Risk factors in the natural habitat of fish: a review

ABSTRACT

Fish can be found in abundance in most bodies of water. Despite the fact that no species has yet been detected in the deepest 25% of the ocean, they are present in almost every aquatic environment, from the abyssal and even hadal depths of the deepest oceans (where they can be found as cusk-eels and snailfish) to the high mountain streams. Habitat destruction is the leading cause of biodiversity loss. The rise in nutrient loading, particularly nitrogen, is one of the main factors contributing to habitat degradation. Trawling diminishes the environment’s complexity by removing sedimentary features and biogenic structures like sponges, bryozoans, and shell aggregates. The construction of dams on tidal rivers has harmed estuarine habitat: estuary community structure, water chemistry, food webs, and loss of freshwater and estuary habitats. Since 1950, the catch of fishes associated with coral reefs has declined by 60% per unit of effort.Ever growing human populations and acidity have significantly impacted fish diversity.The literature reviewed unequivocally demonstrated how anthropogenic effects have altered ichthyofauna and reduced biodiversity in aquatic environments around the globe. Identifying current and potential habitat hazards and the conservation and improvement actions required to eliminate or minimise those concerns is crucial in determining important fish habitats.

Keywords: Aquatic, habitat loss, Human Impacts, Eutrophication, Conservation,

INTRODUCTION

The term "habitat" has been described as "the structural elements of the environment that attracts organisms and serves as a centre of biological activity" [1]. In the present context, it refers to a variety of sediment types, such as mud through boulders, bed patterns, such as sand waves and ripples and flat mud, as well as the co-occurring biological structures, such as coral, seagrass, sponges, shells, and burrows [2].

Geomorphology of the water body (beds, banks, shape), flow characteristics (high, low, quick, slow), and bed substrate (for example, gravel or sand) type are among the abiotic components, along with water chemistry. In inland waters, these traits are typically very dynamic and directly impact fish and other living organisms [3]. Other things that make up fish habitat include the following:

- Substrate-giving substances, such as rocks, coral, gravel, sand, and mud
- The different kinds of vegetation that are there, such as overhanging vegetation, reeds, water plants, algae, dead wood (snags), seaweed, seagrasses, mangroves, and salt marsh
- The habitat's shape and characteristics, such as the presence of reefs, pools, and riffles
- Relationships with other ecosystems and waterways, such as wetlands, streams, estuaries, floodplains, lakes, and beaches.

Causes of habitat loss

Habitat destruction (habitat loss and habitat reduction) is the process by which a natural habitat becomes incapable of supporting its native species. The organisms that previously inhabited the site are displaced or dead, thereby reducing biodiversity and species abundance [4]. Habitat destruction is the leading cause of biodiversity loss [5,39]. Depending on the type of habitat, exposure, and other environmental factors, specific threats to fish habitat will typically vary in type and severity by location [6, 7, 39, 40]. Listed below are some of the most prevalent risks to habitat:

Eutrophication

The rise in nutrient loading, particularly nitrogen, is one of the main factors contributing to habitat degradation. Increased eutrophication has generally negative impacts. Increased amounts of nutrients entering a bay via sewage, agricultural fields, and lawn fertilizers encourage primary production, which in turn causes a rise in phytoplankton and macro-algae growth, a decrease in water clarity, and changes in the water's chemistry [8, 40, 46, 47]. The dominance of species that are difficult to integrate into the existing trophic structures modifies the makeup of the algal species [9, 39]. A notable illustration of the impact of habitat degradation on fish communities is the modification and disappearance of eelgrass habitats as a result of eutrophication [3]. The Pseudo-nitzschia algal bloom coincided with the abrupt mass fish mortality incident (1.25 metric tonnes) in Puducherry, India's Chunnambar backwater [41].According to a Long Island Sound report, Connecticut's oyster aquaculture business saves $470 million yearly compared to more conventional nutrient-reduction strategies, including better wastewater treatment and agricultural best management practices [59].

Trawling

Trawling diminishes the environment’s complexity by removing sedimentary features and biogenic structures like sponges, bryozoans, and shell aggregates [17, 53,54, 55]. This has implications for fisheries since certain fish species' physical structure may be crucial to their survival and growth [10, 53, 57].

