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The environmental effects of the installation and functioning of the submarine *SwePol Link* HVDC transmission line: a case study of the Polish Marine Area of the Baltic Sea

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Abstract

This paper describes the two-phase study of the environmental impact of the *SwePol Link* submarine electrical energy transfer system between Sweden and Poland. During the first phase (1997–1998), the potential effects of proposed technical solutions for the transmission line and different routes across the Baltic Sea were analysed. During the second phase (1999–2000), studies on environmental and background conditions before cable installation (1999) and studies on the environmental effects after cable system installation (2000) were undertaken. During this phase, underwater TV and video inspection of the bottom, observations of the bottom habitats by scuba-divers, sampling and laboratory analysis of macrozoobenthos and measurements of the earth's magnetic field were conducted.

Underwater observations along the cable route indicated that one year after the cable had been laid no mechanical disturbances on the dynamic sandy bottom were visible. Studies of the bottom macrofauna indicated that there had been no significant changes in zoobenthos species composition, abundance or biomass which could have been clearly related to cable installation. Changes in the components of the magnetic field, although significant in the vicinity of the cable itself, did not exceed natural variability at a distance of 20 m.

Keywords: Marine environment; Underwater power cables; Zoobenthos; Baltic Sea; Polish Exclusive Economic Zone

1. Introduction

In addition to pressure from traditional activities such as fishery and shipping, the Baltic Sea ecosystem is being subjected to increasing pressure from various technical constructions. These installations include fixed links, barrages, oil and gas terminals, oil rigs, wind power plants, pipelines, telecommunication cables and high voltage installations for electrical energy transfer. Energy transfer via underwater power cables is done to improve the exploitation of the various power systems in countries located on the Baltic Sea (PreussenElectra, 1994; Söderberg and Johnson, 1997). In contrast to land grid systems, which generally use alternating current, this type of installation uses high voltage direct current.

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The present Baltic Sea cable network consists of seven power transmission lines, including the *SwePol Link* (Fig. 1). One of the first cables in the world was *Gotland*, which connects the Swedish mainland with the Swedish island of Gotland. The *Baltic Cable* installation, which runs from Herrenwyk (Sweden) to Lübeck (Germany), is the longest power transmission cable in the world (250 km). The older cables, e.g. *Gotland* and *Konti-Scan*, are systematically being replaced by new ones laid along the same routes.

The transmission of electrical energy through underwater high voltage direct current (HVDC) lines is under regulations of Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM, 1996) and has been the subject of great public concern due to the possible ecological effects of cable installation and operation. These include mechanical damage to marine life on the bottom, the chemical effects related to the release of toxic chlorine from anodes and the influence of physical fields on macrofauna and migrating fish.

Almost no studies on the interaction between various Baltic HVDC cables and the Baltic ecosystem can be found in the open literature. However, some information regarding the assessment of anticipated environmental effects is available in HELCOM working papers (HELCOM EC, 1994, 1995, 1998a,b). Some of the information included in this paper comes from the results of field studies and was obtained through personal contacts (B.I. Dybern–*Gotland*; O. Sandström–*Fenno-Skan*, W. Matthaus–*Baltic Cable*). Information about the technical details of the *SwePol Link* transmission line was obtained from the *SwePol Link* AB and *Vatenfall* AB companies.

There is concern that the magnetic field around HVDC cables may affect fish migration because some fish may use the geomagnetic field for orientation; however, various research projects have not produced definitive results (Branover and Vasilyev, 1971; Kalmijn, 1978; Karlsson, 1984; Souza et al., 1988; Tesch and Wendt, 1992; Wiltschko and Wiltschko, 1995).

