The potential ecological effects of electromagnetic fields posed by offshore wind farms

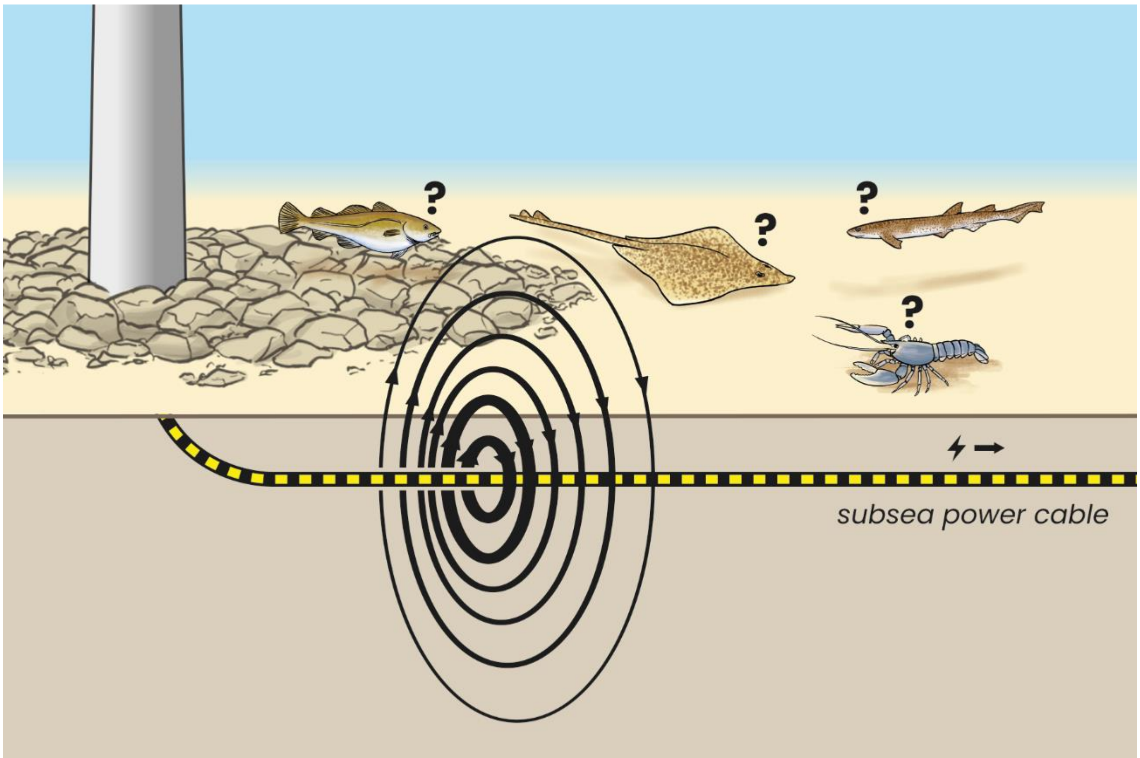

Figure: Hendrik Gheerardyn

Background information

Electromagnetic Fields (EMFs) are present everywhere in our environment, both from natural and anthropogenic sources. The most prominent natural EMF in the marine environment is the geomagnetic field from the Earth.

Electromagnetic fields generated by offshore electrical cables consist of electric fields, produced by electric charges, and magnetic fields that are produced by the flow of electrical current. The direct electric fields are shielded (by insulation of the cable), but when magnetic fields are disturbed by water currents or organisms, induced electric fields occur (iEFs). Reported values for these are in the range of 0.02-0.025 mV/m above the cable (AC three- phase transmission at full power) (Hutchison et al., 2018). The wind turbines themselves also emit EMFs, but these are considerably weaker than those from the cables (Thomsen et al., 2015).

Alternating current (AC) is an electric current which periodically reverses direction and changes its magnitude continuously with time in contrast to direct current (DC) which flows only in one direction. AC is used to transport electricity for short distances (approximately 100 km) and DC is used for longer distance transport.

The existing Dutch offshore wind farms are connected to shore with AC-cables. The planned offshore wind farm IJmuiden Ver will be connected with DC-cables. AC and DC-cables generate different EMFs. The strength of the fields also depends on the depth of the buried cable (distance) and the current running through it. The cables that connect the wind turbines to the high voltage station (inter-array cables, 66 kV cables) and the cables connecting these platforms to shore (export-cable, 525kV DC, or 220kV AC) have electromagnetic fields with different characteristics. DC-cables are normally a combination of two phase wires (+ and -), while AC-cables are composed of three phase wires which could largely cancel each other's magnetic field out, when located closely and parallel (Albert et al., 2020). However, while AC cables only emit an AC field, DC cables seem to emit both AC and DC fields (Hutchison et al., 2018). The emitted EMFs deviations of export cables is higher than the fields of the inter-array cables, which corresponds to the power being transmitted (Thomsen et al., 2015).

