Appendix I - Cable Heating Effects – Marine Ecological Report

Viking Link

Document Reference: VKL-07-30-J800-016

August 2017

Co-financed by the European Union
Connecting Europe Facility

Contents

List of Tables

List of Figures

1 Introduction

1.1.1 The Viking Link interconnector is a high voltage direct current (HVDC) electricity interconnector proposed to link the electricity transmission systems of Great Britain and Denmark. The planned offshore route passes additionally through Dutch and German jurisdictions. Viking Link is being jointly developed by the National Grid through National Grid Viking Link Limited and Energinet.dk.

1.1.2 This report has been prepared to inform the assessment of potential impacts of operation of the interconnector upon marine ecological receptors specifically in relation to physical heating effects upon marine biota. Certain marine fauna have long been known to respond with high sensitivity to ambient temperature increases; OSPAR (2009), for example, cites examples such as increased mortality rates of some intertidal gastropods (Newell, 1979 cited in OSPAR, 2009) and avoidance of areas of elevated temperature by the polychaete worm *Marenzelleria viridis* (Borrmann, 2006 cited in OSPAR, 2009). Postulated mechanisms behind such effects include changes in physiology, reproduction or mortality of certain benthic species and possibly to subsequent alteration of benthic communities due to emigration or immigration.

1.1.3 Following presentation of relevant information from the Offshore Project Description (Rev 1 dated 16 November 2016) and other Project documentation in Section 2 this report summarises available reference information on physical heating effects, including information from a specialist study commissioned for the Viking Link project which has modelled predicted temperature increases in seabed sediments surrounding buried cables of varying design scenarios (Section 3).

1.1.4 The report then considers the sensitivity of marine fauna to heating effects, focusing on species/groups likely to be of greatest importance in relation to the Viking Project (Section 4) and then discusses the likely magnitude of impacts from heating (Section 5).

1.1.5 Finally, in Section 6, the potential impacts associated with heating effects are compared with broader environmental and ecological issues associated with deeper burial and/or covering in order to achieve reduced heating effects within near-surface sediments.

2 Project Description

2.1 Project Overview

2.1.1 The Project proposes to construct a High Voltage Direct Current (HVDC) electrical interconnector with an approximate capacity of 1400MW, which will allow transfer of power between the high voltage grid systems of Denmark and the United Kingdom. The power would be able to flow in either direction at different times, depending on the supply and demand in each country. The proposed cable route would run from Bicker Fen in Lincolnshire, UK to Revsing in Jutland, Denmark (Figure 1). The route passes through the territorial waters of Denmark and the United Kingdom, and the EEZ of Denmark, Germany, The Netherlands and the United Kingdom.

2.1.2 The link would operate as a bipole with two cables at ± 525 kV carrying 1400 A each giving 2x700 MW power transfer.

2.1.3 The proposed link has achieved Project of Common Interest (PCI) status under the Regulation for the trans-European energy infrastructure (EU 347/2013) (TEN-E Regulation).

