Not to be cited without prior reference to the author ICES CM 2007/C:02

Using biological knowledge and decisions of society in spatial prioritization of oil combating

Taina Ihaksi [1], I. Helle[2], T. Lecklin[1], R. Ryömä[3], T. Kokkonen[4] & S. Kuikka[2]

OILECO project, University of Helsinki.

1) *University of Helsinki, Department of Biological and Environmental Sciences, Kotka Research Unit, Sapokankatu 2, FI-48100 Kotka, Finland*
2) *University of Helsinki, Department of Biological and Environmental Sciences, P.O. Box 65 (Viikinkaari 1), FI-00014, Finland*
3) *University of Helsinki, Palmenia Centre for Continuing Education, Keskuskatu 19, FI-48100 Kotka, Finland*
4) *Helsinki University of Technology, Laboratory of Water Resources, P.O.Box 5300, FI-02015 HUT, Finland*

Abstract

Scientists and managers are often confronted with questions concerning nature valuation, at least in relative terms. In oil spill compensation assessment, for instance, the amount of money the polluter has to pay for to compensate the loss is defined in monetary values. It is however difficult or even impossible to put a price tag on some ecological values. A Finnish-Estonian Interreg IIIA project OILECO constructs a ranking system for populations to be used when there is a need to prioritize oil combating in the Gulf of Finland. Because of limited time and resources for oil combating after the oil accident, fast and difficult decisions have to be made on which populations should be safeguarded. Aesthetic and economic values have often had more weight than ecological aspects like e.g. recoverability of species and their status in e.g. international agreements. This has led to the neglect of e.g. many threatened taxa that can be as severely affected by oil spills. We suggest that the aim should be to minimize long term effects on the populations. This means that the ecological role, rarity and genetic uniqueness (probability to lose a genetically adapted population) of species should be used as a basis for valuation instead of aesthetic or economic values that can more readily recover after the oil accident. In the valuation and ranking of the species we use the decisions already made in the society to evaluate, which species should be considered to be more important than others. These decisions include e.g. nature conservation areas and the species´ status in the IUCN classification and EU legislation.

Keywords: valuation, nature, oil spill, recovery potential, threatened species, prioritization, Gulf of Finland, Baltic Sea, sensitivity mapping, oil combating

Contact author:
Taina Ihaksi, University of Helsinki, Department of Biological and Environmental Sciences, Fisheries and Environmental Management Group, http://www.helsinki.fi/science/fem *, Kotka Research Unit, Sapokankatu 2, FI-48100 Kotka, Finland [tel: +358 05 234 4853, fax: +358 5 234 4275, e-mail:* taina.ihaksi@helsinki.fi*]*

Introduction

The Baltic Sea is an important sea route connecting the Nordic countries and Russia to the Atlantic. During the last decades, maritime traffic has increased rapidly in the Baltic Sea and in the Gulf of Finland. Due to the development and expansion of oil terminals and oil transportation volume, the risk of a massive oil spill has increased during the last ten years. The amount of oil transported through the Gulf of Finland was 40 million tons in 2000, approximately 140 million tons in 2004 and is expected to reach at least 200 million tons by the year 2010 (Hietala 2006). At the same time the maximum capacity of oil tankers has risen to 150 000 tons which is also the largest size that can be used in the Baltic Sea (because of practical reasons) (HELCOM 2001). About 15–17 tankers navigate in the Gulf of Finland each day and according to the Finnish Maritime Administration the risk of a severe oil accident is 0.12 occasions per 1000 vessels (Finnish Maritime Administration 1996). If a massive oil accident takes place in the Gulf of Finland, there might be severe but unpredictable effects because of geographical and ecological uniqueness of the area.

The Gulf of Finland, the north-easternmost sub-basin of the Baltic Sea, is approximately 400 km long and the width ranges form 48 to 135 km. The average depth is 37 m and the volume thus comprises only 5% of the total volume of the Baltic Sea (Alenius *et al*. 1998). Gulf of Finland is a unique brackish water basin where salinity varies from 0–3 ‰ in the east to 5–7 ‰ in the west (Alenius *et al*. 1998). The duration of ice cover varies from approximately one and a half months in the western parts to about four months in the east (Seinä & Peltola 1991). Due to limited water exchange and slow microbial degradation suppressed by low temperatures and ice cover in wintertime, any contaminants will persist in the ecosystem for a long time (Furman *et al.* 1998). Ice cover in addition to indented and shallow coastline cause a challenge for navigation and thus raise the risk of accidents. Furthermore, it affects the efficiency of oil combating. Due to the narrowness of the Gulf, oil spreads quickly along the coastline and there is very limited time to respond to the accident and to decide which areas should be safeguarded with limited oil combating equipment.

