32. Celtic Sea frontal systems

Sensitivity Assessment

Table A11.32. Sensitivity assessment for Celtic Sea frontal systems. NR = not relevant, NA = not assessed, NEv = no evidence, H = high, M = medium, L = low, NS = not sensitive. Associated sectors include activities related to offshore renewable energy (O), Fishing (F), or shipping (S).

Pressures		**Associated sector(s)**	**Resistance**				**Resilience**				**Sensitivity**				**References**
Classification	**Pressure type**		**Score**	**QoE**	**AoE**	**DoC**	**Score**	**QoE**	**AoE**	**DoC**	**Score**	**QoE**	**AoE**	**DoC**	
Physical	Physical loss (to land or freshwater habitat)	O	None	L	NR	NR	H	L	NR	NR	H	L	NR	NR	-
	Physical change (to another seabed type)	O, F	M	L	M	M	M	L	M	M	M	L	M	M	-
	Physical change (to another sediment type)	O, F	M	L	M	M	M	L	M	M	M	L	M	M	-
	Habitat structure change-removal of substratum (extraction)	O	M	L	NR	NR	M	L	NR	NR	M	L	NR	NR	-
	Abrasion/disturbance of substratum surface or seabed	O, F	M	L	M	M	M	L	M	M	M	L	M	M	-

Pressures		Associated sector(s)	Resistance				Resilience				Sensitivity				References
Classification	Pressure type		Score	QoE	AoE	DoC	Score	QoE	AoE	DoC	Score	QoE	AoE	DoC	
	Penetration or disturbance of substratum subsurface	O, F	M	L	M	M	M	L	M	M	M	L	M	M	-
	Changes in suspended solids (water clarity)	O, F	H	H	H	M	H	H	H	M	NS	H	H	M	-
Physical	Smothering and siltation changes (light)	O	NEv	L	NR	NR	NEv	L	NR	NR	NEv	L	NR	NR	-
	Smothering and siltation changes (heavy)	O	L	L	H	L	M	L	H	L	M	L	H	L	-
	Underwater noise	O, F, S	M	M	M	H	H	M	H	H	L	M	M	H	-
	Electromagnetic energy	O	NEv	L	L	NR	NEv	L	LNR	NR	L	L	L	NR	-
	Barrier to species movement	O, F	M	L	L	NR	H	L	L	L	L	L	L	NRL	-

Pressures		Associated sector(s)	Resistance				Resilience				Sensitivity				References
Classification	**Pressure type**		**Score**	**QoE**	**AoE**	**DoC**	**Score**	**QoE**	**AoE**	**DoC**	**Score**	**QoE**	**AoE**	**DoC**	
	Death or injury by collision	O, F, S	M	L	NR	NR	M	L	NR	NR	M	L	L	L	-
Hydrological	Water flow changes	O	H	M	M	M	M	M	M	M	M	M	M	M	-
Chemical	Transition elements & organo-metal contamination	O, F, S	M	M	M	H	H	M	L	M	L	M	L	M	-
	Hydrocarbon & PAH contamination	O, F, S	L	H	M	H	H	H	M	H	L	M	L	M	-
	Synthetic compound contamination	O, F, S	NA	NR	NR	NR	NA	NR	NR	NR	Sensitive	NR	NR	NR	-
	Introduction of other substances	O, F, S	NEv	NR	NR	NR	NEv	NR	NR	NR	NEv	NR	NR	NR	-
	Deoxygenation	O	H	H	H	M	H	H	H	M	NS	H	H	M	-
Biological	Introduction or spread of invasive non-indigenous species	O, F, S	NA	NR	NR	NR	NA	NR	NR	NR	NA	NR	NR	NR	-

Pressures		Associated sector(s)	Resistance				Resilience				Sensitivity				References
Classification	Pressure type		Score	QoE	AoE	DoC	Score	QoE	AoE	DoC	Score	QoE	AoE	DoC	
	Removal of target species	F	L	H	H	H	L	H	H	H	H	H	H	H	-
	Removal of non-target species	F	L	H	H	H	L	H	H	H	H	H	H	H	-

References for Celtic Sea frontal systems sensitivity assessment

1. Almeida, R.A., Fajgenblat, M., Lemmens, P., & De Meester, L. (2023). Pesticide exposure enhances dominance patterns in a zooplankton community. *Ecological Applications*, 33, 7. https://doi.org/10.1002/eap.2900

2. Arias, A.H., Souissi, A., Roussin, M., Ouddane, B., & Souissi, S. (2016). Bioaccumulation of PAHs in marine zooplankton: an experimental study in the copepod *Pseudodiaptomus marinus*. *Environmental Earth Sciences*, 75, 1-9. https://doi.org/10.1007/s12665-016-5472-1