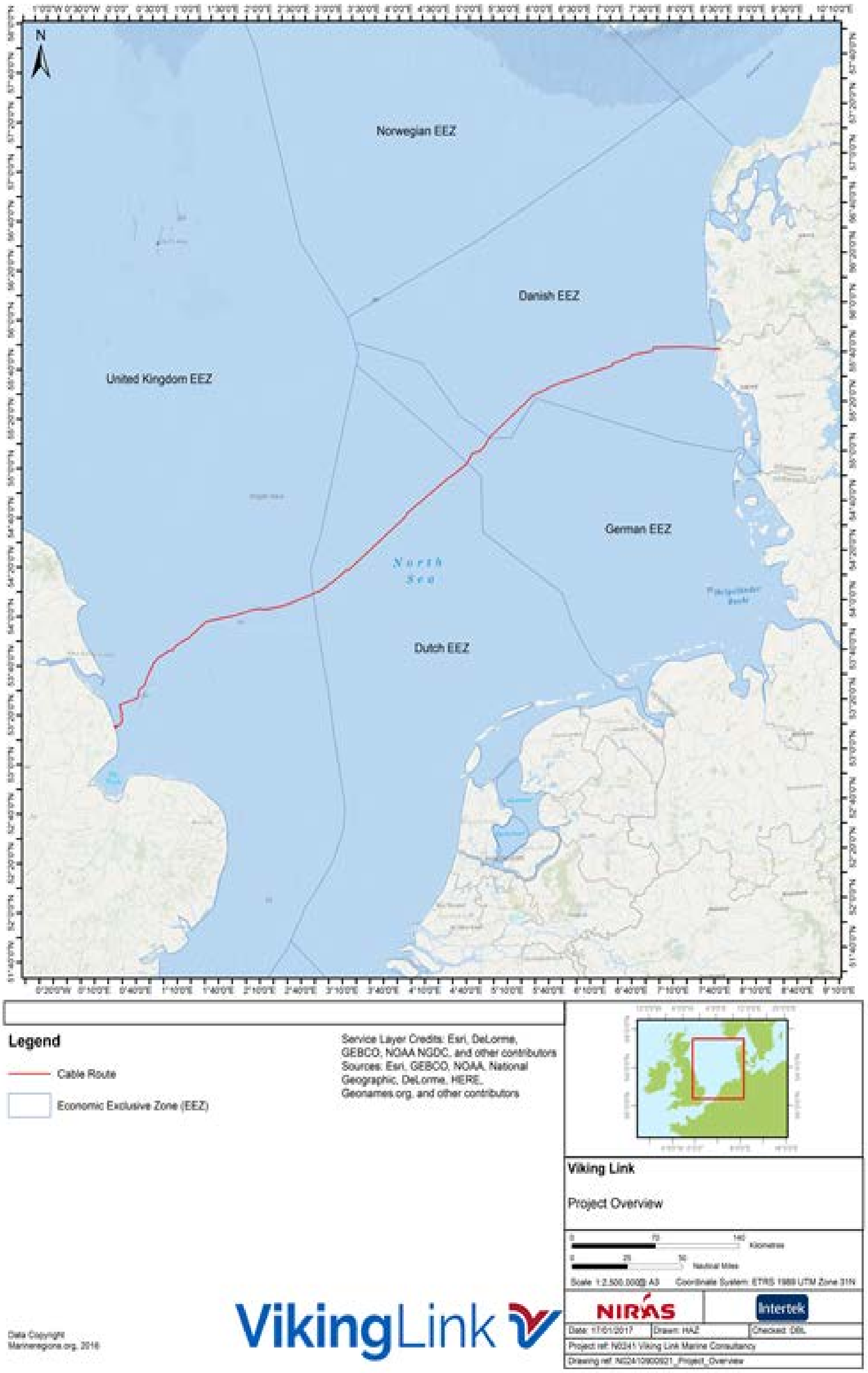

Figure 1. Location overview of the proposed Viking Link Interconnector.

2.2 Cable Design

2.2.1 There are currently two types of HVDC submarine cable available. These will be of either Extruded or Mass Impregnated Non-Draining (MIND) insulation technology (Figure 2). Typically, these cables are 150mm diameter and will operate at a voltage of +/- 525kV. The basic design of the cables is similar with the main difference being the type of insulation used.

Figure 2. Indicative HVDC cable options.

Extruded Cable

2.2.2 Extruded cable is the most common type of HVDC submarine cable currently in use, including the following:

- NordBalt, linking Sweden and Lithuania
- Nemo Link, connecting UK and Belgium
- EirGrid, linking UK and Ireland
- COBRA, connecting Denmark and Netherlands

Mass Impregnated Non-Draining (MIND) Cable

2.2.3 MIND type cable has been widely used on major interconnector projects in service to date including the following:

- UK-France interconnector (IFA)
- BritNed, connecting the UK and the Netherlands
- Skagerak 4 connecting Denmark and Norway
- Storebælt connecting the Eastern and Western grid in Denmark

2.3 Cable Configuration and Installation

2.3.1 The cable will be buried along its entire length, apart from where this is not feasible, for example at crossings with existing cables or pipelines, or where the seabed characteristics are inappropriate for cable burial.

2.3.2 Once laid on the seabed the cables need to either be buried or otherwise protected from the threat of external damage such as anchors or fishing activity. The nature of the seabed varies along the marine cable route between sand, clay and gravel. The choice of burial technique or protection method will vary along the route depending upon the seabed conditions in each section. Where the seabed composition is not suitable for burial, external mechanical protection will be provided through either rock placement, application of concrete mattresses and/or installation of cast iron shells.