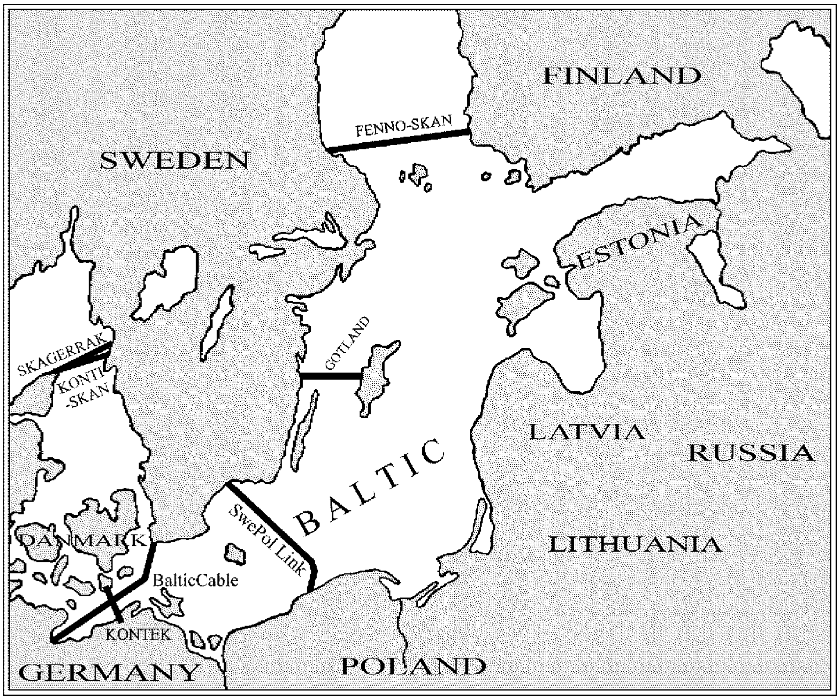

Fig. 1. High voltage electric power cables in the Baltic Sea.

No negative effects on fish stocks or fishing have been reported in connection with the *FennoSkan* cable between Sweden and Finland (County Fisheries Office, Sweden, pers. comm., 1998). The same also applies to the *Gotland* cable line (B.I. Dybern, pers. comm., 1999).

Telemetric measurements of silver-eel migration through the *BalticCable* area, which operates at 1300 A, i.e. the same electrical current value as the *SwePol Link*, suggest that eel migrate using the direction of the induction vector (inclination) not the compass direction (declination) (Swedish National Board of Fisheries, 1997).

The primary aim of these studies was to determine the impact the construction of the *SwePol Link* cable has had on marine sediments. Due to a lack of bottom macrophytes along the cable route, macrozoobenthos was an obvious indicator of physical disturbances on the bottom. Macrozoobenthos communities are relatively stable and they are dominated by long-lived, sedentary species with limited seasonal variability (Bonsdorff, 1983; Sousa, 1984; Bonsdorff et al., 1995). A secondary aim was to evaluate the rate of changes in magnetic fields; this included theoretical studies as well as field measurements.

The first phase of the two-phased studies comprised planning and preparation (1997–1998) and focused on determining the best technical and environmentally safe design and selecting the optimal cable route on the sea bottom. The second phase (1999–2000) was to detect the possible effects of cable installation.

2. Materials and methods

Field measurements before and after cable installation along the selected route (Fig. 2) included TV inspection of the bottom by towed camera (TOV-1, *J.W. Fisheries MFG INC*), visual observations by divers, documentation by divers using a video camera (Sony H-8) and macrozoobenthos sampling (Reineck

