BALANCE Interim Report No. 29

Essential fish habitats and fish migration patterns in the Northern Baltic Sea

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CONTENTS

0 EXECUTIVE SUMMARY

The report summarizes the current state of knowledge on essential fish habitats (EFH) and patterns of fish dispersal within a Baltic archipelago area. Additionally, a preliminary analysis is presented, where breeding and feeding areas of herring are described and discussed for connectivity and representativity with respect to the Finnish Natura 2000 network.

The data is intended for use as input data in spatial planning. Within the BALANCE project, the data has been used in GIS-based analyses of ecological coherence of marine protected areas.

Explicit spatial analyses may be performed for fish species and life stages for which maps of potential EFH are currently available (section 2.3.1) if the analyses are of appropriate scale and resolution in relation to these maps. For the other species (section 2.2, section 4), an evaluation is made of how well their preferred habitat types correspond to habitat types described within the Habitats Directive. Maps of the habitat types presented have previously been produced within BALANCE for Pilot area 3 (the Stockholm archipelago and Archipelago Sea area). This indirect approach can be used for broad, preliminary descriptions of the distribution of EFHs, but should be replaced by maps based on statistical models as soon as enough information is available for predictive modelling.

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1 INTRODUCTION

The aim of this report is to compile the current state of knowledge on essential fish habitats (EFH) and patterns of fish dispersal within BALANCE Pilot Area 3 (defined in Lindeberg et al. 2006). The report is intended as background data for GIS-based analyses of ecological coherence of marine protected areas within BALANCE.

In accordance with HELCOM and OSPAR, four aspects are emphasised when evaluating the ecological coherence of networks of marine protected areas (MPAs) within the BALANCE project, namely *representativity*, *connectivity*, *replication* and *adequacy*. For fish, the four concepts may be analysed based on descriptions of essential fish habitats (supporting analyses of representativity, adequacy and replication) and fish dispersal (supporting analyses of connectivity).

The ecological coherence of the Baltic Sea MPA network, referring to various marine landscapes, habitats and organism groups is analysed in a separate report (Piekäinen & Korpinen 2007), which also includes further analyses and an assessments of the Natura 2000 network from the perspective of essential fish habitats within Pilot area 3.

1.1.1 Definition of essential fish habitats

Essential fish habitats (EFH) were defined in the U.S. Magnuson-Stevens Fishery Conservation and Management Act (1998) as "*those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity*". The EFH concept is increasingly used in fisheries management plans in different countries, aiming to identify geographic sites that are particularly important for the maintenance of vigorous fish populations. As most fish species use different habitat types for different parts of their life cycle, the description of essential habitats for one species should include all habitat types that are critical for a species to complete its life cycle. Examples of categories that should be considered are:

- Spawning areas
- Nursery areas (for larvae and juveniles)
- Adult feeding areas
- Migratory corridors
- Possible specific areas to which a species may be highly restricted

The preferred habitat type within each of these categories varies with species, depending on differences in for example life history patterns, food preferences and physiology. In some cases, the geographical location of the preferred habitat may fluctuate with time, so that the preferred site may vary within and between different years, depending on how the fish respond to for example climatologic factors.

1.1.2 Fish dispersal and connectivity

In the marine environment, populations of a species are connected to each other via either active migration of individuals or via passive transport, the latter of which may be particularly enhanced in areas of unidirectional water flow. Linkages between populations (channels or routes) that are of particular importance for the maintenance of biogeographical patterns at the level of species or communities have been referred to as "blue corridors" (Martin et al. 2006). Connectivity, again, refers to the effectiveness by which population exchanges occur along the trajectories of a blue corridor (Martin et al. 2006). Within an analysis of ecological coherence, connectivity is used as a measure of blue corridors in the study area. For fish, as in some other marine organism groups as well, blue corridors are important both for connecting populations of one species with each other, and for ensuring connections between the different habitats types that one species uses during different parts of its life cycle. Connectivity among essential fish habitats can be evaluated by assessing the distance between EFHs in relation to the distances that pelagic larval and egg stages may drift, or in relation to the distances that adult individuals may migrate.