3. Bailey, S.A., Brown, L., Campbell, M.L., Canning-Clode, J., Carlton, J. T., Castro, N., Chainho, P., Chan, F.T., Creed, J.C., Curd, A., Darling, J., Fofonoff, P., Galil, B.S., Hewitt, C.L., Inglis, J.G., Keith, I., Mandrak, N.E., Marchini, A., McKenzie, C.H., Occhipinti-Ambrogi, A., Ojaveer, H., Pires-Teixeira, L.M., Robinson, T.B., Ruiz, G.M., Seaward, K., Schwindt, E., Son, M.O., Therriault, D.W., & Zhan, A. (2020). Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. *Diversity and Distributions*, 26(12), 1780-1797. https://doi.org/10.1111/ddi.13167

4. Belkin, I.M., Cornillon, P.C., & Sherman, K. (2009). Fronts in large marine ecosystems. *Progress in Oceanography*, 81(1-4), 223-236. https://doi.org/10.1016/j.pocean.2009.04.015

5. Bendtsen, J., Daugbjerg, N., Jensen, R.S., Brady, M.C., Nielsen, M.H., Hansen, J.L., & Richardson, K. (2024). Phytoplankton community changes in relation to nutrient fluxes along a quasi-stationary front. *Marine Ecology Progress Series*, 727, 67-80. https://doi.org/10.3354/meps14489

6. Benoit-Bird, K.J., Waluk, C.M., & Ryan, J.P. (2019). Forage species swarm in response to coastal upwelling. *Geophysical Research Letters*, 46(3), 1537-1546. https://doi.org/10.1029/2018GL081603

7. Bibi, R., Kang, H.Y., Kim, D., Jang, J., Kundu, G.K., Kim, Y.K., & Kang, C. K. (2020). Dominance of autochthonous phytoplankton-derived particulate organic matter in a low-turbidity temperate estuarine embayment, Gwangyang Bay, Korea. *Frontiers in Marine Science*, 7, 580260. https://doi.org/10.3389/fmars.2020.580260

8. Biswas, H., & Bandyopadhyay, D. (2017). Physiological responses of coastal phytoplankton (Visakhapatnam, SW Bay of Bengal, India) to experimental copper addition. *Marine environmental research*, 131, 19-31. https://doi.org/10.1016/j.marenvres.2017.09.008

9. Blain, C.O., Hansen, S.C., & Shears, N.T. (2021). Coastal darkening substantially limits the contribution of kelp to coastal carbon cycles. *Global Change Biology*, 27(21), 5547-5563. https://doi.org/10.1111/gcb.15837

10. Bretherton, L., Hillhouse, J., Kamalanathan, M., Finkel, Z.V., Irwin, A. J., & Quigg, A. (2020). Trait-dependent variability of the response of marine phytoplankton to oil and dispersant exposure. *Marine Pollution Bulletin*, 153, 110906. https://doi.org/10.1016/j.marpolbul.2020.110906

11. Carpenter, J.R., Merckelbach, L., Callies, U., Clark, S., Gaslikova, L., & Baschek, B. (2016). Potential impacts of offshore wind farms on North Sea stratification. *PloS one*, 11(8), e0160830. https://doi.org/10.1371/journal.pone.0160830

12. Casabianca, S., Bellingeri, A., Capellacci, S., Sbrana, A., Russo, T., Corsi, I., & Penna, A. (2021). Ecological implications beyond the ecotoxicity of plastic debris on marine phytoplankton assemblage structure and functioning. *Environmental Pollution*, 290, 118101. https://doi.org/10.1016/j.envpol.2021.118101

13. Cazenave, P. W., Torres, R., & Allen, J. I. (2016). Unstructured grid modelling of offshore wind farm impacts on seasonally stratified shelf seas. *Progress in oceanography*, 145, 25-41. https://doi.org/10.1016/j.pocean.2016.04.004

14. Chang, M.H., Tang, T.Y., Ho, C. R., & Chao, S.Y. (2013). Kuroshio-induced wake in the lee of Green Island off Taiwan. *Journal of Geophysical Research: Oceans*, 118(3), 1508-1519. https://doi.org/10.1002/jgrc.20151

15. Charalampous, E., Matthiessen, B., & Sommer, U. (2018). Light effects on phytoplankton morphometric traits influence nutrient utilization ability. *Journal of Plankton Research*, 40(5), 568-579. https://doi.org/10.1093/plankt/fby037

16. Chitteth Ramachandran, R., Desmond, C., Judge, F., Serraris, J.J., & Murphy, J. (2022). Floating wind turbines: marine operations challenges and opportunities. *Wind Energy Science*, 7(2), 903-924. https://doi.org/10.5194/wes-7-903-2022