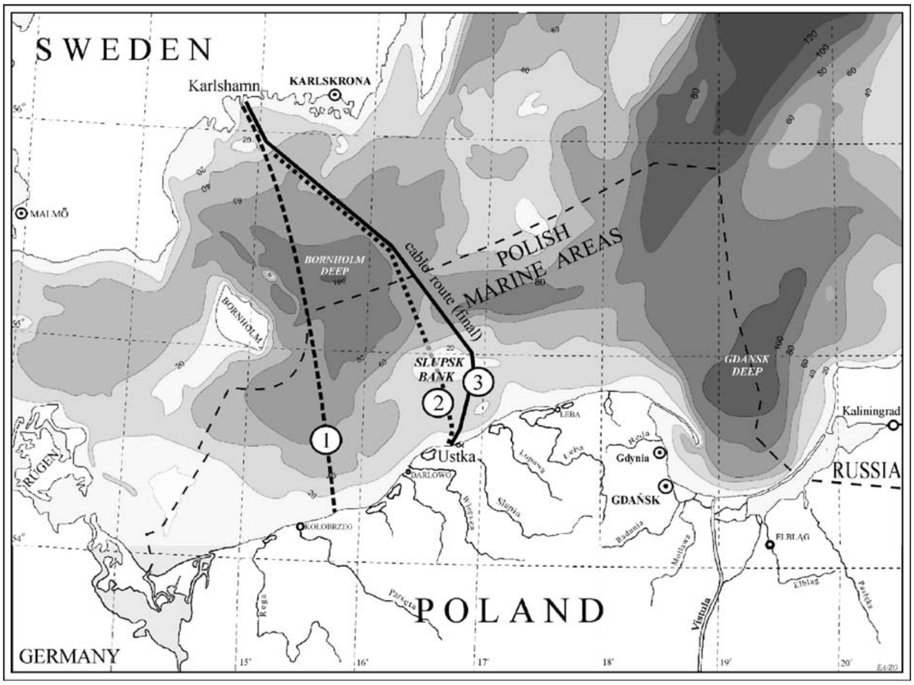

Fig. 2. Changes in the route of the *SwePol Link* transmission line during the planning phase: 1-cable route changed due to protests by local communities; 2-cable route changed to avoid crossing the stone and boulder parts of the Slupsk Bank—a proposed Baltic Sea Protected Area (HELCOM BSPA); 3-implemented cable route.

box corer). No macrozoobenthos sampling with the Reineck box corer was conducted on the Slupsk Bank (study area 5) due to its stone and boulder bottom. Measurements of the earth's magnetic field were taken with a compass for underwater measurements and an underwater magnetometer (Aqua Scan, UK).

Five study areas were designated on different sediment types and at different depths along the cable route (Fig. 3). A total of 36 sampling stations were selected randomly within the study areas. Of these, 18 stations were located on the cable route (cable stations) and another 18 stations (reference stations) were located from 0.1 to 1 nautical mile from the cable route. The same locations were visited in 1999 and 2000. Samples were collected during fair weather, and the precise location of the sampling sites was determined to within a few metres using a DGPS positioning system. One benthos sample was taken at every sampling location using a 200 kg Reineck box corer with a 225 cm^2 catching surface and a maximum penetration depth of 25 cm. Every benthos sample was sieved separately through a 1 mm sieve, which selects the benthos fraction defined as macrozoobenthos. The sieved samples were then preserved with 4% buffered formaldehyde and further analysis was performed by a macrozoobenthos taxonomist according to standard reference methods (Dybern et al., 1976; HELCOM, 1988).

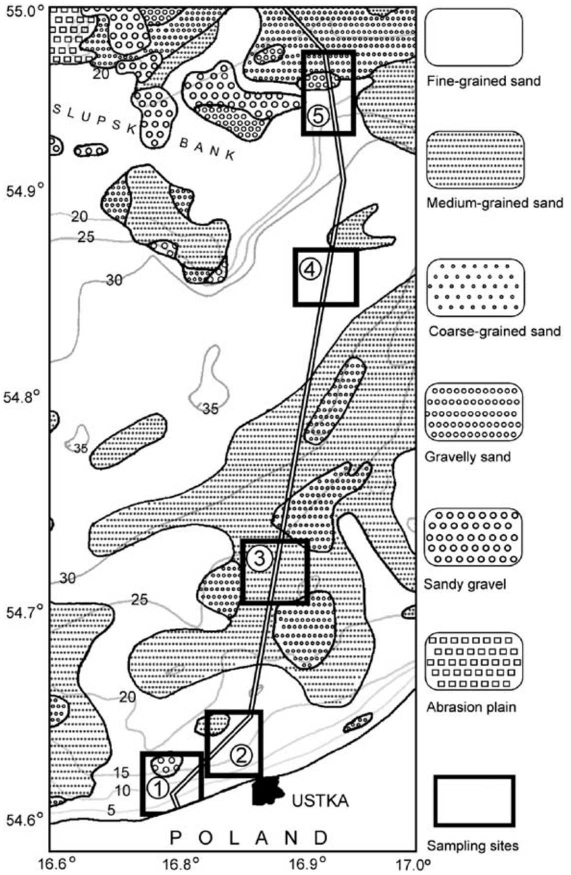

Fig. 3. Study areas and characteristics of sediments along the cable line.