The Gulf of Finland is extremely vulnerable to oil spills also from the ecological point of view. For numerous species the Gulf of Finland and its shores represent the northernmost and often isolated parts of their geographic distribution. There are some nationally threatened species that have only a few occurrences on the Finnish coasts of the Gulf of Finland and thus might never recover after an oil accident. Furthermore, it has been found that some Baltic Sea populations have evolved substantially different from the Atlantic populations and the Baltic can also be seen as a refuge for unique evolutionary lineages (Johannesson & André 2006). The exceptional environmental conditions and geographical isolation of the Gulf of Finland increase the probability of the existence of locally adapted populations. Many unique populations might therefore have a marginal chance to recover after an oil accident especially if the occurrences are restricted to a small area and are suspect to drifting oil.

Scientists and managers are perhaps more often than they realize confronted with questions concerning nature valuation, at least in relative terms. The resources for environmental management are limited and therefore it is essential to use available resources effectively and prioritize between the actions (Montgomery 2002, Dunn *et al.* 1999). This is especially true in oil spill contingency planning. The lack of time and knowledge in the decision-making process concerning the prioritization can lead to the neglect of e.g. some rare species that might deserve attention but are unfamiliar to the scientists, public or to the decision makers.

Oil sensitivity mapping has focused on collecting the ecological data that can be used as background information for oil combating or oil spill compensation assessment. Until the 1990s the focus of oil sensitivity mapping and oil spill contingency planning was strongly concentrated on the physical effects of oil on the shoreline rather than its ecological effects (e. g. Owens & Robilliard 1981, Thomas 1986, Tortell 1992). Since then the sensitivity mapping has focused more on collecting databases on protected areas or occurrences of species that are known to the public, economically important and considered vulnerable to oil spills (e.g. Carter *et al.* 1993, Safetec UK 1999, DNV Consulting 2005). However, only a few sensitivity maps have taken into account the recoverability of species after an oil accident (Tyler-Walters *et al.* 2003, Offringa & Lahr 2007), even though it is natural that the recovery potential should have an essential role in defining combating strategy. Sensitivity maps have rarely penetrated further to the issue and analyzed which species should be taken into account, which species are vulnerable to oil spills or have low recovery capacity and what is the ecological value of different species. Probabilistic analysis by Juntunen *et al*. (2005) suggests that oil spills are likely to have a relatively small impact on the populations of common species in the long-term. The case is different if there is a risk to lose genetically adapted populations or populations of rare species that are already suffering from other human impacts and are nationally or internationally threatened. In such cases, dispersal of new individuals from other areas is uncertain, which can lead to unsuccessful recovery of the populations.

In the Gulf of Finland, the amount of oil combating equipment is very limited compared to the length of the coastline. In case of a large-scale oil spill, fast decisions have to be made on which areas should be safeguarded from oil and how the species should be weighted. OILECO project has concentrated on this question and defined ecological values for species vulnerable to oil spills in the Gulf of Finland. We suggest that the approach should be different if we develop sensitivity maps e.g. for oil spill compensation assessment compared to maps that can be used to prioritize oil combating. Maps developed for oil spill compensation assessment can encompass all vulnerable species. However, if the maps will be used as a reference to decide which areas should be the primary targets of oil combating after the accident, there is a need to prioritize the combating efforts to those species that have 1) high conservation value (valuation issue), 2) slow recovery potential (population dynamic issue) and 3) are possible or reasonable to safeguard with current oil combating methods (technical issue related to tools and species behavior). In addition, we suggest that all taxa should be evaluated using the same criteria when selecting the species and the selection should not be restricted to marine species but also to the terrestrial populations on shore that are dependant on the coastal habitats and might be as severely affected by oil spills. Here we will focus on the issue on how to define the ecological conservation value of species and populations.

Setting values to species or populations

Utilitarian values: Aesthetic and economic value

Aesthetic animals such as marine mammals or large carnivores have been and still are the organisms that attract public attention and this has had a major effect on the way money has been directed between conservation efforts (Montgomery 2002). Almost all studies that investigate public attitudes towards wildlife highlight high-profile species that are common to the public (Montgomery 2002) and therefore it is not surprising that most studies have found that the publics´ appreciation towards nature would be restricted to charismatic species (Kellert 1993). Charismatic species are also often used by the nature conservation organizations in their campaigns, which may lead to their high valuation by the other stakeholders.