2.3.3 It is envisaged that a variety of installation and burial techniques may be required due to the variable nature of the seabed along the submarine cable route. Because of national guidelines it is proposed to that the cables will be installed as bundled pairs in the German sector, and the Project has elected to bundle in the Dutch sector. Elsewhere along the UK and Danish sections of the route the two marine cables may be laid in a similar configuration to the German and Dutch sectors, or separately up to 50m apart as required by water depth and ground conditions.

2.3.4 The cables will be buried into the seabed along the maximum length possible. The burial depth varies along the route and at any given location is determined by the hazard profile, the geotechnical properties and potential environmental impact.

2.3.5 The cable lay configurations and burial depths assumed in this report for each jurisdiction are outlined in Table 1 below.

Table 1. Cable lay configuration and assumed burial depths for each jurisdiction.

Term	UK Sector	NL Sector	DE Sector	DK Sector
HVDC Cable Installation	Cables either within same trench or up to 50m apart	Cables in same trench	Cables in same trench	Cables either within same trench or up to 50m apart
Approximate Assumed Burial Depth (whether by sediment cover or protecting with rock armour)	0.5m	1m 'depth of lowering' but natural backfill may be limited such that depth of sediment cover may be approximately 0.5m	1.5m	0.5m

3 Anticipated Heating Effect

3.1 Overview

3.1.1 The process by which submarine power cables and other imperfect conductors generate heat is termed resistive heating. It is caused by energy loss as electric current flows and leads to heating of the cable surface and warming of the surrounding environment.

3.1.2 The use of high voltages minimises heat losses and resultant environmental warming effects because current loads are relatively small. Additionally, DC systems result in less heat loss to the environment for a given transmission rate than AC cables (OSPAR, 2009) such that relatively smaller environmental heating effects would be expected for a given power transmission.

3.1.3 Where submarine power cables are buried, the surrounding sediment may be heated but cables, whether buried or not, have negligible capability to heat the overlying water column because of the very high heat capacity of water. Demersal and epibenthic organisms which are in direct contact with the water are therefore at no risk of experiencing heating related effects from buried cables (because any heat will be carried away instantaneously by the water). The potential for such effects exists only for burrowing fauna, with deep burrowing species potentially subject to relatively larger effects.

3.2 Predicted heating due to Viking Link Interconnector

3.2.1 The Project commissioned a report (Brakelmann and Stammen, 2016) to provide a prediction of likely physical heating effects as manifested by temperature increases within sediments overlying the buried Viking Link cables. The focus of the report was to consider the predicted temperature rise at a sediment depth of 0.2m below the seabed surface, directly above various cable design scenarios, all buried at 1.5m. This relates specifically to national regulations in Germany where there is a requirement to achieve a burial depth which will result in a temperature elevation of not more than 2^{o}C (equivalent to 2K) at a depth of 0.2m within overlying sediments. The report is therefore referred to as the '2K Study'. The 2K criterion was established by German authorities as a precautionary measure to protect benthic life but is not understood to be underpinned by clear scientific evidence (Worzyk (2009), cited in Müller *et al*., 2016).

3.2.2 The 2K study has been performed primarily for the German sector where there is a 1.5m burial depth requirement. Is has relevance, however, for other jurisdictions where burial depths of 0.5m are anticipated.

3.2.3 The modelling approach used by the 2K Study makes a number of assumptions relating to both the marine environment and power transmission. All assumptions are understood to be conservative. The thermal conductivity of the seabed is assumed to be 1.4 W/(K m) and the background temperature a relatively high 15^{o}C (see also Section 4.1). Calculations also assume a steady-state of power transmission such that all heating processes reach equilibrium. This is an extremely conservative assumption and in reality the fluctuating load carried by the Viking Link Interconnector is expected to result in rather lower heating effects with smaller resultant sediment temperature rises than the predictions summarised below.

3.2.4 The 2K Study suggests that, depending upon cable design criteria, bundled cables will require between 0.7m and 1.15m[1] of sediment cover before the 2K rule is met (i.e. temperature increase at 0.2m sediment depth is < 2^{o}C). Single (i.e. not bundled) cables have a smaller heating effect and are suggested to require between 0.35m and 0.55m of sediment cover to meet the 2K threshold.