To characterise the magnitude of the alteration of the earth's magnetic field during electrical energy transmission, the value of magnetic induction was measured with a proton magnetometer and changes of declination were recorded using a magnetic compass. Both instruments were diver operated and specially constructed for underwater measurements.

3. Results and discussion

3.1. Theoretical studies

The authors were members of a marine environmental advisory panel which participated throughout the planning and preparation phase of cable installation in order to determine the best environmental solution (Andrulewicz et al., 1997–1998). Most of the environmental problems in the planning phase came from the original proposal of a monopolar design (one cable and sea electrodes) (Fig. 4A). The main concern with this design was the environmental effect that chlorine production on the anodes would have. This solution was abandoned and replaced by a bipolar system (main cable and return cable) (Fig. 4B). Consequently, the environmental problems which could have been caused by the electrodes were eliminated.

The original route of the cable was planned from Karlskrona, Sweden to a popular tourist community near Kolobrzeg, Poland (Fig. 2, line 1). Due to the concern of the local communities regarding the negative influence of physical fields, the cable was rerouted to the military area near Ustka (Fig. 2, line 2). This proposal was altered again in order to avoid the central part of the Slupsk Bank, an area which had

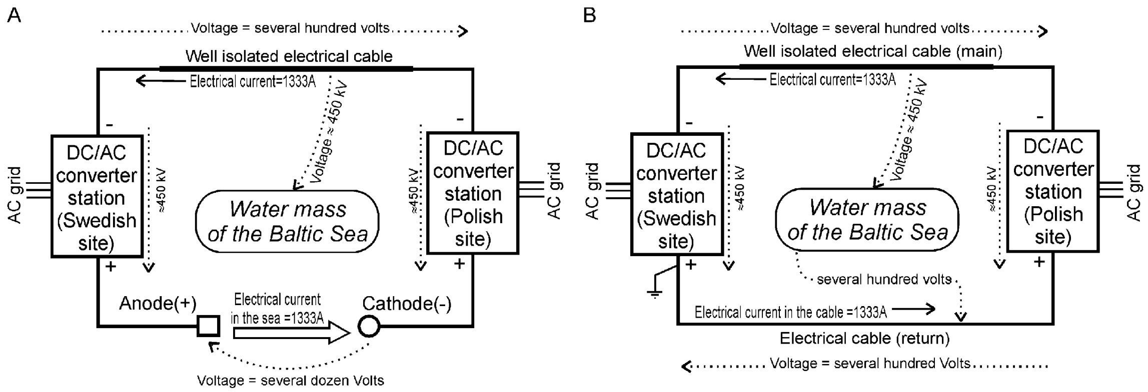

Fig. 4. Simplified scheme of the two HVPC cable line solutions for the *SwePol Link*—initial proposal (A) monopolar (one cable and electrodes); implemented solution (B) bipolar (main and return cables).

already been proposed as off-shore HELCOM Baltic Sea Protected Area (Fig. 2, line 3) (Andrulewicz and Wielgat, 1999).

Ultimately, the cable was laid through the central part of the Polish Exclusive Economic Zone, from the military area close to Ustka through the eastern part of the Slupsk Bank, the western part of the Slupsk Furrow (western ridge) and the northwestern part of the Bornholm Basin, to the Swedish Exclusive Economic Zone (Fig. 2, line 3).

According to the HELCOM biotope classification (HELCOM, 1998), most of the cable route passes through listed, endangered bottom habitats which are classified as category 3 (on a four-point scale: 0-completely destroyed; 1-immediately threatened; 2-heavily endangered; 3-endangered). The most valuable area, which is located in the stone and boulder parts of the Slupsk Bank (category 2), contains declining red algae species (Andrulewicz and Wielgat, 1999), and it was avoided thanks to negotiations during the planning phase. The habitats along the cable route have also been described in various papers (Warzocha, 1995; Osowiecki and Warzocha, 1996).

3.2. Field studies

3.2.1. Visual inspection

Prior to laying the cable, a background study was conducted in 1999 which included video and photographic documentation to establish undisturbed reference conditions along the proposed cable route. Video documentation was repeated in 2000 after the cable had been laid. The analysis of this documentation indicated that the bottom along the cable route did not appear to have changed in relation to 1999. The cable itself was buried in the sediments of the soft bottom so it was not visible on the surface except on the hard, stone and boulder areas of the bottom in the eastern part of the Slupsk Bank.