At some fields of ecology, the researchers aim to find charismatic species that can be used as umbrella species by conservation biologists to attract the publics' attention (Decaëns *et al.* 2006). Some studies have however shown that common people value ecological significance more than utilitarian (recreational), aesthetic, symbolic or humanistic values and the contrasting results might be due to ignorance about the species (Montgomery 2002). Furthermore, the public has been found to be willing to pay for the conservation of species that they will probably never observe (Christie *et al.* 2006). In Finland, the public seem to value the nature in the Gulf of Finland more than the recreational possibilities and would want to aim resources to safeguard nature values instead of recreational values (Ahtiainen 2007).

Cute and cuddly animals attract medias´ attention after an oil accident and they also get most sympathy from the public. However, the use of aesthetic values to prioritize oil combating might be misleading from the ecological point of view. Some aesthetic vertebrates such as birds and seals attract attention from the media and have therefore often been highlighted in sensitivity mapping. However in literature, it is suggested that seals are less sensitive to the effects of oil compared to some other species (e.g. Jenssen 1996, Loughlin 1994) Seals are also fairly difficult to safeguard because of their mobile behavior. Therefore we suggest that aesthetic values should not be used as a criterion to select or prioritize between species in oil combating.

Oil spill contingency planning has often included species that have high economic value such as commercial fish species and aquacultures (e.g. Safetec UK 1999, DNV Consulting 2005). We may consider one example, demonstrating how different conclusions may be drawn when applying economical valuation instead of ecological valuation. In the year 2006 the economically most important species in the Gulf of Finland were sander (*Sander lucioperca L.*), sprat (*Sprattus sprattus*) and salmon (*Salmo salar*) (Pers comm. Pirkko Söderkultalahti 2007). However, the recovery of these species through dispersal from adjacent areas is very likely after an oil accident. In contrast, the total catch of vendace (*Coregonus albula*) in the Gulf of Finland is very low, but a collapse of this population would probably lead to an irrecoverable damage, since because of the isolation there is little chance of recovery though migration and the population might be genetically distinct.

Aldo Leopold (1939) was probably one of the first scientists questioning the utilitarian aspects of valuing species and expressed the equality of species in ecological terms. Species can be seen to have intrinsic value (Callicott 1995). Likewise, we suggest that all taxa should have a similar ecology based assessment on weather they should be taken into account and how much weight should they have in the spatial prioritization of oil combating. This assessment should be free from the potential aesthetic or economic values that the population might have.

Ecological value

The Convention on Biological Diversity (1992) in Rio de Janeiro acknowledged the intrinsic value of biodiversity and since then the main concern in ecological valuation has been the importance of species for the functions, diversity, complexity and stability of the ecosystem (Bengtsson 1998). There are some species in the Baltic that might be considered as more important than others because they have a significant effect on the food webs. These species are usually referred to as key or keystone species (Begon *et al.* 2006). The debate over these two definitions and the overall usefulness of the terms is ongoing (Mills *et al.* 1993, Piraino & Fanelli 1999, Bond 2001) but the main determination is that the extinction of such species might lead to extinction or large changes in abundance of several other species. Keystone species were originally described as having a major bottom-up or top-down effect on the communities of which they are a part in a manner disproportionate to their abundance (Paine 1966, Power *et al.* 1996) whereas key species are those that drive ecosystem processes or energy flows a few of them being keystone species because of their high abundance (Piraino & Fanelli 1999). If the common key species are included, the focus could be on the most representative occurrences, since they could serve as a recolonization source after the accident.

In the Gulf of Finland, common eider (*Somateria mollissima*) is one of the species that can be seen as a keystone species since it has a strong top-down effect on the food-web. Habitats constructing species such as bladder wrack (*Fucus vesiculosus*) (e. g. Wikström & Kautsky 2007, Kangas *et al.* 1982, Orav-Kotta & Kotta 2004) or eelgrass (*Zostera marina*) (Boström *et al.* 2006) in the Baltic are in turn considered as key species. Local extinction of these species might lead to long-term changes in the ecosystem functions. However, despite their significant role in the ecosystem it is not straightforward to include key and keystone species in the prioritization of oil combating. Keystone species are extremely difficult to identify and key species are often so common that they should not be self-evidently taken into account. We argue that if they occur in vast areas, some of the occurrences will in any case be safeguarded while concentrating on the rare populations and therefore also the recovery is much more efficient compared to rare or local populations.

