



Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on “Electromagnetic fields from submarine power cables: A 35 year synthesis of effects on aquatic biota” by James et al. in Marine Environmental Research (2026)

Category [low frequency, review]

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Competence Centre for Electromagnetic Fields (KEMF)

1 Context

Offshore renewable energy installations have expanded rapidly in recent years. As a consequence, more submarine transmission cables carrying more electrical power are deployed in coastal waters worldwide. This results in increased exposure of marine life to anthropogenic magnetic and induced electric fields. In parallel, research on biological and ecological effects of these fields on marine biota was intensified. While a few narrative reviews on this topic, which are either regionally restricted or limited to certain taxonomic groups, are available [2, 3], a comprehensive systematic review summarising effects of electric and magnetic fields (EMF) across taxa, life stages, and biological endpoints was still lacking.

2 Results and conclusions from the perspective of James et al.

James et al. [1] conducted a systematic literature review to assess the biological impact of EMF corresponding to those generated by submarine power cables on aquatic organisms. They applied the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guidelines [4] to provide a structured and transparent synthesis of the relevant studies. The review protocol was registered in the “International Prospective Register of Systematic Reviews” (PROSPERO). Peer-reviewed studies published between 1990 and 2024 were searched for in the databases Google Scholar, Web of Science, EBSCO, ScienceDirect, and PubMed. Studies investigating the behavioural, physiological, or developmental responses of aquatic organisms to AC or DC fields relevant for operational submarine cables, with magnetic flux densities up to 3,200 μT , under laboratory or environmental conditions were included. This threshold was chosen in accordance with the reported upper range of fields close to DC cables and experimental exposures simulating high load conditions.

Study quality was evaluated in terms of the description of EMF sources, biological endpoints, and statistical robustness. Ecological relevance was assessed by distinguishing between laboratory and field studies and considering whether life stage and sex were taken into account. These criteria correspond to those for evaluating systematic reviews [5]. The evidence was synthesised qualitatively. A meta-analysis was not performed due to the high degree of heterogeneity between the studies.

From 1,637 studies identified, 67 were included in the review. Of these, 47 (70%) were laboratory studies, 19 (28%) were field studies, and one combined both approaches. Laboratory studies more frequently reported statistically significant biological effects of EMF exposure (72%) compared to field studies (47%).

Approximately half of the studies investigated DC exposures, one third investigated AC exposures, and the remainder either combined both types of exposure or did not specify the type of current. Most studies focused exclusively on magnetic fields. Statistically significant effects were observed at all EMF exposure levels, including weak exposures below 250 μT .

Investigations were performed on 54 identified species, in addition to multispecies field studies. The majority of studies focused on fish (55%), and crustaceans (27%), while fewer studies examined molluscs, polychaetes, echinoderms, and elasmobranchs. The effects of EMF exposure varied between taxonomic groups; statistically significant effects were reported in 73% of fish studies, 59% of crustacean studies, and 40% of mollusc studies.

Of the 67 included studies, 32 investigated behavioural responses, 22 examined physiological endpoints, and 13 investigated both. Behavioural effects included changes in swimming speed, exploration, attraction or avoidance, and habitat use. Physiological effects included haematological, cardiac, and metabolic changes. 91% of the physiological studies and 66% of the behavioural studies reported statistically significant exposure effects. In combined studies, 46% reported impacts in both domains. The observed effects varied with the developmental stage. Early life stages exhibited the greatest responsiveness: 93% of studies on fish embryos or larvae reported statistically significant effects of EMF exposure compared to 86% for juveniles and 53% for adults. Most studies did not differentiate between the sexes. A recent study published after the re-

view period [6] provides an example of sexual differences in the behavioural reactions of crabs to EMF, illustrating the importance of sex-specific analyses.

One of the most important findings is the high sensitivity of early developmental stages to EMF exposure across taxa. The embryos and larvae of fish, crustaceans, polychaetes, and echinoderms exhibited consistently higher rates of effects related to EMF compared with juveniles and adults. This is particularly relevant since submarine cables often concentrate in coastal areas, which are also preferred egg-laying and nursery habitats [3].