3.2.5 The modelling results suggest that the 2K criterion, if applied[2], will be met for single cables in all jurisdictions with the exception of one cable design (cross linked polyethylene (XLPE) insulated cable with 2000mm^2 aluminium conductor core) where an additional 5cm of sediment cover would be required in Dutch, UK and Danish waters if the (conservative) modelling results are applied directly.

3.2.6 For bundled cables there is predicted to be a relatively greater heating effect and an elevation of more than 2^{o}C is predicted for all cable designs in Dutch, UK and Danish waters (assuming 0.5m cable burial).

3.2.7 With the greater proposed burial depth in German waters (1.5m) the 2K threshold is comfortably met for all cable design and installation scenarios.

3.2.8 This is believed to represent a highly cautious prediction of the likely heating effects of the Viking Link interconnector. Recent research (Müller *et al*., 2016) suggests that approaches such as finite element modelling may overestimate cable temperature by up to 10^{o}C and highlight seasonal heating and cooling from seawater as the dominant factor influencing seabed sediment temperature.

3.2.9 Taking the above into account, together with the highly conservative assumptions made by the 2K study, heating in excess of 2^{o}C at 20cm sediment depth appears likely only to be possible if cables are bundled and burial depth is less than approximately 0.75m, i.e. bundled cables in UK, Dutch and Danish waters.

[1] The use of two decimal places here, and elsewhere, does not imply that the 2K study has centimetre accuracy. This is the stated level of reporting in the 2K study but is assumed to be indicative.

[2] The 2K criterion relates specifically to German national waters and is only applied here to other jurisdictions to provide an indication of potential heating effects. See also Section 4.

4 Sensitivity of marine biota to heating effects

4.1 Invertebrates

4.1.1 In relatively shallow and well mixed water bodies such as the southern North Sea the temperature of the water varies markedly with the seasons. For example, at Cleethorpes to the north of the UK landfall site average surface water temperature varies by nearly 10^{o}C annually, being coldest in February and March (6.5^{o}C) and warmest in August (15.6^{o}C) (World Sea Temperatures, 2017). Minimum and maximum temperatures can be well in excess of these figures and typically vary between 3^{o}C and 17^{o}C in the North Sea (Rei, 2012, cited in Brakelmann and Stammen, 2016). Even where mixing is less pronounced seasonal variation in water temperatures can be expected. Water temperature near to the sea bed can generally be expected to be cooler than at the surface during the warmest months of the year.

4.1.2 Although temperature variations are most pronounced in surface waters due to factors such as solar warming any marine organism living in surficial sediments will experience similar annual temperature changes, albeit buffered for the burrowing fauna which are potentially exposed to temperature increases associated with submarine power cable operation. Relatively more extreme temperature fluctuations can be expected for intertidal organisms both seasonally and diurnally. In such an environment it would not be expected that organisms which are highly sensitive to small scale temperature fluctuations would thrive.

4.1.3 The most abundant and frequently occurring taxa in grab samples collected in relation to the cable route (Fugro, 2016) are dominated by epibenthic taxa (organisms living on the seabed) which will not be subject to any cable heating effects (see Section 3.1.3).

4.1.4 The majority of marine infauna (invertebrates burrowing into sediments) occur in the upper few cm of the seabed. Kingston (2001) reported that 95-99% of animals are typically within the top 5cm of sediment). Those species which burrow more deeply tend to be larger and although less abundant (Holme 1964) their size may mean that a significant proportion of the biomass is present deeper within the sediments.

4.1.5 Examples of shallow burrowing fauna present in survey data for the project include the sand mason worm (*Lanice conchilega*). The thermal tolerance of this species has been reviewed by MarLIN (website accessed 2017) and it was assessed to be of low sensitivity to temperature increases. Comprehensive data on the thermal sensitivity of many species are lacking but given the proximity to overlying waters it is likely, as stated above, that such species do not have high sensitivity to temperature fluctuations because they will experience temperature fluctuations due to seasonal effects and, perhaps most importantly, because the overlying water body is expected to rapidly dissipate any heat build-up within the shallow sediments inhabited by the majority of infauna.