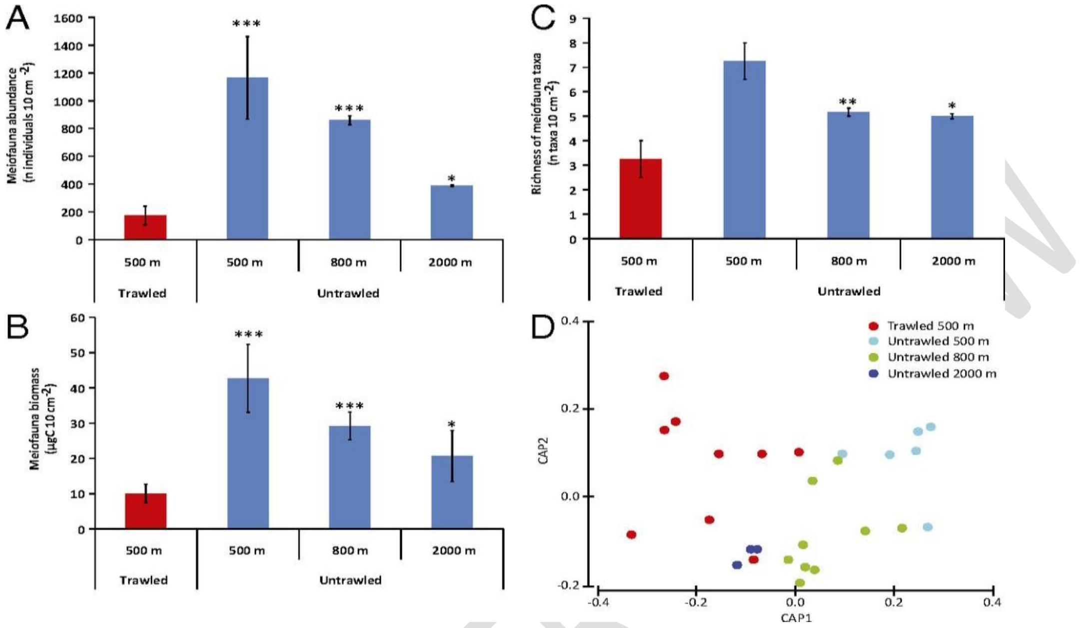

Figure 1. Showing meiofauna in sediments from the La Fonera Canyon that were trawled and untrawled at various depths. Abundance (A), biomass (B), and biodiversity (as richness of taxa) (C) A biplot after canonical analysis of the primary coordinates shows differences in the composition of the meiofauna communities Error bars show SEs between stations at comparable depths and impact levels or SDs between replicates for data at 2,000 m deep.*P < 0.05; **P < 0.01; ***P < 0.001 vs. untrawled samples from 500, 800, and 2,000 m. [56].

Bycatch

Bycatch discards, or non-targeted species or undersized individuals, can also significantly impact the habitat of fisheries [16]. Large amounts of dead bycatch may be disposed of, which may change the organic matter loading, lead to changes in dissolved oxygen profiles, and affect nutrient cycling in addition to the apparent direct consequences on populations and marine food chains [15, 14, 40]. According to an FAO analysis, the annual global marine capture fisheries discards between 2010 and 2014 were 9.1 million tonnes (95% CI: 6.7 - 16.1 million tonnes), or 10.8% (10.1% -11.5%) of the average annual catch over that period. The bottom trawls, including otter trawls, shrimp trawls, pair bottom trawls, twin otter trawls and beam trawls, were responsible for about 46% (4.2 million tonnes) of the yearly discards [58]

Dams

The construction of dams on tidal rivers has harmed estuarine habitat. Estuary community structure, water chemistry, food webs, and loss of freshwater and estuary habitats are all affected by flow, sediment delivery, salinity, and temperature variations. By removing or diverting 40% of the Skokomish River's annual runoff, Washington State has lost 6% of its total unvegetated flats, 40% of its low intertidal area, 18% of its eelgrass area, and less of its mesohaline mixing zone [18, 40].

Power plant

Numerous reviews have been conducted on the effects of power plants on power plants can have an impact on fisheries by:

- Modifying estuarine production cycles through variations in water temperature and circulation patterns fisheries [19].
- Rising water temperatures increase death, decrease growth, and disrupt spawning [20].
- Raising mortality rates through direct impingement of larvae and juveniles on input screens [21].
- Increasing fisheries species mortality due to the direct impact of their feed species.
- Increasing mortality and decreasing growth by the release of poisons such as chlorine, bromine, copper, and zinc [22, 23].