2 DESCRIPTIONS OF THE FISH HABITATS

2.1 Habitat preferences of fish

Fish of different species show a wide variety in life history patterns and habitat requirements. By broad categorization, fish are defined as either feeding in the open water column (pelagic) or bottom-feeding (demersal). The earliest life stages, such as eggs and larvae, may be defined similarly, according to where they are typically found. Demersal species and life stages are better suited for EFH mapping, as these species generally have a stronger relationship to certain habitat types. For the same reason, the habitat preferences of rather stationary species are more easily modelled than those of more mobile species. Habitat choice is to a large extent determined by environmental variables, such as temperature, water depth, bottom substrate, and habitat complexity. A description of typical habitat preferences of some commonly occurring species within pilot area 3, and for different life stages, is presented in table 1.

2.2 Connection between EFHs and Natura 2000 areas

The Natura 2000 network does not encompass protection of fish by its definition. However, EU Member States can, according to the Habitats Directive, regulate fishing in the Natura 2000 sites. The Natura 2000 sites may also, by protecting the habitats important for spawning and feeding of many fish species, provide areas of superior habitat quality compared to marine areas where the habitat is not protected. Thus, the Natura 2000 network may serve to support the productivity of commercial and non-commercial fish stocks. Analysing whether the Natura 2000 network is coherent with regard to fish is therefore an interesting aspect, and an example of how nature conservation and fisheries management objectives may be merged into the concept of ecosystem-based management.

Analyses of ecological coherence of the Natura 2000 network in relation to EHFs can be performed using existing maps of designated Natura 2000 sites, and maps of Natura 2000 habitat types. Maps of Natura 2000 habitat types have been produced within Balance for Pilot area 3 (Stockholm - Åland - Turku), based on physiographic characteristics (Wennberg & Nöjd, 2007). These are intended to identify all areas that potentially agree with any of the definitions of Natura 2000 habitat types (see Annex 1), and not only the ones that are actually designated for protection.

For a preliminary assessment of how well Natura 2000 habitat types may be representative of potential EFHs, the expected association of different fish species with defined Natura 2000 habitat types was estimated. The evaluation was based on the information described in table 1 for spawning and nursery areas and the applied definitions of Natura 2000 habitat types (annex 1), and is presented in table 2. Adult feeding areas were not included, as adult fish are commonly quite mobile and are generally not as closely linked to certain habitat types as spawning areas and juvenile feeding areas may be.

Table 1. Habitat preferences of selected fish species in Pilot area 3. Data compiled from various sources, mainly Fishbase, Koli (1999) and Ojaveer et al 2003).

Species	Spawning area	Nursery area	Adult feeding area

Perch - *Perca fluviatilis*	Sheltered bays, fresh water outlets, vegeta-tion	Shallow vegetated bays	Demersal, warm-water
Pike - *Esox lucius*	Sheltered bays, fresh water outlets, vegeta-tion	Shallow vegetated bays	Demersal, warm-water, shallow areas, habitat complexity
Pikeperch - *Sander lucioperca*	Sheltered bays, fresh water outlets, high-turbidity, vegetation, stones	High-turbidity bays	Demersal, warm water
Grayling – *Thymallus thymallus*	Fresh water outlets, turbulent, gravel	Pelagic, near river mouths	Demersal, cold water
Salmon - *Salmo salar*	Rivers, on gravel	Rivers and river mouths	Pelagic, cold water
Roach – *Rutilus rutilus*	Sheltered bays, fresh water outlets	Shallow vegetated bays	Demersal, warm water
Turbot – *Psetta maxima*	10-15 m depth in Baltic Sea, 6-7 psu	Shallow areas, sand, stone, mud	Demersal warm-cold intermediate, sand, stone, mud
Whitefish (river-spawning) - *Coregonus lavaretus*	Rivers, on gravel	Rivers and river mouths	Demersal, cold-water
Whitefish (sea-spawning) - *Coregonus lavaretus*	Shallow sandy and gravelly substrates	Demersal	Demersal, cold-water
Sprat - *Sprattus sprattus*	Coastal slopes, 20-100m depth	Pelagic	Pelagic, cold water
Flounder - *Platichthys flesus*	Pelagic deeper areas in SW Baltic, shallow ar-eas in N Baltic	Shallow coastal waters	Demersal warm-cold intermediate
Herring - *Clupea harengus*	Vegetation, stones, gravel, good water cir-culation, 2-10 m depth close to deeper waters, temp (2)5-13(16) deg	Pelagic, close to ther-mocline	Pelagic, cold-water , below thermocline, 2-6 deg
Cod - *Gadus morhua*	Pelagic, sal over 10, oxygen above 2,3 ml/L, preferred temp 3-6 deg.	Demersal, cold-water, habitat complexity	Demersal, cold-water
Eel-pout - *Zoarces viviparus*	Vegetation	Vegetation	Demersal, cold water, vegetation
Eel - *Anguilla anguilla*	Sargasso Sea	Estuaries fresh water	Demersal, cold water
Trout - *Salmo trutta*	Sand and gravel in rivers	Rivers	Coastal-Pelagic, cold water