Models and legislation on EMF values are currently still based on onshore circumstances and only a few in situ studies were performed on the EMF topic related to biological effects. Recent measurements of EMF values in the vicinity of AC export cables of three Dutch offshore wind farms (OWFs) during relatively low wind speeds, show increases of 0.004 - 0.039 μT, compared to a background level of ± 0.032 μT (Snoek et al., 2020). They also showed that the field is measurable up to 25 meters distance from the cables. Other measurements on DC cables operating at full power (1320 A), show deviations of 0.4-20.7 μT, compared to a background level of the Earth's magnetic field of 51,3 μT (Hutchison et al., 2020).
A modelling study on AC cables shows that the deviation in EMF values rapidly decrease within meters (Hutchison et al., 2020; Olsson et al., 2010). However, depending on the sensitivity of the species and cable characteristics, the detection range varies from zero to several hundreds of meters. Little is known what the range will be with higher wind speeds and there is very limited research concerning the effects of realistic EMF strength conditions on (North Sea) marine organisms. Especially the small differences in electromagnetic fields might be relevant for detection, as this is common in natural circumstances. Also, fields will be changing over time, through changes in wind force and therefore current.

Snoek et al. (2016) described four main effects of EMFs on marine life:

- Disturbance of behavioural responses and movement: attraction / avoidance;
- Disturbance of navigation and migratory behaviour;
- Disturbance of predator/prey interactions and distribution of prey;
- Disturbance of physiology, embryonic and cellular development.

Effects on elasmobranchs

Elasmobranch species (sharks and rays) use EMFs for orientation and finding prey. The development of OWFs give therefore rise to questions about the potential negative effects of anthropogenic EMFs on elasmobranch migration and behaviour around offshore wind farms and the connecting cables. The North Sea is home to 16 shark and ray species (Daan et al., 2005; Sguotti et al., 2016), but the potential effects of EMFs are barely investigated. Measured electrical fields are within the range of detection by elasmobranchs (Thomsen et al., 2015). However, this is debatable for the emitted magnetic field (Nyqvist et al., 2020; Thomsen et al., 2015). A review by Snoek et al. (2016) shows that possible behavioural and physiological effects were found for thornback and lesser spotted dogfish, while results were inconclusive for spur dog. Little skates were found to be attracted to subsea power cables (Hutchison et al., 2018), although attraction was in the case of the MARS cable also found for longnose skates before energising the cable (Barry et al., 2008). No migration barrier effect was found so far for these species, but it might be difficult to track this around the inter-array cables within an offshore wind farm,where the chance of confusion is higher than around the export cable.

None of the sparse results from existing studies demonstrate the implications on individual survival or reproductive success, let alone the ecological impact on population level. Elasmobranchs can either be scared away by EMFs, or attracted to it when levels are for example in the same range as emitted by their prey. More detailed studies need to assess to what extent this directly interferes with the species ability to orientate, feed, mate, or deposit egg cases, and what the effects are of behavioural changes.

Effects on other species

Several bony fish species, mammals and invertebrates seem to make use of magnetic and/or electric sensitivity for life functions (Snoek et al., 2016). Migrating species are mainly making use of direct currents, as they use the Earth's magnetic field for navigation. Benthic species, as they live closer to the subsea power cables and thus sense stronger EMFs, are potentially more affected.

Fish

Many species of fish are known to detect magnetic signals, however it is generally unknown if they can detect the levels used in anthropogenic fields. Besides, this does not need to result in a measurable change in behaviour or physiology. Several studies indicate species-specific effects, but a literature review shows limited evidence that fish are influenced by submarine cables (Öhman et al., 2007). Some commercially interesting fish species including cod, plaice and European eel showed behavioural changes, with some species also showing anatomical or physiological changes such as slowing down of the heartbeat for eels (Snoek et al., 2016). European flounders and plaice tend to cross the cables during low wind speeds, while cod accumulated in and European eels departed from the area. In an experimental setup with eggs and larvae of rainbow trout, EMF had no significant effect on embryonic or larval mortality, hatching time, larval growth or the swimming time of larvae (Fey et al., 2019). However, EMF seemed to enhance adsorption of the yolk-sac, which indirectly could lead to lower weight at age.