It was discovered that high levels of forage fish entrainment by power plants could result in significant (>25%) losses to total population production for striped bass and bluefish [22]. Dams may be the first significant disturbance for anadromous river herring, (*Alosapseudoharengus*) and blueback herring (*A. aestivalis*), in numerous rivers and streams in the northeastern United States [37, 38].

Low DO level

One of the most serious consequences of coastal waterway eutrophication is habitat deterioration and loss caused by a lack of dissolved oxygen (DO). Reducing the amount of oxygen in the water or sediments causes changes in the microbial community composition and even the mortality of some species (hypoxia, 2 mg/L) or all of them (anoxia) [42,43]. Although oxygen depletion occurs naturally in some systems, especially offshore basins, it has been exacerbated by increased sewage and fertiliser inputs caused by development and agriculture near estuaries [44, 45, 46]. According to study, excessive nitrogen imports have moderately to severely deteriorated 65 percent of the contiguous U.S.'s estuaries and coastal waters. Excessive nutrient loading results in algal blooms and waterways with low oxygen levels (hypoxic waters), which can kill fish and seagrass and diminish vital fish habitats [59].

Sea level rise

Global warming and rising sea levels may significantly impact estuarine fish populations and coastal fisheries [24, 25, 47,51,52]. Future high tides will frequently flood a larger portion of salt marsh surfaces if the sea level rises more quickly than the capacity of these surfaces to accrete peat and sediment [48, 49, 50, 51]. If the marsh retains its stability, it will expand the estuarine fish habitat. But the marginal sea-level shift over the past 50 years is insufficient to account for the current sharp declines in fisheries.

Fishing

Fishing can interfere with the dynamics of organic matter and benthic primary production. Such effects can be observed at relatively small spatial scales in semi-closed systems, including bays, estuaries, and fjords. There may be disturbances in these processes in open coastal and outer continental shelf systems [60].In the Mozambique Channel, effective small-scale fishing activity increased 60 times from a little over 386,000 kilo-watt days in 1950 to over 23 million kilo-watt days in 2016 [62].From the late 1970s to roughly 2010, fishing effort and capacity expanded dramatically around the world before stabilizing [64]. Depending on the quantity of fishing effort, however, the relative rates of other processes (such as natural processes) may reduce the consequences of fishing disturbances [61].Fish health and quantity is impacted by bottom trawling when the ratio of available prey to competitor density changes [65].

Human Impacts

Numerous factors have changed the water quality and fish habitat over the past century, impacting native fish populations. Examples include:

a. **Coastal Development**: Rising coastal development threatens coastal wetlands' function and diversity. Removing trees and vegetation from riverbanks can reduce the amount of shade and raise the water temperature. Additionally, a lack of vegetation causes more erosion and sedimentation, which changes spawning grounds. Fish can't migrate upstream to reach essential spawning habitats if there are dams or other barriers in their way.

b. **Invasive Species:** Fish endemic to the area contend with invasive species for food and habitat. Fish that have replaced local species in some areas include the round goby and the Eurasian ruffe. An invasive species may alter its habitat. Zebra mussels boost water clarity and minimise food for native species by filtering bacteria, encouraging aquatic plant growth.

c. **Pollution:** Sewage overflows, urban and agricultural runoff, and industrial pollutants are just a few of the pollution-related factors that continue to harm fish habitat and the Great Lakes water quality. For example, the native *schizothorax* fish species in Kashmir’s Dal and river Jhelum of India has drastically declined due to changes in water quality parameters [34, 35, 36]

Management

1. Human activities and stressors impacting freshwater and marine fishes will likely become more widespread, intense, and damaging if prevention, effective management (such as fisheries), restoration, or adaptation programmes are not implemented.
2. Decades of study and experience in the field of freshwater management have yielded a wealth of knowledge regarding integrated catchment management [26], the restoration of aquatic habitats [27], the management and removal of dams [28], and the provision of environmental flows. [29] riparian and floodplain processes and their restoration [30, 31]. Enforcing proper laws (such as catch-and-release restrictions), establishing no-take zones in places essential for reproduction and recruitment, and even managing relocation and reintroductions, fish populations can be restored [32].
3. Identification of current and potential habitat hazards, as well as the conservation and improvement actions required to eliminate or minimise those concerns, is a crucial step in the process of determining important fish habitats. A major problem is the destruction and deterioration of aquatic ecosystems, which are crucial for the sustainability of fish populations. According to Kennish (1998),[33] 60% of the world's population resides within 60 kilometres of the shore.
4. FRPA rules pertaining to fish habitats In the Forest Planning and Practises Regulation (FPPR) and the Woodlot License Planning and Practices Regulation (WLPPR), the government has set goals and practice specifications for managing water, riparian regions and fish habitats. Wherever these habitats are found on the land base, FRPA regulations safeguarding such habitats are in effect.