Another aspect of the ecological value is the genetic uniqueness of species or population. Genetic diversity has been suggested to enhance the recovery of populations afer climatic changes (Reusch *et al.* 2005) Many Baltic populations have been found to differ significantly from the Atlantic populations, and the Baltic Sea has been suggested to be a refugee area for unique evolutionary lineages despite of the short 8000 years evolutionary history (Johannesson & André 2006). Since the Gulf of Finland is even more remote area with perhaps even more pronounced adaptive pressure, there might be many species or populations that are genetically adapted to the environment, especially if species are occurring in the margin of their distributional range and are isolated from other populations in the Baltic. There is however very little knowledge of the genetics of the species that might be affected by oil spill in the Gulf of Finland. In addition, the genetic analyses often focuses on the non-functional part of the genome, i.e. they describe only, whether the two compared populations have been isolated in the sense of reproduction. Therefore, the application of modern genetic methods like microsatellites to the prioritization of oil combating is not straightforward.

As Crandall et al. (2000) suggested the conservation effort should be directed at maintaining the part of the population that is needed to the adaptive diversity within the species. The inclusion of both genetic and ecological evidence is crucial to identify these Ecologically Significant Units (ESU) in the populations (e.g. Ryder 1986, Moritz 1994, Rannel 2000). The methodology to find adaptive mechanisms that affect the recovery potential after an oil spill should be based on the functional features of the individuals and populations. For example, it has been shown that Baltic cod (*Gadus morhua*) eggs have more buoyancy in the Baltic brackish water than the eggs of North Sea cod (Nissling & Westin 1997). Similar biological evidence would be needed for other populations in order to show the importance and uniqueness of local adaptations. Knowledge related to the migration rates may also be useful when assessing the likely adaptation of the population to the Gulf of Finland. This type of assessment is a major task for experimental ecology and physiology in the future, if we want to facilitate the conservation decisions. Certainly, these populations can be seen to have a high conservation value and should be taken into account in the prioritization of oil combating if occurrence data is provided.

People value the preservation of threatened species because of the irreversible nature of extinctions (Giraud *et al.* 1999). Even though local or national extinctions are certainly not as severe as global and the recovery through migration might be possible, nationally threatened species should have high priority in oil combating because of their often small population size, restricted distribution and usually low resilience towards population decrease. Unfortunately, only the more charismatic threatened species like threatened seals and birds have often been included in the sensitivity maps because of limited knowledge of the occurrence or just unintentional exclusion of the more unknown taxa like insects or plants. In OILECO project we have actually found that some insect species might become nationally extinct after an oil accident in the Gulf of Finland. These species are dependant on the coastal habitats like natural sand dunes or meadows and have only a couple of occurrences in the Finnish coasts of the Gulf of Finland. If these occurrences disappear, they might never recover from the accident because these species are very sensitive to oil and migration from other areas is highly unlikely.

Conclusions

The prioritization of oil combating according to nature values is a difficult task requiring thorough analysis before the decisions. Which species should be primarily safeguarded and how should the species be weighted? An interreg IIIA project OILECO has focused on the prioritization of oil combating in the Gulf of Finland. We suggest that the economic and aesthetic values of species should not have much weight in the prioritization, because this might lead to the decision to safeguard the species that actually have high recovery potential instead of species that have a very low resilience towards population decrease. Instead all the species independently of their taxonomic state in the evolutionary tree should go though similar approach on whether they should be included in the prioritization maps and how they should be weighted. The ecological value, such as importance of the species in the ecosystem as key or keystone species should be taken into account in the valuation but the recovery potential and geographical extent of the occurrences and oil combating efficiency should also be considered to ensure that we are using the limited combating equipment efficiently. Special attention should be focused to those species that are rare or threatened, whose populations might be severely affected by oil spills and which are possible to safeguard with current oil combating methods. We have transferred the expert knowledge to management by using international agreements and legislation as a bases for valuation. The species are weighted according to their national IUCN classification, status as a responsibility species in Europe and status as a directive species in EU. Furthermore the occurrences of different species have been weighted by their significance for the survival of the species in Finland.

References

Ahtiainen, H. 2007. The willingness to pay for reducing the harm from future oil spills in the Gulf of Finland. Discussion papers n:o 18. Department of Economics and Management. University of Helsinki. Available online at: http://www.mm.helsinki.fi/mmtal/abs/DP18.pdf.

Alenius, P., Myrberg, K. & Nekrasov, A. 1998. Physical oceanography of the Gulf of Finland: a review. Boreal Environment Research 3: 97-125.