4.1.6 Deeper burrowing species do occur in the Fugro (2016) survey data. Two deep-burrowing decapods *Callianassa subterranea* and *Upogebia deltaura* were recorded which can construct burrows 60-80cm deep. These two species have ranges that extend as far south as the Mediterranean (MarLIN, 2017), where water temperatures are much higher than in the North Sea, and therefore are likely to be relatively tolerant of increases in sediment temperature as they thrive in a large range of ambient temperatures.

4.1.7 Other deeper burrowing species which could potentially occur include the sand gaper (*Mya arenaria*, a bivalve mollusc) and Norway lobster (*Nephrops norvegicus*). MarLIN (2017) again provides an assessment of temperature sensitivity. The sand gaper is a large, long-lived and deep burrowing bivalve and has been recorded at up to 50cm depth in sand, mud and sandy gravels from intertidal to fully subtidal areas up to nearly 200m water depth. The southern distribution of the sand gaper may be restricted by a limit of 28°C (Nedwell & Hidu, 1986; Strasser, 1999: both cited in MarLIN, accessed 2017) whilst over-wintering individuals in Alaska tolerate temperatures as low as -2°C (Strasser, 1999: cited in MarLIN, 2017). *N. norvegicus* burrows in soft sediments but to a more shallow depth than *Mya*, typically to around 20—30cm, and might therefore be expected to experience more pronounced temperature changes. The species is recorded as far south as the Mediterranean and Adriatic and therefore adapted to temperatures well in excess of those occurring in the southern North Sea. Both these species, which represent examples of deeper burrowing members of the invertebrate infauna, are regarded as having low intolerance of temperature increases (i.e. they are not sensitive).

4.2 Other Taxa

4.2.1 As noted above, only organisms present within seabed sediments could be exposed to anything other than very small temperature changes because of the presence of the overlying water body and its great heat capacity. The majority of marine vertebrate fauna do not bury themselves within seabed sediments and will therefore not be at any risk of exposure to temperature change associated with operation of the cable.

4.2.2 The principal vertebrates which periodically bury themselves in seabed sediments as adults are sandeels (e.g. *Ammodytes marinus* and *A. tobianus*) and flatfish although a range of other species, e.g. gobies (*Pomatoschistus* spp.), may also bury themselves in sediment. In all cases burial depths are believed to be relatively shallow (i.e. a few cm) since oxygen exchange with the overlying water column is required and the potential for exposure to cable heating effects is therefore limited because along with oxygen exchange with the overlying water there will be heat exchange.

4.2.3 Similarly, adequate oxygenation is required by the eggs of those fish species which bury their eggs within seabed sediments. This limits the likely burial depth to the upper sediments.

4.3 Summary

4.3.1 Only deep burrowing invertebrates are considered likely to be potentially exposed to anything more than trivial heating effects from cable operation.

5 Likely magnitude of heating effects

5.1 Deep burrowing invertebrates

5.1.1 Invertebrates such as *C. subterranean, U deltaura* and others mentioned in Section 4.1 which burrow beyond the upper few centimetres of sediment could potentially be exposed to temperature increases due to cable heating effects. Modelling of cable heating (Brakelmann and Stammen, 2016 (i.e. the 2K Study)) suggests that even for the worst case scenario of bundled cables any increases in temperature will be limited to a very narrow band above the cables with negligible lateral heat transfer. The footprint of any effect will therefore be extremely narrow, less than a 1m strip above the cable although it is not possible to define the area precisely and it will also vary in response to current load.

5.1.2 Where species are widely distributed, and the Project Area does not lie towards the southern limit of a range, it is very unlikely that temperature changes will be ecologically significant at a local scale, i.e. the footprint of the heating effect. Since this footprint is so small the potential for population level effects is considered to be negligible.

5.1.3 None of the species understood likely to occur in the Project Area are understood to be present near the southern limit of their ranges and it is suggested that any heating effect of the cable would have to be marked, in excess of around 5^{o}C to use the MarLIN definition for acute temperature rises (MarLIN), to represent a potential impact to individual fauna. In light of the inherent tolerance of marine fauna to fluctuations in temperature as discussed in this report, the overall effect is considered likely to be of not more than low magnitude for deep burrowing fauna living directly over the cable. At the scale of local populations and above any effect would likely be of negligible magnitude.