3.2.2. Macrozoobenthos studies

A total of 18 taxa of macrozoobenthos were identified—15 species and 3 undetermined taxa (Oligochaeta, Hydrobiidae and Gammaridae). Crustacea was the most diverse group, followed by Polychaeta and Bivalvia. *Macoma balthica* was the most frequent species and occurred in almost all the samples. The composition of fauna was similar in 1999 and 2000 (Andrulewicz et al., 1999, 2000). The comparisons of species abundance and biomass between 1999 and 2000 are presented in Figs. 5 and 6. The lowest mean values among the stations along the cable route were observed in 2000 in study area 1, while in study areas 2, 3 and 4 the mean values were very similar in 1999 and 2000.

The data were subjected to variance analysis (ANOVA test) to determine the significance of differences of various parameters between cable and reference stations. It was noted that the differences in the mean values of abundance and biomass in study area 1 (Figs. 5 and 6) were relatively high; simultaneously,

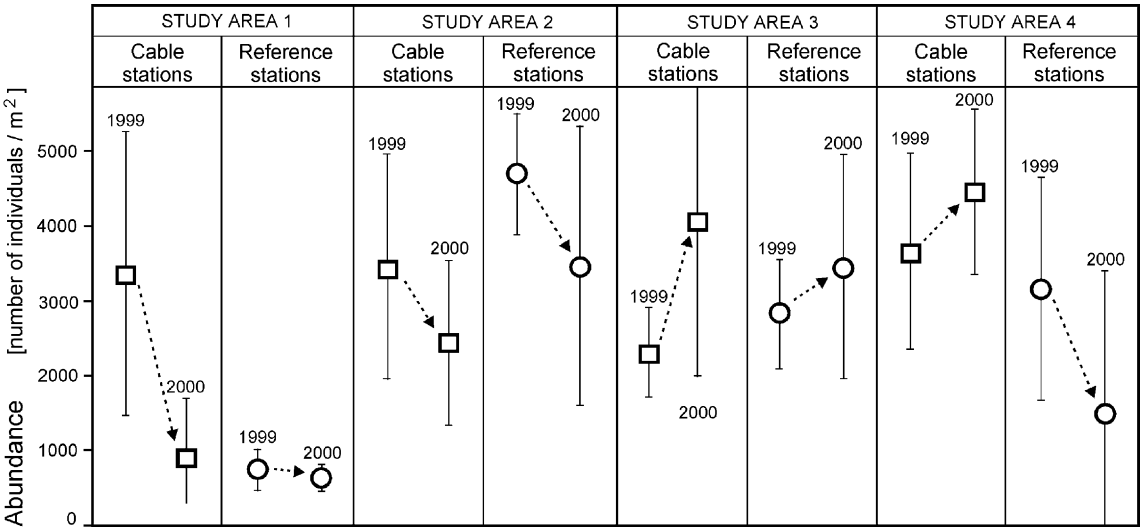

Fig. 5. Mean abundance of macrozoobenthos (at a 95% confidence limit) at stations located on the cable route and reference stations in 1999 and 2000.

variability was also high. Therefore, it is impossible to determine whether these differences are related to cable installation.

The impact of the construction phase on the macrozoobenthos is apparent at the deepest station, study area 4, where the mean size of individuals changed as abundance increased and biomass decreased. This may indicate that, following bottom disturbances, the macrozoobenthos recovered and resettled the impacted area around the cable.