Begon, M., Harper, J. L. & Townsend, C. R. 2006. Ecology: Individuals, Populations and Communities. 4th Ed. Chpt 20.2.6 pp. 584-586. Strong interactions and keystone species. Blackwell Science. Oxford

Bengtsson, J. 1998. Which species? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function. Applied Soil Ecology 10: 191-199.

Bond, W. 2001. Keystone species-hunting the shark? Science 292: 63-64.

Boström, C., O´Brien, K., Roos, C. & Ekebom, J. 2006. Environmental variables explaining structural and functional diversity of seagrass macrofauna in an archipelago landscape. Journal of Experimental Marine Biology and Ecology 335: 52-73.

Brown, J. H. 1995. Macroecology. University of Chicago Press. Chicago.

Brown, J. H., Marquet, P. A. & Taper, M. L. 1993. Evolution of body size: consequences of an energetic definition of fitness. American Naturalist 142: 573-584.

Callicott, J. B. 1995. Intrinsic value in Nature: a metaethical analysis. The Electronic Journal of Analytic Philosophy 3: 1-16.

Carter, I. C., Williams, J. M., Webb, A. & Tasker, M. L. 1993. Seabird concentrations in the North Sea: an atlas of vulnerability to surface pollutants. 39 pp. Aberdeen: Joint Nature Conservation Committee.

Christie, M., Hanley, N., Warren, J., Murphy, K., Wright, R & Hyde, T. 2006. Valying the diversity of biodiversity. Ecological Economics 58: 304-317.

Convention on Biological Diversity. 1992. Rio de Janeiro. Available online at: http://www.cbd.int/convention/convention.shtml

Crandall, K. A., Bininda-Emonds, O. R. P., Mace, G. M. & Wayne, R. K. 2000. Considering evolutionary processes in conservation biology. Tree 15: 290-295.

Decaëns, T., Jiménez, J. J., Gioia, C., Measey, G. J. & Lavelle, P. 2006. The values of soil animals for conservation biology. European Journal of Soil Biology 42: S23-S38.

DNC Consulting. 2005. Areas vulnerable to acute oil pollutions in the Norwegian Barents Sea. Report no. 2005-0456. Available online at: http://www.panda.org/about_wwf/where_we_work/europe/what_we_do/arctic/publications/index.cfm?uNewsID=21394

Dunn, E. H., Hussell, D. J. T. & Welsh, D. A. 1999. Priority setting tool applied to Canada´s landbirds based on concern and responsibility for species. Conservation Biology 13(6): 1404-1415.

Finnish Maritime Administration. 1996. Accident analysis 1982-1994. Groundings and collisions with vessel (In Finnish). Helsinki.

Furman, E., Dahlström, H. & Hamari, R. 1998. The Baltic – Man and Nature. Otava Publishing Company Ltd. Helsinki.

Giraud, K. L., Loomis, J. B. & Johnson, R. L. 1999. Internal and external scope in willingness-to-pay estimates for threatened and endangered wildlife. Journal of Environmental Management 56: 221-229.

Hagvar, S. 1998. The relevance of the Rio-Convention to conserving the biodiversity of soils. Applied Soil Ecology 9: 1-7.

HELCOM 2001. Resume of the report "Traffic restrictions and escort requirements for various types of oil tankers navigating in the Gulf of Finland waters". HELCOM

SEA 2/2001: 3.1/8. Available online at: http://sea.helcom.fi/dps/docs/documents/Sea-based%20Pollution%20Group%20(HELCOM%20SEA)/HELCOM%20SEA%202,%202001/3_1_8.pdf

Hietala, M. 2006. Oil transportation in the Gulf of Finland. Finnish Environment Institute. 4 pp. Available online at: http://www.environment.fi/download.asp?contentid=53583&lan=fi

Jenssen, B. J. 1996. An overview of exposure to, and effects of, petroleum oil and organochlorine pollution in grey seals (*Halichoerus grypus*). Science of the Total Environment 186: 109-118.

Johannesson, K. & André, C. 2006. Life on the margin: genetic isolation and diversity loss in a peripheral marine ecosystem, the Baltic Sea. Molecular Ecology 15(8): 2013-2029.

Juntunen, T., Rosqvist, T., Kuikka, S. & Rytkönen, J. 2005. Assessment of oil combating technologies using Bayesian networks - an application in the Baltic Sea. ICES CM 2005/S:02.