However, the estimates should be viewed with caution and be replaced by empirical data when new information is produced. One potential source of error is that the ecological preferences of some of the species may not be known well enough. Also, at different geographical sites, the same assigned habitat type may vary in qualitative aspects that affect the expected abundance of fish, such as temperature or nutrient status. The approach enables a first attempt to compare EFHs and Natura 2000 habitats, and could give a broad indication on the current state of protection for fish based on present knowledge.

Explicit analyses of connectivity and other aspects of ecological coherence (for example representativity) may be performed based on those fish species and life stages for which maps of potential EFH are currently available (see section 3).

Table 2. Natura 2000 habitat types in Pilot area 3 with examples on how they may correspondence to essential spawning and nursery areas for fish identified in table 1. For definition of the habitat types, see appendix 1.

Habitat type	Example of fish spawning area	Example of fish nursery area
Sublittoral sand banks (1110)	Sea-spawning whitefish	Flounder, turbot
Estuaries (1130)	River-spawning white-fish, grayling	Whitefish, grayling, salmon, trout
Coastal lagoons (1150)	Perch, roach, sander, pike	Perch, roach, sander, pike
Large shallow inlets and bays (1160)	Perch, roach, sander, pike	Perch, roach, sander, pike
Reefs (1170)	Eel-pout, herring	Cod, whitefish
Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation (1629)	Herring, whitefish	Herring, whitefish, flounder, perch
Boreal Baltic islets and small islands (1620)	Herring, sea-spawning whitefish	Cod, whitefish, turbot
Other habitat	Eel, sprat, cod, turbot, flounder, salmon, trout	Sprat, eel

2.3 Fish habitat maps

2.3.1 Currently available maps

The distribution of potential essential fish habitats in an area may be initially deduced by comparing the habitat requirements of different species with maps showing the distribution of different habitat types. In table 2, this exemplified for Natura 2000 habitat types, as maps of these are available within Pilot area 3 (Wennberg & Nöjd, 2007). However, such estimates are combined with considerable uncertainty for the reasons explained in section 2.2. If sufficient information on species-habitat relationships and on habitat distribution is available, more detailed maps of potential EFHs can be produced. Indeed, such maps can be produced directly from fish inventories, but as the collection of true field data is laborious and temporally dependent, a more efficient approach is to use GIS modelling. In the models, empirical information on species-habitat relationships are used for producing statistical explanation models, which are then used for making spatial predictions over the areas of interest. For pilot area 3, maps based on empirical fish habitat models have been produced within Balance (Bergström et al. 2007), and are available to describe essential recruitment areas of a number of the most important coastal fish species (Table 3, Appendix 2).