Preventing landslides, maintaining natural surface drainage, re-vegetation, road construction, maintenance, and deactivation are examples of general practice requirements that may also protect fish habitat. Other requirements include general wildlife measures, resource features, and wildlife habitat features. Frequent dredging is necessary to ensure proper water exchange between the sea and the backwaters.Oyster aquaculture can be promoted wherever required to absorb the excess nutrients from turbid waters.Besides, institutions must uphold right-based fishery management to strike a balance between global social, ecological, and economic needs.

Conclusion

Both biotic (living) and abiotic (non-living) elements make up a habitat. Habitat destruction is the leading cause of biodiversity loss. The rise in nutrient loading, particularly nitrogen, is one of the main factors contributing to habitat degradation. There are many reasons for habit loss, such as Eutrophication, Pollution, Invasive Species, Fishing, Sea level rise etc. Dal Lake has likely degraded due to increased sewage inflow, pollution, organic loads, and other factors. The production of *schizothorax*fish had a dramatic fall due to the significant changes recorded since the 1990s to 2023. The dissolved oxygen levels have drastically decreased due to excessive weed and macrophyte development, which directly results from lake pollution. However, some measures should be taken for the management of habitat, such as the restoration of aquatic habitats, enforcing proper laws (such as catch-and-release restrictions), establishing no-take zones in places essential for reproduction and recruitment, and even managing relocation and reintroductions, fish populations can be restored, the government has set goals and practice specifications for managing water, riparian regions and fish habitats. So, to protect nature, we must take the necessary steps to prevent habitat loss. Besides, there is much to be learned by studying past fishing practices, and they can guide essential decisions for conserving the marine as well as inland resources and the habitats on which humanity depends now and in the distant future.

REFERENCES

1) Peters, D. S., and F. A. Cross. (1992). What is coastal fish habitat? Pages 17–22 in R. H. Stroud, editor. Stemming the tide of coastal fish habitat loss. Marine recreational fisheries, volume 14. National Coa

2) Auster, P. J., and Langton, R. W. (1999). The effects of fishing on fish habitat. In *American Fisheries Society Symposium* (Vol. 22, No. 150-187).

3) Koehn, J.D. and Kennard, M.J. (2013). Habitats, In, Ecology of Australian Freshwater Fishes., Humphries, P. and Walker, K (eds), pp 81-104, CSIRO Publishing, Victoria, Australia

4) Yancey, P. H., Gerringer, M. E., Drazen, J. C., Rowden, A. A., and Jamieson, A. (2014). Marine fish may be biochemically constrained from inhabiting the deepest ocean depths. *Proceedings of the National Academy of Sciences*, *111*(12), 4461-4465.

5) Marvier, Michelle; Kareiva, Peter; Neubert, Michael G. (2004). "Habitat Destruction, Fragmentation, and Disturbance Promote Invasion by Habitat Generalists in a Multispecies Metapopulation". Risk Analysis. 24 (4): 869–878

6) Sindermann, Carl J. (1996). Ocean pollution: effects on living resources and humans. Boca Raton : CRC Press

7) Kennish, M.J. (1997). Pollution Impacts on Marine Biotic Communities (1st ed.). CRC Press.

8) Schindler, David W., Vallentyne, John R. (2008). The Algal Bowl: Overfertilization of the World's Freshwaters and Estuaries, University of Alberta Press, ISBN 0-88864-484-1.

9) Paerl, H. W. (1988). Nuisance phytoplankton blooms in coastal, estuarine, and inland waters 1. Limnology and Oceanography, 33(4part2), 823-843.

10) Lough, R. G., P. C. Valentine, D. C. Potter, P. J. Auditore, R. G. Bolz, J. D. Nelson, and R. I. Perry. (1989). Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. Mar. Ecol. Progr. Ser. 56:1-12.