17. Chouvelon, T., Strady, E., Harmelin-Vivien, M., Radakovitch, O., Brach-Papa, C., Crochet, S., Knoery, J., Rozuel, E, Thomas, B., Tronczynski, J., & Chiffoleau, J.F. (2019). Patterns of trace metal bioaccumulation and trophic transfer in a phytoplankton-zooplankton-small pelagic fish marine food web. *Marine Pollution Bulletin*, *146*, 1013-1030. https://doi.org/10.1016/j.marpolbul.2019.07.047

18. Christiansen, N., Daewel, U., Djath, B., & Schrum, C. (2022). Emergence of large-scale hydrodynamic structures due to atmospheric offshore wind farm wakes. *Frontiers in Marine Science*, 9, 64. https://doi.org/10.3389/fmars.2022.818501

19. Copping, A.E., & Hemery, L.G. (2020). *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development around the World.* Report for Ocean Energy Systems (OES). Richland, WA (United States). https://doi.org/10.2172/1632878

20. Copping, A.E., Hemery, L.G., Viehman, H., Seitz, A.C., Staines, G.J., & Hasselman, D.J. (2021). Are fish in danger? A review of environmental effects of marine renewable energy on fishes. *Biological Conservation*, 262, 109297. https://doi.org/10.1016/j.biocon.2021.109297

21. Daewel, U., Akhtar, N., Christiansen, N., & Schrum, C. (2022). Offshore wind farms are projected to impact primary production and bottom water deoxygenation in the North Sea. *Communications Earth & Environment*, 3, 1, 292. https://doi.org/10.1038/s43247-022-00625-0

22. Daly, K.L., Remsen, A., Outram, D.M., Broadbent, H., Kramer, K., & Dubickas, K. (2021). Resilience of the zooplankton community in the northeast Gulf of Mexico during and after the Deepwater Horizon oil spill. *Marine Pollution Bulletin*, 163, 111882. https://doi.org/10.1016/j.marpolbul.2020.111882

23. Degraer, S., Brabant, R., Rumes, B., & Vigin, L. (2016). *Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Environmental impact monitoring reloaded*. Marine Ecology and Management Section. OD Natural Environment, Royal Belgian Institute of Natural Sciences, Brussels. 287 pp. https://tethys.pnnl.gov/sites/default/files/publications/Degraer-et-al-2016.pdf

24. Doty, M. S., & Oguri, M. (1956). The island mass effect. *ICES Journal of Marine Science*, 22, 1, 33-37. https://doi.org/10.1093/icesjms/22.1.33

25. Filimonova, V., Goncalves, F., Marques, J.C., De Troch, M., & Goncalves, A.M. (2016). Biochemical and toxicological effects of organic (herbicide Primextra® Gold TZ) and inorganic (copper) compounds on zooplankton and phytoplankton species. *Aquatic toxicology*, 177, 33-43. https://doi.org/10.1016/j.aquatox.2016.05.008

26. García-Garay, J., Franco-Herrera, A., & Machuca-Martinez, F. (2018). Zooplankton sensitivity and phytoplankton regrowth for ballast water treatment with advanced oxidation processes.

Environmental Science and Pollution Research, 25, 35008-35014. https://doi.org/10.1007/s11356-018-2308-4

27. Gass, S.E., & Roberts, J.M. (2006). The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: colony growth, recruitment and environmental controls on distribution. *Marine Pollution Bulletin*, 52, 5, 549-559. https://doi.org/10.1016/j.marpolbul.2005.10.002

28. Ghanbari, B., & Gómez-Aguilar, J.F. (2018). Modeling the dynamics of nutrient–phytoplankton–zooplankton system with variable-order fractional derivatives. *Chaos, Solitons & Fractals*, 116, 114-120. https://doi.org/10.1016/j.chaos.2018.09.026

29. Golubkov, M. S., Nikulina, V. N., & Golubkov, S. M. (2022). Impact of the Construction of New Port Facilities on the Biomass and Species Composition of Phytoplankton in the Neva Estuary (Baltic Sea). *Journal of Marine Science and Engineering*, 11, 1, 32. https://doi.org/10.3390/jmse11010032

30. Hasegawa, D., Lewis, M.R., & Gangopadhyay, A. (2009). How islands cause phytoplankton to bloom in their wakes. *Geophysical Research Letters*, 36, 20. https://doi.org/10.1029/2009GL039743

31. Helbling, E.W., Banaszak, A.T., Valiñas, M.S., Vizzo, J.I., Villafañe, V.E., & Cabrerizo, M.J. (2023). Browning, nutrient inputs, and fast vertical mixing from simulated extreme rainfall and wind stress alter estuarine phytoplankton productivity. *New Phytologist*, 238(5), 1876-1888. https://doi.org/10.1111/nph.18874

32. Heneghan, R.F., Everett, J.D., Blanchard, J.L., & Richardson, A.J. (2016). Zooplankton are not fish: improving zooplankton realism in size-spectrum models mediates energy transfer in food webs. *Frontiers in Marine Science*, 3, 201. https://doi.org/10.3389/fmars.2016.00201