Table 3. Available maps of fish habitats in Balance Pilot Area 3 (Bergström et al. 2007)

Species	Habitat type
Perch	Spawning area
Perch	Nursery area
Pike	Nursery area
Sander	Nursery area
Roach	Nursery area

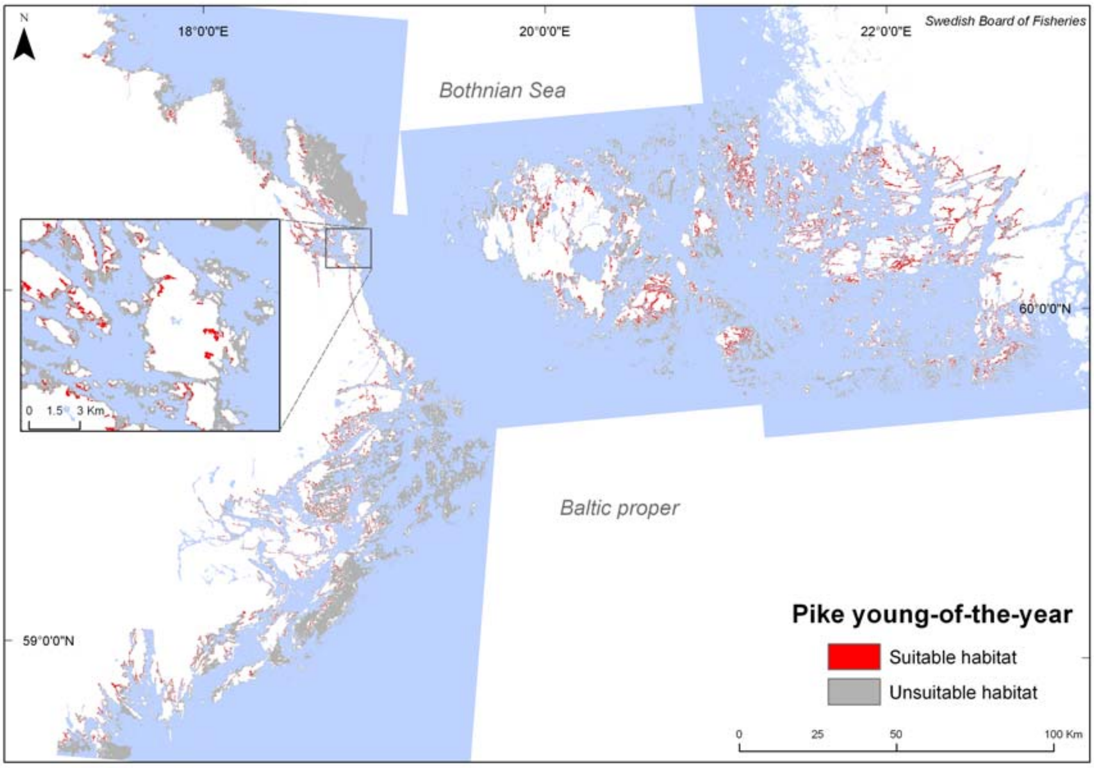

Figure 1. Example of EFH map in pilot area 3 (potential pike nursery areas).

2.3.2 Potential additional maps

For this report, an additional effort was made to refine the current view on potential spawning areas of Baltic herring in the area. Herring is a cold-water adapted pelagic species with habitat requirements quite different from those of the demersal warm-water species previously mapped within the area. Being pelagic, herring is not strongly associated with habitat features in the adult life stage, while its spawning on littoral areas depends highly on specific habitat requirements and on local habitat quality. However, the extent of spawning at each of the potential spawning sites is often strongly variable in reality. This is because variations in climatologic or other factors may determine which specific site, out of a larger set of potential sites within an area, the herring actually uses for spawning a certain year A more detailed description of the habitat requirements of herring is included in chapter 6.

Potential herring spawning grounds were identified using information on sites used for commercial trapnet fishing (Hurtta 1984). Trapnets are used specifically for herring fishery in littoral areas < about 10 m depth, in areas where herring gather before spawning or at the actual spawning areas (Ojaveer et al 2003). In the context of mapping herring habitats, the trapnet fishing sites are used to indicate sites that are often frequented by spawning herring and known to fishermen. Before analyses of ecological coherence, the level of information should preferably be further improved by spatial modelling, using environmental variables at the trap net sites as reference input data. Also, information from other data sources of potential value should be added. Potential additional data sources include information from local fishermen and field inventories of herring spawning sites in the involved countries. The trapnet sites may serve as a basis for a preliminary assessment of the Finnish Archipelago Sea (Figure 2. However, for a complete coherence analysis the concept remains to be further developed.

