 32 outfalls along the south-east shore); (2) estuary wide counts (encompassing low and high tides) of godwits across the Tejo suggest that the average proportion of godwits regularly foraging on areas within c 150 m of a sewage outfall is only c. 17% ± 0.02 SE ($n = 26$ counts) and, within these flocks, only the longer-billed godwits may be capable of foraging on the profitable very large polychaetes; (3) the lack of any seasonal declines in the abundance of bivalves or polychaetes during winter (Fig. 4) suggests that sufficient resources are likely to be available elsewhere on the Tejo to accommodate godwits that can no longer exploit high polychaete densities adjacent to sewage streams.

Reducing the amount of untreated wastewater currently discharged into the Tejo estuary is therefore unlikely to

greatly affect the number of godwits supported on the estuary, and possibly of any other waterbirds foraging in these areas. Besides godwits, only black-headed gulls *Larus ridibundus* are common and frequently recorded foraging on areas in the close vicinity of sewage outfall. Moreover, reductions in inputs of chemical toxins to the estuary that led to the local extinction of oysters *Crassostrea angulata* (Dias & Marques, 1999), and are probably also the cause of the high levels of lead currently found in *S. plana* (DR, 2007), may very well benefit several invertebrate species. The improvement of wastewater treatment in the Tejo estuary is thus likely to be far more beneficial to the estuarine ecosystem than the current situation.

The location of the Tejo estuary in southern Europe makes it an extremely important stop-over and winter location for many waterbirds from across Europe (Delany *et al.*, 2009), and may also contribute to the diversity of prey and lack of strong seasonal depletion in prey abundance on this estuary. In south Europe and North Africa, both *H. diversicolor* and *S. plana* are reported to have two recruitment periods per year and to grow throughout the winter months (Gillet, 1990, 1993; Silva, 1991; Sola, 1997; Ait Alla *et al.*, 2006). In estuaries at more northerly latitudes where climatic conditions may constrain reproduction and growth, and invertebrate communities can be more dominated by polychaetes, the implications for predatory shorebirds of reducing organic loading through improved wastewater treatment may be more significant. However, the evidence presented here suggests that the benefits of reducing nutrient inputs into estuaries as part of the implementation of the EU Water Framework Directive will not necessarily incur high costs for the waterbirds for which many of these sites receive international protection.

Acknowledgements

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