James et al. recommend further research with respect to feasibility. High feasibility priorities include methodological standardisation, harmonised exposure reporting, and routine consideration of sex and life stage as biological variables. Moderate feasibility priorities encompass coordinated laboratory experiments, extended chronic exposures, and comparative studies across taxa or life stages. Low feasibility priorities include long-term observations and population-level assessments.

3 Comments by the BfS

To our knowledge, this study is the first systematic review to summarise the effects of electromagnetic fields from submarine power cables on all taxa of marine animals worldwide published between 1990 and 2024. Although the review comprehensively captures published data that is relevant for radiation protection of the marine environment, some limitations make it difficult to interpret the results in terms of their significance and reliability. James et al. performed a quality appraisal which they did not describe in detail. They did not report the results of the quality assessment at study level, which makes a validation impossible. It remains unclear, if and how the quality assessment of the studies was used to assess the overall strength of evidence. A systematic assessment of the strength of the evidence, for example using the “Grading of Recommendations Assessment, Development, and Evaluation” (GRADE) approach [7] was not performed.

In terms of radiation protection for marine biota, one of the most important outcomes of the review is the observation that effects predominantly occurred during embryonic development, even at environmentally relevant low exposure levels occurring close to submarine power cables. This effect was consistently reported across studies and taxonomic groups. Eggs cannot move and some larval stages are restricted in their ability to move; unlike adults, they cannot leave the exposed area. They remain in the exposed area for the entire duration of their embryonic development, and even minor changes in metabolism, size, motility, behaviour and orientation due to EMF exposure could possibly affect their entire adult life, with potential consequences at the population level. Therefore, further research is needed to evaluate the ecological consequences of exposure to developing stages. The effect of sex should also be considered. To minimise possible ecological consequences, the exposed area should be minimised as far as possible.

References

- [1] James, E, Ghodsi, M, Ford, AT. Electromagnetic fields from submarine power cables: A 35 year synthesis of effects on aquatic biota. *Marine Environmental Research*. 2026; 216:107916.
DOI: <https://doi.org/10.1016/j.marenvres.2026.107916>.
- [2] Taormina, B, Bald, J, Want, A, Thouzeau, G, Lejart, M, Desroy, N, Carlier, A. A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renewable and Sustainable Energy Reviews*. 2018; 96:380–391.
DOI: <https://doi.org/10.1016/j.rser.2018.07.026>.
- [3] Hermans, A, Winter, HV, Gill, AB, Murk, AJ. Do electromagnetic fields from subsea power cables effect benthic elasmobranch behaviour? A risk-based approach for the Dutch Continental Shelf. *Environmental Pollution*. 2024; 346:123570.
DOI: <https://doi.org/10.1016/j.envpol.2024.123570>.
- [4] Page, MJ, Moher, D, Bossuyt, PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*. 2021; 372:n160.
DOI: <https://doi.org/10.1136/bmj.n160>.
- [5] Whaley, P, Roth, N. How we promote rigour in systematic reviews and evidence maps at Environment International. *Environment International*. 2022; 170:107543.
DOI: <https://doi.org/10.1016/j.envint.2022.107543>.
- [6] James, E, Ghodsi, M, Ford, AT. Female crabs are more sensitive to environmentally relevant electromagnetic fields from submarine power cables. *Environmental Science & Technology Letters*. 2025; 12(11):1487–1494.
DOI: <https://doi.org/10.1021/acs.estlett.5c00862>.
- [7] Guyatt, GH, Oxman, AD, Schunemann, HJ, Tugwell, P, Knottnerus, A. GRADE guidelines: A new series of articles in the Journal of Clinical Epidemiology. *Journal of Clinical Epidemiology*. 2011; 64(4):380–382.
DOI: <https://doi.org/10.1016/j.jclinepi.2010.09.011>.

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