Figure 2. Trap net fishing site at the Finnish coast as an indicator of herring spawning sites.

3 PATTERNS OF FISH DISPERSAL

3.1 General migration patterns of fish

Fish species may disperse by both passive and active movements. Pelagic life stages, particularly larvae, commonly use water flows for passive transport to other areas (e.g. Roberts 1997, Hinrichsen et al. 2003), and adult fish may also ease their swimming ef-

fort by utilising water flows (Aro 1989). More specific migrations are made by actively swimming post-larvae and adult fish, but a certain extent of active retention of larvae to nursery grounds has also been shown (e.g. Urho 1999, Cowen et al. 2000).
A large part of the fish migration patterns observed may be explained by changes in water temperature, so that fish actively seek areas with temperature conditions suitable for growth and development. Typically, some species and life stages are physiologically adapted to cold waters, whereas others prefer warmer waters. Additionally, during reproduction periods migrations towards areas suitable for spawning are of high significance. Many species show a homing behavior, so that they return to spawn at the same sites where they had hatched. Highly suitable spawning areas will be utilised by individuals from a larger surrounding area than poorer spawning areas. Between spawning periods, specific migrations are mainly motivated by search for food and shelter.

Data on the spatial structure and dispersal of fish populations is commonly collected by tagging experiments. These are commonly applied as mark-recapture experiments, where the fish is first tagged at one location and then caught by fishing, at another location. Tagging studies are increasingly conducted using acoustic tags and tags with data loggers. Acoustic tags emit sound signals, which can be continuously monitored from the surface by fixed or hand-held hydrophones. Tags that log data on, for example pressure, temperature and salinity, can be used to back-calculate approximate migration routes. Tagging experiments are useful for detecting true patterns of migration in a study area. The obtained data will show how far fish can potentially migrate and to some extent it will also indicate the preferred destination of migration. However, the data must be combined with other types of information in order to show if population exchange actually takes place. For example, population exchange is likely if individuals from different feeding areas gather at a spawning area during spawning, but is less likely if individuals from many spawning areas gather at a feeding area. Increasingly, population genetic studies are used as an ultimate means for identifying biological populations and estimating effective population sizes within management areas.

For an overall picture of the characteristic migration distance of a species, both adult and larval stages should be included. Many fish species have a pelagic larval phase, which may be the most important means of long-distance migrations. Obtaining data on larval stage motility is more complicated than for adults. The potentially most useful methods include population genetics, otholit chemistry and biological oceanographic modeling. For these methods, however, further research and development is needed for reliable use within management.

3.2 Estimates of dispersal in Pilot Area 3

Observed distances of dispersal for some commonly occurring species in Pilot area 3 (Stockholm - Åland - Turku) are provided in Table 4. For some species there is no experimental data available and therefore the approximated distances of dispersal have been derived based on their general ecological characteristics. In order to enable relative comparison among all species, this information is provided separately. The approximations applied are based on a global review by Palumbi (2004) on the mobility of different fish species and their responsiveness to protection. According to Palumbi, adult fish may be grouped into five generalized type categories:

- Large pelagic species, which have a home range size > 200 km (Cat. V)
- Smaller pelagic fish, which range about 50-200 km (Cat. IV)
- Larger bottom-dwelling fish, range < 100 km (Cat. III)
- Reef associated species, range about 10 km (Cat. II)
- Highly stationary, range about 1 km (Cat. I)

The indicated distances refer to adult individuals, and juvenile fish are in general more sedentary. Even for pelagic larvae, results from microchemistry and genetics have suggested more restricted dispersal patterns than previously thought, so that larval dispersal profiles tend to cluster in the range of 10 to 100 km (Palumbi 2004).

In practical applications, a distinction should be made between the maximum migration distance observed for a species, and its typical migration distance. Whereas the maximum dispersal distance may be of significance for patterns of genetic structuring, the typical migration distance may better reflect the scale at which population dynamics occur.