33. Hindarti, D., & Larasati, A.W. (2019, March). Copper (Cu) and Cadmium (Cd) toxicity on growth, chlorophyll-a and carotenoid content of phytoplankton Nitzschia sp. In *IOP Conference Series: Earth and Environmental Science* 236, 012053. https://doi.org/10.1088/1755-1315/236/1/012053

34. Hung, C.C., Ko, F.C., Gong, G.C., Chen, K.S., Wu, J.M., Chiang, H.L., Peng, S.C., & Santschi, P.H. (2014). Increased zooplankton PAH concentrations across hydrographic fronts in the East China Sea. *Marine pollution bulletin*, 83(1), 248-257. https://doi.org/10.1016/j.marpolbul.2014.03.045

35. Hyun, B., Baek, S.H., Shin, K., & Choi, K.H. (2017). Assessment of phytoplankton invasion risks in the ballast water of international ships in different growth conditions. *Aquatic Ecosystem Health & Management*, 20(4), 423-434. https://doi.org/10.1080/14634988.2017.1406273

36. Hyun, B., Shin, K., Jang, M.C., Jang, P.G., Lee, W.J., Park, C., & Choi, K.H. (2015). Potential invasions of phytoplankton in ship ballast water at South Korean ports. *Marine and Freshwater Research*, 67, 12, 1906-1917. https://doi.org/10.1071/MF15170

37. Ikhennicheu, M., Lynch, M., Doole, S., Borisade, F., Matha, D., Dominguez, J. L., Rubén, D.V., Habekost, T., Lizet, R., Sabina, P., Climent, M., & Trubat, P. (2020). *D2. 1 Review of the state of the art of mooring and anchoring designs, technical challenges and identification of relevant DLCs*. Technical Report. Core Wind Project. https://corewind.eu/wp-content/uploads/files/publications/COREWIND-D2.1-Review-of-the-state-of-the-art-of-mooring-and-anchoring-designs.pdf

38. Kamalanathan, M., Mapes, S., Prouse, A., Faulkner, P., Klobusnik, N. H., Hillhouse, J., Hala, D. & Quigg, A. (2022). Core metabolism plasticity in phytoplankton: Response of *Dunaliella tertiolecta* to oil exposure. *Journal of Phycology*, 58(6), 804-814. https://doi.org/10.1111/jpy.13286

39. Karama, K.S., & Yoshiki. (2019). A review on anchored fish aggregating devices (aFADs) as a tool to promote and manage artisanal fisheries. *Journal of Fisheries Engineering*, 56(1), 1-13. https://doi.org/10.18903/fisheng.56.1_1

40. Keister, J.E., Winans, A.K., & Herrmann, B. (2020). Zooplankton community response to seasonal hypoxia: a test of three hypotheses. *Diversity*, 12(1), 21. https://doi.org/10.3390/d12010021

41. Kordan, M.B., & Yakan, S.D. (2024). The effect of offshore wind farms on the variation of the phytoplankton population. *Regional Studies in Marine Science*, 69, 103358. https://doi.org/10.1016/j.rsma.2023.103358

42. Kovač, Ž., Platt, T., & Sathyendranath, S. (2020). Stability and resilience in a nutrient-phytoplankton marine ecosystem model. *ICES Journal of Marine Science*, 77(4), 1556-1572. https://doi.org/10.1093/icesjms/fsaa067

43. Lass, H.U., Mohrholz, V., Knoll, M., & Prandke, H. (2008). Enhanced mixing downstream of a pile in an estuarine flow. *Journal of Marine Systems*, 74(1-2), 505-527. https://doi.org/10.1016/j.jmarsys.2008.04.003

44. Le Fevre, J. (1987). Aspects of the biology of frontal systems. *Advances in marine biology*, 23, 163-299. https://doi.org/10.1016/S0065-2881(08)60109-1

45. Leruste, A., Pasqualini, V., Garrido, M., Malet, N., De Wit, R., & Bec, B. (2019). Physiological and behavioral responses of phytoplankton communities to nutrient availability in a disturbed Mediterranean coastal lagoon. *Estuarine, Coastal and Shelf Science*, 219, 176-188. https://doi.org/10.1016/j.ecss.2019.02.014

46. Lieber, L., Nimmo-Smith, W.A.M., Waggitt, J.J., & Kregting, L. (2019). Localised anthropogenic wake generates a predictable foraging hotspot for top predators. *Communications Biology*, 2(1), 123. https://doi.org/10.1038/s42003-019-0364-z

47. Ludewig, Elke. (2015). Analysis 02: OWF Effect on the Ocean. pp 51-25 in *On the Effect of Offshore Wind Farms on the Atmosphere and Ocean Dynamics*. Springer. https://doi.org/10.1007/978-3-319-08641-5