11) Langton, R.W. and W. E. Robinson. (1990). Faunal associations on scallop grounds in the Western Gulf of Maine. J. Exp. Mar. Biol. Ecol. 144:157-171

12) Auster, P. J., R. J. Malatesta, S. C. LaRosa, R. A. Cooper and L. L. Stewart. (1991). Microhabitat utilization by the megafaunal assemblage at a low relief outer continental shelf site - Middle Atlantic Bight, USA. J. NW. Atlan. Fish. Sci. 11:59-69.

13) Auster, P. J., R. J. Malatesta and C. L. Donaldson. (1994). Small-scale habitat variability and the distribution of postlarval silver hake, Merlucciusbilinearis. Proceedings of the Gulf of Maine Habitat Workshop. RARGOM Report Number 94-2:82-86.

14) Auster, P. J., R. J. Malatesta and S. C. LaRosa. (1995). Patterns of microhabitat utilization by mobile fauna on the southern New England (USA) continental shelf and slope. Marine Ecol. Progr. Ser. 127:77-88

15) Malatesta, R. J., P. J. Auster and B. P. Carlin. (1992). Analysis of transect data for microhabitat correlations and faunal patchiness. Mar. Ecol. Prog. Ser. 87:189-195.

16) Walters, C. J. and F. Juanes. (1993). Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taking by juvenile fishes. Can. J. Fish Aquat. Sci. 50:2058-1070.

17) Tupper, M. and R. G. Boutilier. (1995). Effects of habitat on settlement, growth, and postsettlement survival of Atlantic cod (Gadusmorhua). Can. J. Fish. Aquatic Sci. 52: 1834-1841.

18) Jay, D.A and Simenstad, C.A. (1994) Downstream effects of water withdrawal in a small, high gradient basin: Erosion and deposition on the Skokomish River Delta. Estuaries 17(3), 702-715.
19) Uziel, M. S. (1980). Entrainment and impingment at cooling water intakes. J. Water. Pollut. Control. Fed. 52(6):1616-1630.
20) Larsen, P. F. (1981). Some potential environmental consequences of proposed tidal power developments in the Gulf of Maine and Bay of Fundy. Estuaries 4:253.
21) Boynton, W. R., W. M. Kemp, C. G. Osborne, E. Spalding, and C. W. Keefe. (1982). Estuarine community dynamics in relation to power plant operations: Benthic process program. University of Maryland, Solomons, MD. 87 pp. NTIS Order No.: PB83-101915.
22) Summers, L. H. (1989). Some simple economics of mandated benefits. *The American Economic Review*, *79*(2), 177-183.
23) Reeves, R. R., & Bunch, J. N. (1993). Forum on science and resource related issues in hydroelectric development. Dept. of Fisheries and Oceans, Ottawa, Canada. NTIS-accession number MIC-93-06931/1.
24) Kennedy, V. S. (1990). Anticipated effects of climate change on estuarine and coastal fishers. *Fisheries* 15:16–24.
25) Bigford, T. E. (1991). Sea- level rise, nearshore fisheries, and the fishing industry. Coastal Management, 19(4), 417-437.
26) Collares- Pereira, M. J., and Cowx, I. G. (2004). The role of catchment scale environmental management in freshwater fish conservation. *Fisheries management and Ecology*, *11*(3- 4), 303-312.
27) Roni, P., Hanson, K., and Beechie, T. (2008). Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. *North American Journal of Fisheries Management*, *28*(3), 856-890.
28) Olden, J.D. (2016). Challenges and opportunities for fish conservation in dam-impacted waters. In *Conservation of Freshwater Fishes*, GP Closs, M Krkosek, JD Olden (eds). Cambridge University Press: Cambridge; 107– 148
29) Arthington, A. H. (2012). *Environmental flows: saving rivers in the third millennium* (Vol. 4). Univ of California Press.

30) Naiman, R. J., Decamps, H., and McClain, M. E. (2010). Riparia: Ecology, conservation, and management of streamside communities. Elsevier.

31) Kingsford, Richard T. "Conservation of floodplain wetlands–out of sight, out of mind?." *Aquatic Conservation: Marine and Freshwater Ecosystems* 25, no. 6 (2015): 727-732.

32) Cooke, S. J., & Schramm, H. L. (2007). Catch- and- release science and its application to conservation and management of recreational fisheries. *Fisheries Management and Ecology*, *14*(2), 73-79.