Table 4. Mobility estimates for some common Baltic fish species. Migration distances are obtained from tagging experiments on adult fish (Saulamo & Neuman 2002). Generalized mobility type estimated according to Palumbi (2004).			
Species	Typical adult migration distance	Maximum adult migration distance	Generalized mobility type
Perch - *Perca fluviatilis*	10km	no data	III-V
Pike - *Esox lucius*	3km	50km	I
Pikeperch - *Sander lucioperca*	10km	300km	II
Grayling – *Thymallus thymallus*	no data	no data	
Salmon - *Salmo salar*	100-1000 km	no data	V
Roach – *Rutilus rutilus*	no data	no data	II
Turbot – *Psetta maxima*	10km	no data	III
Whitefish (river-spawning) - *Coregonus lavaretus*	70-100km	700km	V
Whitefish (sea-spawning) - *Coregonus lavaretus*	20-40km	200km	III
Sprat - *Sprattus sprattus*	no data	no data	IV
Flounder - *Platichthys flesus*	"short"	no data	III
Herring - *Clupea harengus*	150km	no data	IV
Cod - *Gadus morhua*	100-800km	1000km	III-V
Eel-pout - *Zoarces viviparus*	no data	no data	I
Eel - *Anguilla anguilla*	>5000 km	>5000 km	V
Trout - *Salmo trutta*	100km	no data	V

4 CONNECTIVITY AND REPRESENTATIVITY OF THE FINNISH NATURA 2000 NETWORK IN RELATION TO BREEDING AND FEEDING AREAS OF BALTIC HERRING

4.1 Introduction

In this chapter, the spatial distribution and migration patterns of Baltic herring (Clupea harengus membras L.) in Finnish coastal areas are reviewed, and an assessment is made on whether the existing Finnish Natura 2000 sites cover herring spawning grounds. Herring is a suitable model species for connectivity assessment of essential fish habitats, as it uses different habitat types for spawning, nursery grounds and adult feeding grounds during its life history.

In Finland, the Natura 2000 sites are very seldom used for fish protection. However, it is conceived that the protection of the habitats, for biodiversity reasons, may also have a positive effect also on the fish populations The transition of the Natura 2000 areas to Finland's legislation, primarily either by the Environmental Protection Act or the Water Act, has started slowly. Natura 2000 areas will potentially benefit herring populations through providing good-quality environments for spawning and feeding.

4.2 Herring spawning areas

Herring spawns from the Bothnian Bay to the eastern Gulf of Finland, along the whole Finnish coastline. The spawning grounds are situated mostly in the inner archipelago and in well-oxygenated waters (Kääriä et al. 1988, Rajasilta et al. 1993, Kääriä et al. 1997). Herring spawns on hard bottom vegetation, on at least 32 different plant species (Aneer 1989). Eggs are attached on the vegetation after visual inspection and after sensing the substratum by the fins (Kääriä 1999 and references therein). The spawning grounds typically reach down to about 8 m depth, depending on water quality, and are often close to deep water areas (Kääriä et al. 1988, Rajasilta et al. 1993, Kääriä et al. 1997). Soft bottom substrates are generally not used for spawning (Rajasilta et al. 1989, Kääriä et al. 1997). The spawning beds can be some square meters or tens of meters wide (Kääriä 1999).

Studies on the biological and physical characteristics of herring spawning grounds in the Archipelago Sea indicate that the environmental requirements on the spawning grounds are very strict, and that only part of all potential spawning sites are actually used for spawning (Rajasilta & Kääriä 1986, Kääriä et al. 1988, Rajasilta et al. 1993, Kääriä et al. 1997). Sites similar in terms of wave exposure, bottom profile, bottom quality, vegetation cover, species composition and quality of water were not used for spawning to the same extent, indicating that additional, unknown factors, also affect the selection of spawning grounds.

As herring returns to the same spawning grounds year after year (Oulasvirta & Lehtonen 1988), losing a site that is critical for spawning may have a long-term effect on herring population size. Habitat degradation due to eutrophication has reduced the amount of suitable spawning areas in inner bays (Kääriä et al. 1988), but some have been restored during the last years (Niinimäki et al. 2004). In the Gulf of Finland, spawning in the outer archipelago off Helsinki has declined in recent years, whereas the opposite has happened in the inner areas (Niinimäki et al. 2004). This is probably linked to improvement in water quality in inner archipelago, whereas the water quality further out has remained poor.