48. Ma, K.T., Luo, Y., Kwan, C. T.T., & Wu, Y. (2019). *Mooring system engineering for offshore structures*. Gulf Professional Publishing. https://doi.org/10.1016/C2018-0-02217-3

49. Maclean, I. M., Inger, R., Benson, D., Booth, C.G., Embling, C.B., Grecian, W.J., Heymans, J.J., Plummer, K.E., Shackshaft, M., Sparling, C.E., Wilson, B., Wright, L.J., Bradbury, G., Christen, N., Godley, B.J. Jackson, A.C., McCluskie, A., Nicholls-Lee, R., & Bearhop, S. (2014). Resolving issues with environmental impact assessment of marine renewable energy installations. *Frontiers in Marine Science*, 1, 75. https://doi.org/10.3389/fmars.2014.00075

50. McLean, D. L., Ferreira, L. C., Benthuysen, J. A., Miller, K. J., Schläppy, M. L., Ajemian, M. J., Berry, O., Birchenough, S.N.R, Bond, T., Boschetti, F., Bull, A.S., Claisse, J.T., Condie, S.A., Consoli, P., Coolen, J.W.P, Elliott, M., Fortune, I.S., Fowler, A.M., Gillanders, M.B., Harrison, H.B., Hart, K.M., Henry, L., Hewitt, C.L., Hicks, N., Hock, K., Hyder, K., Love, M., Macreadie, P.I., Miller, R.J., Montevecchi, W.A., Nishimoto, M.M., Page, H.M., Paterson, D.M., Pattiaratchi, C.B., Pecl, G.T., Porter, J.S., Reeves, D.B., Riginos, C., Rouse, S., Russell, D.F.F., Sherman, C.D.H., Teilmann, J., Todd, V.L.G., Treml, E.A., Williamson, D.H., & Thums, M. (2022). Influence of offshore oil and gas structures on seascape ecological connectivity. *Global change biology*, 28(11), 3515-3536. https://doi.org/10.1111/gcb.16134

51. Messié, M., & Chavez, F. P. (2017). Nutrient supply, surface currents, and plankton dynamics predict zooplankton hotspots in coastal upwelling systems. *Geophysical Research Letters*, 44, 17, 8979-8986. https://doi.org/10.1002/2017GL074322

52. Messié, M., Petrenko, A., Doglioli, A.M., Aldebert, C., Martinez, E., Koenig, G., Bonnet, S., & Moutin, T. (2020). The delayed island mass effect: How islands can remotely trigger blooms in the oligotrophic ocean. *Geophysical Research Letters*, 47, 2, e2019GL085282. https://doi.org/10.1029/2019GL085282

53. Othman, H.B., Lanouguère, É., Got, P., Hlaili, A.S., & Leboulanger, C. (2018). Structural and functional responses of coastal marine phytoplankton communities to PAH mixtures. *Chemosphere*, 209, 908-919. https://doi.org/10.1016/j.chemosphere.2018.06.153

54. Ozhan, K., & Bargu, S. (2014). Distinct responses of Gulf of Mexico phytoplankton communities to crude oil and the dispersant corexit® Ec9500A under different nutrient regimes. *Ecotoxicology*, 23, 370-384. https://doi.org/10.1007/s10646-014-1195-9

55. Özhan, K., Miles, S.M., Gao, H., & Bargu, S. (2014). Relative phytoplankton growth responses to physically and chemically dispersed South Louisiana sweet crude oil. *Environmental monitoring and assessment*, 186, 3941-3956. https://doi.org/10.1007/s10661-014-3670-4

56. Ozhan, Koray, Michael L. Parsons, and Sibel Bargu. 2014. How Were Phytoplankton Affected by the Deepwater Horizon Oil Spill? *BioScience*, 64(9), 829–36. https://doi.org/10.1007/s10661-014-3670-4

57. Parsons, M.L., Morrison, W., Rabalais, N.N., Turner, R.E., & Tyre, K.N. (2015). Phytoplankton and the Macondo oil spill: a comparison of the 2010 phytoplankton assemblage to baseline conditions on the Louisiana shelf. *Environmental Pollution*, 207, 152-160. https://doi.org/10.1016/j.envpol.2015.09.019

58. Paskyabi, M.B., & Fer, I. (2012). Upper ocean response to large wind farm effect in the presence of surface gravity waves. *Energy Procedia*, 24, 245-254. https://doi.org/10.1016/j.egypro.2012.06.106

59. Payton, T.G., Beckingham, B.A., & Dustan, P. (2020). Microplastic exposure to zooplankton at tidal fronts in Charleston Harbor, SC USA. *Estuarine, Coastal and Shelf Science*, 232, 106510. https://doi.org/10.1016/j.ecss.2019.106510

60. Perkol-Finkel, S., Zilman, G., Sella, I., Miloh, T., & Benayahu, Y. (2008). Floating and fixed artificial habitats: Spatial and temporal patterns of benthic communities in a coral reef environment. *Estuarine, Coastal and Shelf Science*, 77, 3, 491-500. https://doi.org/10.1016/j.ecss.2007.10.005