33) Kennish, M. J. (1998). Trace metal-sediment dynamics in estuaries: pollution assessment. *Reviews of environmental contamination and toxicology*, 69-110. 10.1007/978-1-4612-1684-1_2

34) Mir, S.A., Ojha, S.N., Ananthan, P.S., Qureshi, N.W., Argade, S.D., Gul, S. and Thangavel, V. 2022. Assessment of Fisheries and Management-Insights from Dal Lake, Kashmir. *Indian Journal of Extension Education*, 58(4), pp.60-65.

35) Mehmood, M.A., Shafiq-ur-Rehman, A.R. and Ganie, S.A. 2017. Spatio-temporal changes in water quality of Jhelum River, Kashmir Himalaya. *Int J Environ Bioener*, *12*(1), pp.1-29.

36) Rashid, I., Rather, M.I. and Khanday, S.A. 2021. Investigating the 2017 Erratic Fishkill Episode in the Jhelum River, *Kashmir Himalaya.* Pollutants, 1(2), pp.87-94.

37) Hall, CJ, Jordaan, A, Frisk, MG. 2012. Centuries of Anadromous Forage Fish Loss: Consequences for Ecosystems Connectivity and Productivity. *Bioscience* 62: 723- 731.

38) Hall CJ, Jordaan A, Frisk MG. 2011. The historic influence of dams on diadromous fish habitat with a focus on river herring and hydrologic longitudinal connectivity. *Landscape Ecology* 26: 95-107.

39) Kumar, R., Parvaze, S., Huda, M. B., &Allaie, S. P. (2022). The changing water quality of lakes- a case study of Dal Lake, Kashmir Valley. *Environmental Monitoring and Assessment*, 194(3), 1-16.

40) Sor, R., Ngor, P.B., Lek, S. *et al.* Fish biodiversity declines with dam development in the Lower Mekong Basin. *Sci Rep* **13**, 8571 (2023). https://doi.org/10.1038/s41598-023-35665-9

41) Mishra, P., Naik, S., Babu, P.V., Pradhan, U., Begum, M., Kaviarasan, T., Vashi, A., Bandyopadhyay, D., Ezhilarasan, P., Panda, U.S. and Murthy, M.R., 2022. Algal bloom, hypoxia, and mass fish kill events in the backwaters of puducherry, southeast coast of India. *Oceanologia*, *64*(2), pp.396-403.

42) Ram, A., Jaiswar, J.R.M., Rokade, M.A., Bharti, S., Vishwasrao, C., Majithiya, D., 2014. Nutrients, hypoxia and mass fish kill events in Tapi Estuary, India. Estuar. Coast. *Shelf Sci*. 148, 48—58. https://doi.org/10.1016/j.ecss.2014.06.013

43) Zhang, J., Gilbert, D., Gooday, A.J., Levin, L., Naqvi, S.W.A., Middelburg, J.J., Scranton, M., Ekau, W., Pena, A., Dewitte, B., Oguz, T., 2010. Natural and human-induced hypoxia and consequences for coastal areas: synthesis and future development. Biogeosciences 7 (5), 1443—1467. https://doi.org/10. 5194/bg-7-1443-2010.

44) Villate, F., Iriarte, A., Uriarte, I., Intxausti, L. and de la Sota, A., 2013. Dissolved oxygen in the rehabilitation phase of an estuary: influence of sewage pollution abatement and hydro-climatic factors. *Marine Pollution Bulletin*, *70*(1-2), pp.234-246.

45) Raja, S.U.K., Ebenezer, V., Kumar, A., Sanjeevi, P., Murugesan, M., 2019. Mass mortality of fish and water quality assessment in the tropical Adyar estuary, South India. Environ. Monit. Assess. 191 (8), 512. https://doi.org/10.1007/s10661-019-7636-4

46) Carpenter, R.S., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8 (3), 559—568. https://doi.org/10.1890/10510761(1998)008[0559: NPOSWW]2.0.CO;2

47) Rabalais, N.N., Turner, R.E., Dortch, Q., Justic, D., Bierman Jr., V.J., Wiseman Jr., W.J., 2002. Nutrient-enhanced productivity in the northern Gulf of Mexico: past, present and future. Hydrobiologia 475 (476), 39—63. https://doi.org/10.1023/ A:1020388503274

48) Khojasteh, D., Glamore, W., Heimhuber, V. and Felder, S., 2021. Sea level rise impacts on estuarine dynamics: A review. *Science of The Total Environment*, *780*, p.146470.