5.1.4 In this respect, the sensitivity to temperature increases of burrowing fauna reported or likely to occur in the Project Area is low.

5.2 Shallow infauna and other taxa

5.2.1 As discussed in sections 4.1 and 4.2, heating effects in the shallow sediments inhabited by most infauna and other taxa such as fish which self-bury are expected to be trivial. The magnitude of any effect would therefore be expected to be negligible.

6 Comparison with impacts from deeper burial

6.1.1 It is understood that it may be challenging to achieve full installation burial depth in certain areas of the offshore route. In Dutch waters the typically expected minimum required burial depth is 1m, and the majority of projects are in more dynamic locations where trench back-fill is highly likely. However evidence from the Project area suggests that there is minimal sediment movement and although the initial trench will be 1m or more deep the subsequent naturally assisted backfilling process may be limited such that the final burial depth is around 0.5m.

6.1.2 There is an apparent conflict between the plan to bundle cables in Dutch waters, which will serve to minimise other potential environmental effects including electromagnetic fields (EMF) in the marine environment, and the greater heating effect of bundled cables. It is therefore relevant to consider the likely comparative scale of impacts due to heating effects (negligible magnitude effect expected for all taxa other than deep burrowing invertebrates living directly over the cable for which a low magnitude effect is considered possible) and those associated with measures to achieve greater burial depth, i.e. deeper burial or additional cover with either local sediment of gravel/rock.

6.1.3 Rock dump has been considered within the wider project assessment in terms of its potential use to cover cables where there are crossing over other cables or pipelines. At this scale the principal effect relates to the introduction of hard substrate over areas likely to be predominantly finer sediment and the resultant habitat loss/change. The use of rock dump to infill a cable trench over multiple kilometres has not been specifically assessed but it is possible to identify a range of likely effects, including:

- Loss of existing habitat;
- Presence of new habitat which will develop a markedly different colonising community associated with hard ground;
- Temporary effects of suspended sediment increases and underwater noise associated with the deposition of rock material into the sea;
- Potential for secondary scour (although this will likely be negligible where natural sediment movement is limited);
- Other effects associated with sourcing the material for infill and its transport to site.

6.1.4 Deeper burial is likely to be associated with a number of effects. These are described below:

- The volume and footprint of the burial operation will be increased, increasing habitat disturbance effects.
- The total duration and consequently installation cost will increase. The deeper the trench needs to be made, the more locations may be encountered where soil conditionss are not

conducive, and thus there will be either less burial and more required backfill, or more cost due to slower operation or multiple passes.

6.1.5 Whilst direct comparisons are somewhat artificial it is apparent that the overall scale of environmental impact associated with achieving greater burial depth is likely to be very much larger than the effects of heating.

7 References

Brakelmann, IH and Stammen, IJ (2017) Thermal Emissions of the Submarine Cable Installation Viking Link in the German AWZ. BCC Cable Consulting report to IFAÖ GmbH, Rostock.

Holme, NA (1964) Methods of sampling the benthos. Advances in Marine Biology, 2, 171-260.

Kingston, PF (2001) Benthic Organisms Review. In Encyclopedia of Ocean Sciences, 2nd Edition. Compiled by Steele, JS and edited by Steele, JS; Thorpe, SA & Turekian, KK.

MarLIN (2017) MarLIN, The Marine Life Information Network. www.marlin.ac.uk accessed January 2017.

Müller, C, Usbeck, R and Miesner, F (2016) Temperatures in shallow marine sediments: Influence of thermal properties, seasonal forcing, and man-made heat sources. Applied Thermal Engineering, 108, 20-29.

OSPAR (2009) OSPAR (2009) Assessment of the Environmental Impact of Cables. OSPAR Commission, 437/2009. 19pp. http://qsr2010.ospar.org/media/assessments/p00437_Cables.pdf

World Sea Temperatures (2017) https://www.seatemperature.org accessed 3rd January, 2017.

Viking Link – Contact Us

Great Britain

By phone: Freephone + 440800 731 0561

By email: vikinglink@communityrelations.co.uk

By post: FREEPOST VIKING LIN

Denmark

By phone: + 45 7010 22 44

By email: vikinglink@energinet.dk

By post: Energinet.dk, Att. Viking Link, Tonne Kjærsvej 65, DK - 7000 Fredericia

K