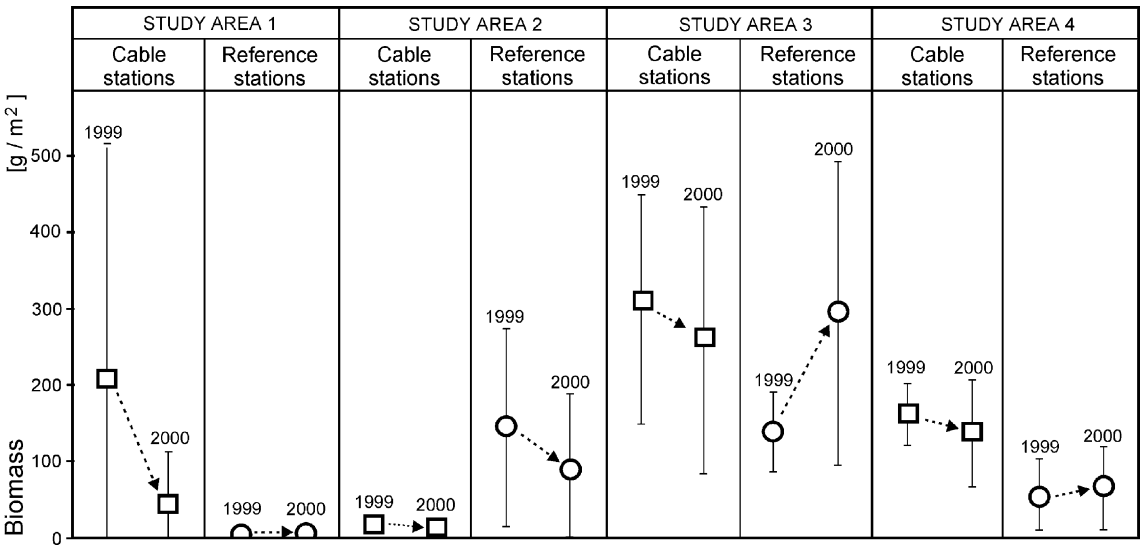

Fig. 6. Mean biomass of macrozoobenthos (at a 95% confidence limit) at stations located on the cable route and reference stations in 1999 and 2000.