61. Petersen, J.K., & Malm, T. (2006). Offshore windmill farms: threats to or possibilities for the marine environment. *AMBIO: A Journal of the Human Environment*, 35, 2, 75-80. https://doi.org/10.1579/0044-7447(2006)35[75:OWFTTO]2.0.CO;2

62. Powell, J.R., & Ohman, M.D. (2015). Covariability of zooplankton gradients with glider-detected density fronts in the Southern California Current System. *Deep Sea Research Part II: Topical Studies in Oceanography*, 112, 79-90. https://doi.org/10.1016/j.dsr2.2014.04.002

63. Putzeys, S., Juárez-Fonseca, M., Valencia-Agami, S.S., Mendoza-Flores, A., Cerqueda-García, D., Aguilar-Trujillo, A.C., Martínez-Cruz, M.E., Okolodkov, Y.B., Arcega-Cabrera, F., Herrera-Silveira, J.A., Aguirre-Macedo, M.L., & Pech, D. (2022). Effects of a light crude oil spill on a tropical coastal phytoplankton community. *Bulletin of Environmental Contamination and Toxicology*, 108(1), 55-63. https://doi.org/10.1007/s00128-021-03306-4

64. Quigg, A., Parsons, M., Bargu, S., Ozhan, K., Daly, K.L., Chakraborty, S., Kamalanathan, M., Erdner, D., Cosgrove, S., & Buskey, E.J. (2021). Marine phytoplankton responses to oil and dispersant exposures: Knowledge gained since the Deepwater Horizon oil spill. *Marine pollution bulletin*, 164, 112074. https://doi.org/10.1016/j.marpolbul.2021.112074.

65. Ropert-Coudert, Y., Kato, A., & Chiaradia, A. (2009). Impact of small-scale environmental perturbations on local marine food resources: a case study of a predator, the little penguin. *Proceedings of the Royal Society B: Biological Sciences*, 276(1676), 4105-4109. https://doi.org/10.1098/rspb.2009.1399

66. Rudiyanti, S., Anggoro, S., & Rahman, A. (2018). Mapping of trophic states based on nutrients concentration and phytoplankton abundance in Jatibarang Reservoir. In *IOP Conference Series: Earth and Environmental Science* 116(1), 012048. https://doi.org/10.1088/1755-1315/116/1/012048

67. Ruiz, L.H., Ekumah, B., Asiedu, D.A., Albani, G., Acheampong, E., Jónasdóttir, S.H., Koski, M., & Nielsen, T.G. (2021). Climate change and oil pollution: A dangerous cocktail for tropical zooplankton. *Aquatic Toxicology*, 231, 105718. https://doi.org/10.1016/j.aquatox.2020.105718

68. Sato, M., Horne, J.K., Parker-Stetter, S.L., Essington, T.E., Keister, J.E., Moriarty, P.E., Li, l., & Newton, J. (2016). Impacts of moderate hypoxia on fish and zooplankton prey distributions in a coastal fjord. *Marine Ecology Progress Series*, 560, 57-72. https://doi.org/10.3354/meps11910

69. Silva, J.C., Echeveste, P., & Lombardi, A.T. (2018). Higher biomolecules yield in phytoplankton under copper exposure. *Ecotoxicology and environmental safety*, 161, 57-63. https://doi.org/10.1016/j.ecoenv.2018.05.059

70. Simpson, J.H., & Hunter, J.R. (1974). Fronts in the Irish sea. *Nature*, 250(5465), 404-406. https://doi.org/10.1038/250404a0

71. Simpson, J.H., & Pingree, R.D. (1978). Shallow sea fronts produced by tidal stirring. In Bowman, M.J., Esaias, W.E. (Eds) *Oceanic Fronts in Coastal Processes: Proceedings of a Workshop Held at the Marine Sciences Research Center, May 25–27, 1977*, Berlin, Heidelberg: Springer Berlin Heidelberg, 29-42. https://doi.org/10.1007/978-3-642-66987-3_5

72. Sims, D.W., & Southall, E.J. (2002). Occurrence of ocean sunfish, Mola mola near fronts in the western English Channel. *Journal of the Marine Biological Association of the United Kingdom*, 82(5), 927-928. https://doi.org/10.1017/S0025315402006409

73. Singh, R., Kumar Tiwari, S., Ojha, A., & Kumar Thakur, N. (2023). Dynamical study of nutrient-phytoplankton model with toxicity: Effect of diffusion and time delay. *Mathematical Methods in the Applied Sciences*, 46(1), 490-509. https://doi.org/10.1002/mma.8523