Invertebrates

Although certainly not covering biological impact, most reviewed literature concerning behaviour of invertebrates shows their attraction towards the electromagnetic fields, while only a few studies find repulsion or disruption. In tank experiments, edible crabs seem to be attracted to the area with elevated EMFs (Scott et al., 2018, 2021). Furthermore, less time roaming (searching for food/mates) and signs are found that some stress related hormonal levels could be affected by EMFs as well. Another research contradicts this and did not find any influence of EMF on catchability of two crab species (Love, Nishimoto, Clark, et al., 2017). Also, no behavioural difference was found for these species in an experiment with lightly buried and unburied cables. For lobsters, results seem to be species- and study specific. In a field experiment with American lobsters, EMF resulted in the altered behaviour of staying closer to the seabed and making more turns, while an experiment with juveniles from the close relative European lobster did not prove any behavioural changes (Hutchison et al., 2018; Taormina et al., 2020). Both edible crab and lobsters did not differ in movements across the cable, suggesting EMF does not create a barrier for these species.

The only study on short-range migration of an invertebrate showed disorientation of a small Antarctic amphipod after a short exposure to very low EMF values (Tomanova & Vacha, 2016). Concerning the infauna, an important group of species living in the soft sediment of the North Sea, ragworms showed no avoidance or attraction for EMF exposed or non-exposed areas and maintained healthy growth, but the bioturbation activity seemed to be enhanced in the EMF treatment (Jakubowska et al., 2019). Life-stage specific responses make it more difficult to assess the impact of EMFs on invertebrates (Albert et al., 2020).

Research considering multiple species groups, with round crab, glacial relict isopod, young flounder, North Sea prawn and blue mussel, did not find any lethal effects in a test of several weeks with a static magnetic field (Bochert & Zettler, 2004). A Californian study on communities of benthic organisms found no effects on species composition in the two tested communities of 19 and 44 different species (Love, Nishimoto, Snook, et al., 2017). Biodiversity was found to be higher in the exposed areas, but this is likely due to increased habitat complexity (addition of hard substrate).

For some dolphins and harbour porpoises, theoretical evidence shows that they can be impacted by EMFs, but only for bottlenose dolphins physiological and behavioural evidence has been found so far. As stranding events due to changes in the Earth's magnetic field are known for cetaceans, there are reasons to organise further investigation for this topic.

There is enough evidence to conclude that individual marine animals could be affected by certain values of anthropogenic EMFs, caused by subsea power cables. However, the effect on animal populations cannot be assessed due to a lack of data. The severity and direction of effects is therefore generally unknown as well. Do offshore wind farms act as refugia or are EMFs confusing for marine animals and so, do we need to decrease the EMF values or might it be better to increase them to prevent confusion with natural sources? Species selection for EMF research until now was often focused on commonly used bio-indicators for marine pollution or commercial species (Albert et al., 2020), but should probably be focussing on species that are known to use magnetic or electric fields for navigation, orientation and finding food.

A method to reduce the level of added EMF at the seabed and in the water could be increasing the distance by deeper burial of cables. Also, the design of the cables could be adjusted, e.g. with core twisting, to a situation in which they can largely cancel out each other's effects (Hutchison et al., 2018). DC cables, as they have a constant direction, might be less disturbing than AC cables, but this needs further research. Effects of transporting molecules are not discussed in this chapter, but the transition to hydrogen can reduce the amount of current that needs transportation through cables and therefore EMF effects.

The North Sea Foundation recommends the following:

To make a proper assessment of EMF effects, more research is needed on:

- Electric sensing abilities and functional role for invertebrates;
- AC versus DC cable differences in effects on several species;
- Physical and biological field monitoring of EMF levels around export and inter-array cables before and after energising the cable, also during stronger winds;
- Realistic dose-response EMF effects on (commercial, protected or ecological relevant)North Sea species, certainly including cetaceans;
- Mitigation strategies to be explored and – if needed from a precautionary point of view –prescribed for cables;
- After further evaluation, mitigation measures should be considered for integration in existing measures/frameworks such as the European Marine Strategy Framework and OSPAR.

If you would like to know more about the other potential ecological risks discussed in our report, please click here.

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The North Sea Foundation

The North Sea Foundation is an independent nature and environmental organization and has been the go-to organization for protection and sustainable use of the North Sea for over 40 years. Our main goals are toachieve sufficient space for nature in the form of marine protected areas, a clean sea, the production of sustainable food, and eco-friendly offshoreenergy.

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