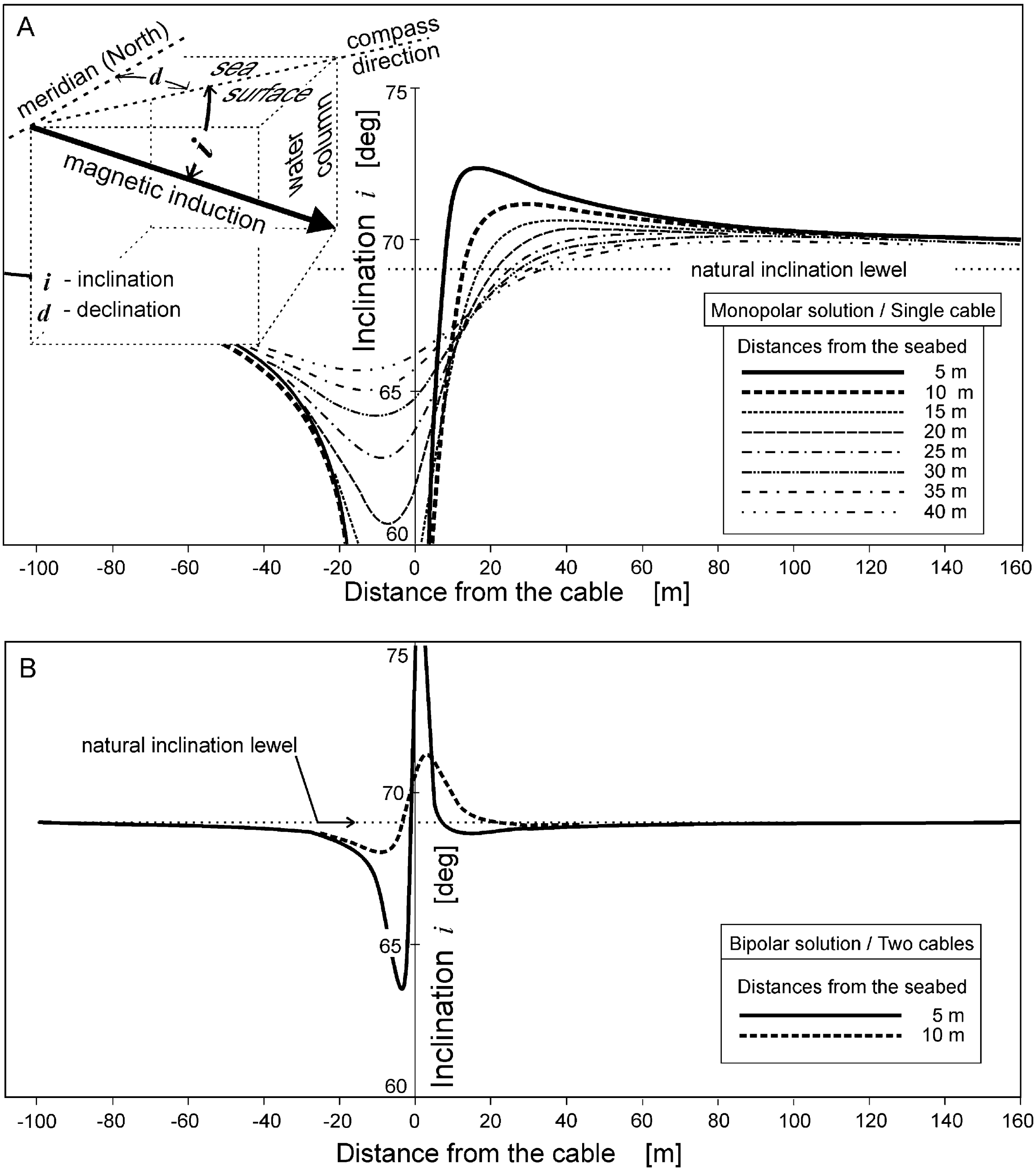

Fig. 7. Changes of magnetic inclination depending on the distance from the cable. (A) one cable with sea electrodes; (B) two-cable system with 2 m distance between them.

3.2.3. Cable line magnetic field

Two components of the induction vector were measured, i.e. declination with an underwater compass and the module of induction vector with an underwater magnetometer. Official data regarding three factors of induction vector were also obtained from the Hel Geomagnetic Observatory, which is associated with INTERMAGNET (Kerridge, 2002).

These data, as well as the intensity of the electric current in the cables, were used in the theoretical calculations.

Fig. 7 presents the mathematical simulation of the dependence of magnetic inclination on the distance from the cable. As the figure indicates, changes of inclination in the vicinity of the transmission line are much higher with the monopolar solution than with the bipolar one. Moreover, the inclination disturbance disappears as the distance between the main and return cables decreases, i.e. the shorter the distance, the weaker the inclination disturbance.

Since the distance between the cables in the *SwePol Link* transmission line does not exceed 2 m, the anticipated changes of inclination caused by the operation of the transmission line do not exceed natural changes in the terrestrial field at a distance exceeding 20 m from the cables. Measurements of the underwater magnetic field show that the values registered do not exceed those obtained with the simulations.

Migrating fish swimming close to the cable will be in a strongly altered magnetic field; however, at a distance exceeding 20 m they will not be subjected to the cable's magnetic field. At present, there is no definitive answer to the question of whether some migrating fish are indifferent to HVDCs.

4. Summary

The *SwePol Link* transmission line was designed using a bipolar technical solution which employs a return cable instead of electrodes. This eliminated the serious environmental concern of chlorine release into the sea and significantly minimises the magnetic field which, in turn, reduces the probability of disrupting fish migrations.

The studies conducted prior to cable installation (1999) and one year after the construction (2000) demonstrated that there had been no visible changes to the surface of the sea bottom. The cable itself was buried in the soft bottom, and only on the hard stone and boulder bottom in the eastern part of the Slupsk Bank did the cable appear in some places on the surface of the bottom. Studies of macrozoobenthos indicated that one year after construction there were no obvious changes in macrozoobenthos species composition, abundance or biomass which could be related to bottom disturbance caused by cable construction. In study area 4, which is the deepest station with a significantly less dynamic bottom than those of other study areas, some indications that the construction phase could have had an impact were noted in that the mean size of individuals was smaller one year after cable installation.

Although the modification of the magnetic field within a few metres from the cable line is significant, at a distance of more than 20 m changes in the magnetic field did not exceed the value of natural changes in the earth's magnetic field. At present, the question of whether some migrating fish are indifferent to HVDCs cannot be answered.

Through effective co-operation between the investor and an interdisciplinary team of scientists as well as implementing the more costly environmental principles recommended by HELCOM and applying BAT (Best Available Technology) and BEP (Best Environmental Practice), the *SwePol Link* transmission line can be regarded as the most environmentally friendly cable line to have been constructed to date.

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