74. Snodgrass, D.J., Orbesen, E.S., Walter, J.F., Hoolihan, J.P., & Brown, C.A. (2020). Potential impacts of oil production platforms and their function as fish aggregating devices on the biology of highly migratory fish species. *Reviews in Fish Biology and Fisheries*, 30, 405-422. https://doi.org/10.1007/s11160-020-09605-z

75. Strogyloudi, E., Paraskevopoulou, V., Campillo, J.A., Zervoudaki, S., Bouga, V., Catsiki, V.A., Dassenakis, E., & Krasakopoulou, E. (2021). Metal and metallothionein levels in zooplankton in relation to environmental exposure: spatial and temporal variability (Saronikos Gulf, Greece). *Environmental Science and Pollution Research*, 28, 28640-28657. https://doi.org/10.1007/s11356-021-12591-9

76. Tanaka, M. (2019). Changes in vertical distribution of zooplankton under wind-induced turbulence: A 36-year record. *Fluids*, 4(4), 195. https://doi.org/10.3390/fluids4040195

77. Tang, D., Sun, J., Zhou, L., Wang, S., Singh, R.P., & Pan, G. (2019). Ecological response of phytoplankton to the oil spills in the oceans. *Geomatics, Natural Hazards and Risk* 10(1), 853–872. https://doi.org/10.1080/19475705.2018.1549110

78. van der Molen, J., Smith, H.C., Lepper, P., Limpenny, S., & Rees, J. (2014). Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem. *Continental shelf research*, 85, 60-72. https://doi.org/10.1016/j.csr.2014.05.018

79. Van Haren, H. (2014). Internal wave–zooplankton interactions in the Alboran Sea (W-Mediterranean). *Journal of plankton research*, 36(4), 1124-1134. https://doi.org/10.1093/plankt/fbu031

80. Vignardi, C.P., Adeleye, A.S., Kayal, M., Oranu, E., Miller, R.J., Keller, A.A., Holden, P.A., & Lenihan, H.S. (2023). Aging of copper nanoparticles in the marine environment regulates toxicity for a coastal phytoplankton species. *Environmental Science & Technology*, 57(17), 6989-6998. https://doi.org/10.1021/acs.est.2c07953

81. Wang, T., Yu, W., Zou, X., Zhang, D., Li, B., Wang, J., & Zhang, H. (2018). Zooplankton community responses and the relation to environmental factors from established offshore wind farms within the Rudong coastal area of China. *Journal of Coastal Research*, 34(4), 843-855. https://doi.org/10.2112/JCOASTRES-D-17-00058.1

82. Wang, Y., Xu, M., Feng, Z., Zhang, F., Cao, F., & Wu, H. (2023). Tidal variability of phytoplankton distribution in the highly turbid Changjiang River Estuary: Mechanisms and implications. *Journal of Geophysical Research: Oceans*, 128(12), e2023JC020090. https://doi.org/10.1029/2023JC020090

83. Wei, H., Zhao, L., Zhang, H., Lu, Y., Yang, W., & Song, G. (2021). Summer hypoxia in Bohai Sea caused by changes in phytoplankton community. *Anthropocene Coasts*, 4(1), 77-86. https://doi.org/10.1139/anc-2020-0017

84. Whitt, D.B., Lévy, M., & Taylor, J. R. (2017). Low-frequency and high-frequency oscillatory winds synergistically enhance nutrient entrainment and phytoplankton at fronts. *Journal of Geophysical Research: Oceans*, 122(2), 1016-1041. https://doi.org/10.1002/2016JC012400

85. Woodson, C.B., McManus, M.A., Tyburczy, J.A., Barth, J.A., Washburn, L., Caselle, J.E., Carr, M.H., Malone, D.P., Raimondi, P.T., Menge, B.A., & Palumbi, S.R. (2012). Coastal fronts set recruitment and connectivity patterns across multiple taxa. *Limnology and Oceanography*, 57(2), 582-596. https://doi.org/10.4319/lo.2012.57.2.0582

86. Zhang, P., Liu, Y., & Zhang, L. (2022). Copper uptake and subcellular distribution in five marine phytoplankton species. *Frontiers in Marine Science*, 9, 1084266. https://doi.org/10.3389/fmars.2022.1084266

87. Ziyadi, N. (2023). A discrete-time nutrients-phytoplankton-oysters mathematical model of a bay ecosystem. *Journal of Biological Dynamics*, 17, 1, 2242720. https://doi.org/10.1080/17513758.2023.2242720

Literature search

The sensitivity analysis of the Celtic Sea frontal stytems treats the fronts as a habitat type and is an aggregated sensitivity table based on the sensitivity analysis of features (individual species or a grouping of closely related species) which are closely associated with fronts and therefore classed as 'characterising species'. In total, 7 sensitivity tables were aggregated. A precautionary approach was used whereby the feature with the highest sensitivity to a specific pressure was used to provide the sensitivity scores for the final aggregated sensitivity table.