49) Hanslow, D.J., Morris, B.D., Foulsham, E., Kinsela, M.A., 2018. A regional scale approach to assessing current and potential future exposure to tidal inundation in different types of estuaries. Sci. Rep. 8, 7065.

50) Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, et al. Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change: IPCC, 2014.

51) Stoltz, A.D., Shivlani, M. and Glazer, R., 2021. Fishing industry perspectives on sea-level rise risk and adaptation. *Water*, *13*(8), p.1124.

52) Kizhakudan, S.J., 2014. Correlation between changes in sea surface temperature and fish catch along Tamil Nadu coast of India-an indication of impact of climate change on fisheries?.

53) Gianni, M., 2004. *High seas bottom trawl fisheries and their impacts on the biodiversity of vulnerable deep-sea ecosystems: options for international action*. Iucn.

54) Watling, L., Victorero, L., Drazen, J. and Gianni, M., 2020. Exploitation of deep-sea fishery resources. *Natural Capital and Exploitation of the Deep Ocean. Oxford Scholarship Online. doi*, *10*.

55) Pusceddu, A., Bianchelli, S., Martín, J., Puig, P., Palanques, A., Masqué, P. and Danovaro, R., 2014. Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. *Proceedings of the National Academy of Sciences*, *111*(24), pp.8861-8866.

56) Pusceddu, A., Bianchelli, S., Martín, J., Puig, P., Palanques, A., Masqué, P. and Danovaro, R., 2014. Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. *Proceedings of the National Academy of Sciences*, *111*(24), pp.8861-8866.

57) Mytilineou, C., Herrmann, B., Smith, C.J., Mantopoulou-Palouka, D., Anastasopoulou, A., Siapatis, A., Sala, A., Megalofonou, P., Papadopoulou, N., Vassilopoulou, V. and Stamouli, C., 2022. Impacts on biodiversity from codend and fisher selection in bottom trawl fishing. *Frontiers in Marine Science*, *9*, p.1021467.

58) Roda, M.A.P., Gilman, E., Huntington, T., Kennelly, S.J., Suuronen, P., Chaloupka, M. and Medley, P., 2019. *A third assessment of global marine fisheries discards* (p. 78). Food and Agriculture Organization of the United Nations.

59) National Ocean Service, 2023. National ocean and Atmospheric Service (NOAA). https://oceanservice.noaa.gov/facts/eutrophication.html. Assessed on 27-07-2023.

60) Steadman, D., Thomas, J.B., Villanueva, V.R., Lewis, F., Pauly, D., Deng Palomares, M.L., Bailly, N., Levine, M., Virdin, J. and Rocliffe, S., 2021. New perspectives on an old fishing practice: Scale, context and impacts of bottom trawling. *Our Shared Seas, Report*, *44*.

61) Thurstan, R.H., Hawkins, J.P. and Roberts, C.M., 2014. Origins of the bottom trawling controversy in the British Isles: 19th century witness testimonies reveal evidence of early fishery declines. *Fish and Fisheries*, *15*(3), pp.506-522.

62) Zeller, D., Vianna, G.M., Ansell, M., Coulter, A., Derrick, B., Greer, K., Noël, S.L., Palomares, M.L.D., Zhu, A. and Pauly, D., 2021. Fishing effort and associated catch per unit effort for small-scale fisheries in the Mozambique Channel region: 1950–2016. *Frontiers in Marine Science*, *8*, p.707999.

63) Warren, C. and Steenbergen, D.J., 2021. Fisheries decline, local livelihoods and conflicted governance: An Indonesian case. *Ocean & Coastal Management*, *202*, p.105498.

64) Bell, J.D., Watson, R.A. and Ye, Y., 2017. Global fishing capacity and fishing effort from 1950 to 2012. *Fish and Fisheries*, *18*(3), pp.489-505.

65) Hiddink, J.G., Moranta, J., Balestrini, S., Sciberras, M., Cendrier, M., Bowyer, R., Kaiser, M.J., Sköld, M., Jonsson, P., Bastardie, F. and Hinz, H., 2016. Bottom trawling affects fish condition through changes in the ratio of prey availability to density of competitors. *Journal of Applied Ecology*, *53*(5), pp.1500-1510.