Kangas, P., Autio. H., Hällfors, G., Luther, H., Niemi, Å. & Salemaa, H. 1982. A general model of the decline of *Fucus vesiculosus* at Tvärminne, south coast of Finland in 1977—1981. Acta Botanica Fennica 118: 2-27.

Kellert, S. R. 1993. The biological basis for human values of nature. In: *The Biophilia Hypothesis*, pp. 42-69. Kellert S. R. & Wilson E. O. (eds.), Island Press, Washington DC.

Leopold, A. 1939. A biotic review of land. Journal of Forestry 37: 113-116.

Loughlin, T.R. (ed.) 1994. Marine mammals and the *Exxon Valdez*. Academic Press, Inc., San Diego, California.

Marquet, P. A., Navarrete, S. A, Castilla, J. C. 1995. Body size, populations density, and the energetics equivalence rule. Journal of Animal Ecology 64: 325-332.

Mills, L. S., Soulé, M. E., Doak, D. F. 1993. The keystone-species concept in ecology and conservation. BioScience 43: 219-224.

Montgomery, C. A. 2002. Ranking the benefits of biodiversity: an exploration of relative values. Journal of Environmental Management 65: 313-326.

Moritz, C. 1994. Defining ´evolutionary significant units for conservation. Trends in Ecological Evolution 9: 373-375.

Nissling, A. and Westin, L. 1997. Salinity requirements for successful spawning of Baltic and Belt Sea cod and the potential for cod stock interactions in the Baltic Sea. Marine Ecology Progress Series 152: 261-271.

Offringa, H. & Lahr, J. 2007. Safetyatsea. An integrated approach to map ecologically vulnerable areas in marine waters in the Netherlands (V-maps). Report no. A09.

Orav-Kotta, H. & Kotta, J. 2004. Food and habitat choice of the isopod *Idotea Baltica* in the noprtheastern Baltic Sea. Hydrobiologia 514: 79-85.

Owens, E. H. & Robilliard, G. A. 1981. Shoreline Sensitivity and Oill Spills—a Re-evaluation for the 1980´s. Marine Pollution Bulletin 12(3): 75-78.

Paine, R. T. 1966. Food web complexity and species diversity. American Naturalist 103: 91-93.

Piraino, S. & Fanelli, G. 1999. Keystone species: What are we talking about? Conservation Ecology 3(1): r4. [online] URL: http://www.consecol.org/vol3/iss1/rep4/

Power, M. E., Tilman, D. Estes, J. A., Menge, B. A., Bond, W. J., Mills, L. S., Daily, G., Castilla, J. C., Lubchenco, J. & Paine, R. T. 1996. Challenges in the quest of keystones. Bioscience 46(8): 609-620.

Rannell, J. R. 2000. The calculus of biodiversity: integrating phylogeny and conservation. Tree 15: 92-94.

Reusch, T. B. H., Ehlers A., Hämmerli A. & Worm B. 2005. Ecosystem recovery after climatic extremes enhanced by genotypic diversity. Proceedings of the National Academy of Sciences of the United States of America, 201: 2826-2831.

Ryder, O. A. 1986. Species conservation and systematics: the dilemma of subspecies. Trends in Ecological Evolution 1: 9-10.

Safetec UK. 1999. Identification of the Environmental High Risk Areas MEHRA´S in the UK. Department of the Environment, Transport and regions.

Seinä, A. & Peltola, J. 1991. Duration of the ice season and statistics of fast ice thickness along the Finnish coast 1961–1990. Finnish Marine Research 258.

Söderkultalahti, P. 2007. Pers. comm. Finnish Game and Fisheries Research Institute.

Thomas, M. L. H. 1986. A physically derived exposure index for marine shorelines. Ophelia 25(1): 1-13.

Tortell, P. 1992. Coastal zone sensitivity mapping and its role in marine environmental management. Marine Pollution Bulletin 25(1-4): 88-93.

Tyler-Walters, H., Lear, D. & Hiscock, K. 2003. The Marine Life Information Network® for Britain and Ireland (*MarLIN*). Sensitivity mapping for Oil Pollution Incident Response. *Report to Cyngor Vefn Gwlad Cymru / Countryside Council for Wales from Marine Life Information Network (MarLIN).* Plymouth: Marine Biological Association of the UK. [Contract no. FC 73-02-282]

Wickström, S. A. & Kautsky, L. 2007. Structure and diversity of invertebrate communities in the presence and absence of canopy-forming *Fucus vesiculosus* in the Baltic Sea. Estuarine, Coastal and Shelf Science 72: 168-176.