The 7 features used for the final aggregated table were:

1. Phytoplankton
2. Mesozooplankton
3. Macrozooplankton (see barrel assessment, appendix)
4. Planktivorous forage fish (see forage fish assessment, appendix)
5. Large planktivorous fish (see basking shark assessment, appendix)
6. Benthic predatory fish (see flapper skate assessment, appendix)
7. Pelagic predatory fish (see porbeagle assessment, appendix)

The reference list in this appendix includes all literature used to assess sensitivity for phytoplankton, zooplankton and potential broadscale ecosystem impacts where pressures or cumulative pressures might affect multiple taxa, trophic groups and ecosystem services. Other trophic groups were assessed using additional literature referenced within the specific assessment cross referenced in the list above.

Web of Science search terms zooplankton sensitivity analysis

(TI = ("phytoplankton") AND TI=("ballast" OR "barrier*"OR "beach*" OR "moor*" OR "noise" OR “ship*” OR "steaming" OR "construction" OR "electro*" OR "turbine*"OR "renewable*" OR "wind farm*" OR "anoxia" OR "copper" OR "disease*" OR "disturbance" OR "heavy metals" OR "hydrocarbon" OR "hypoxia" OR "litter" OR "nitrate*" OR "nitrite*" OR "noise" OR “radionuclide” OR "nutrient*" OR "oil*" OR "PAH*" OR "pathogen*" OR "PCB*" OR "plastic*" OR “regime” OR “salinity” OR "sedimentation" OR "silt*" OR “translocation” OR "tributyltin" OR “turbid*”) NOT AB=("forest*" OR "terrestrial" OR "fresh*" OR "Seagrass" OR "lake") NOT TI=("fresh*" OR "lake*" OR "forest*" OR "terrestrial" OR "freshwater" OR "Seagrass")) AND (PY==("2024" OR "2023" OR "2022" OR "2021" OR "2020" OR "2019" OR "2018" OR "2017" OR "2016" OR "2015" OR "2014"))

Database

ISI Web of Science

Search date

18th April 2024 - 561 results

Search output and screening process

Article titles screened for relevance by including the words ‘phytoplankton’ and one of the pressures under consideration, e.g. ‘bottom trawl*. Workflow follows the Rapid Evidence Assessment approach. The title and all auxiliary information (including abstract) were downloaded from ISI Web of Science in a .ris and excel format. In Excel, abstracts were read and listed to either pass or fail the initial screening process with a reason provided.

Outcome from screening

59 (0.1%) abstracts passed initial screening. Of these 59, 34 (0.06%) were used to provide evidence for the sensitivity analysis, along with expert knowledge within the advisory group.

Web of Science search terms zooplankton sensitivity analysis

TI = ("zooplankton") AND TI=("angl*" OR “beam” OR "bottom trawl*" OR "dredge*" OR "fish*" OR “gear” OR "gillnet*" OR "hook*" OR “injury” OR "net*" OR "otter trawl*" OR “remov*” OR “aggregate*" OR "anchor*" OR "ballast" OR "barrier*"OR "beach*" OR "launch*" OR "moor*" OR "noise" OR “ship*” OR "steaming" OR "collision*" OR "construction" OR "electro*" OR "turbine*"OR "renewable*" OR "wave" OR "wind" OR "wind farm*" OR "anoxia" OR "copper" OR "current*" OR "disease*" OR "disturbance" OR "endocrine disru*" OR "eutrophication" OR “exposure” OR "heavy metals" OR "hydrocarbon" OR "hypoxia" OR "litter" OR "nitrate*" OR "nitrite*" OR "noise" OR “radionuclide” OR "nutrient*" OR "oil*" OR "PAH*" OR "pathogen*" OR "PCB*" OR "plastic*" OR “regime” OR “salinity” OR "sedimentation" OR "silt*" OR “temperatur*” OR “translocation” OR "tributyltin" OR “turbid*” OR “visual” OR "warm*") NOT AB=("forest*" OR "terrestrial" OR "freshwater" OR "Seagrass" OR "benthic" or "lake") NOT TI=("forest*" OR "terrestrial" OR "freshwater" OR "Seagrass" OR "benthic" or "lake*" OR "stream*" OR "river*")

Database

ISI Web of Science

Search date

23rd April 2024 - 355 results

Search output and screening process

Article titles screened for relevance by including the words ‘zooplankton’ and one of the pressures under consideration, e.g. ‘bottom trawl*. Workflow follows the Rapid Evidence Assessment approach. The title and all auxiliary information (including abstract) were downloaded from ISI Web of Science in a .ris and excel format. In Excel, abstracts were read and listed to either pass or fail the initial screening process with a reason provided.

Outcome from screening

28 (0.08%) abstracts passed initial screening. Of these 28, 20 (0.06%) were used to provide evidence for the sensitivity analysis, along with expert knowledge within the advisory group. within the advisory group.