Early in the spring, spawning occurs first in inner bays and later in outer areas (Sjöblom 1961). In the Archipelago Sea and Bothnian Sea, spawning peaks from May to June, but also occurs as late as in August (Rajasilta et al. 1986, Parmanne 1993). In the Bothnian Bay, spawning occurs a bit later, in June and July (Kronholm et al. 2005). Although autumn-spawning has been insignificant or low in Finnish coastal waters (Hellevaara 1912), the proportion of autumn-spawners has increased in western Bothnian Sea in recent years (Bergström et al. 2006).

Some days or a week prior to spawning, large herring shoals swim to the spawning grounds close to the shore (Kääriä 1999 and references therein). The shoals come in successive waves to the same areas (Hahtonen & Joensuu 1984). Herring may "double-spawn" by laying another layer of eggs over previous one (Aneer et al 1983). In the Åland archipelago, genetic differentiation has been observed between successive spawning groups (Jørgensen et al. 2005).

4.3 Nursery areas

When hatching, herring larvae are 7-9 mm long (Arrhenius & Hansson 1996). Young larvae have been observed to migrate or drift to the littoral zone (Urho & Hildén 1990), possibly to benefit from higher temperature and food concentrations (Kääriä 1999, Parmanne 2001). Larvae drift or swim also to bays outside spawning grounds (Urho & Hildén 1990). They are often found near river mouths, at the vicinity of fresh water, which may be significant for juvenile herring (Kääriä & Sorakunnas 1999). Retention of larvae to littoral areas may last several months or up to one year (Kääriä 1999). The littoral area is important nursery area for larval stage of the Baltic herring (Urho & Hildén 1990).

Larvae are more abundant in inner archipelagos and bays than in outer archipelago or open sea areas throughout the Finnish coastline (Parmanne 2001). Later in the summer, when sea water warms up, larvae become abundant also in the outer parts of the archipelago (Parmanne 2001). Considering the whole Finnish coastline, the abundance of herring larvae is densest in the Archipelago Sea (Taivassalo-Kustavi area), about 7.8 ind. m^{-2}, while lowest densities are found from the Bothnian Bay (Kalajoki), about. 0.1 ind. m^{-2} (Parmanne 2001). The highest densities in the Archipelago Sea are similar to those near the Rügen island in the southern Baltic Sea (Biester & Brielmann 1977). The mean density of larvae (0.33 ind. m^{-2}) at the Finnish coastline (Parmanne 2001) is similar to that at the Estonian coast of the Gulf of Finland (Raid 1985). In the Archipelago Sea, the bays of Mynälahti and Paimionlahti are important larval feeding and nursery areas (Rajasilta et al. 1999). In the western Gulf of Finland, deep slopes in the inner Inkoo archipelago support almost as high larval densities as in the Archipelago Sea (Parmanne 2001). In the eastern part of the Gulf, Pernajanlahti bay and Pernaja archipelago supported larvae, in average, 1.2 ind. m-2 (Parmanne 2001). In the Bothnian Sea, high larval densities are found off the coast between Pori and Merikarvia (Parmanne 2001). In the Quark, larval densities are low and difference between pelagic and coastal densities was not found significant (Parmanne 2001). During the littoral phase, herring larvae comprise a significant proportion of all fish in littoral waters (Kääriä & Sorakunnas 1999).

The larvae stay in littoral, shallow areas until they reach a length of about 30 mm. At the end of August the juveniles migrate from the coastal nursery areas to nearby off-shore areas (e.g. Aneer 1979, Rudstam et al. 1988, Urho & Hildén 1990, Costa et al. 2002).

4.4 Adult feeding grounds and migration patterns

Herring migration patterns in the Baltic Sea have similar features as in oceans (Hourston 1982, Wheeler & Winters 1984, Aro 1989, Parmanne 1990). Generally, herring migrate during summer from the coast to the pelagic zone onto slopes of deep water areas (Ojaveer 1981). In the autumn, herring have dispersed over large feeding areas, whereas, in the winter, wintering shoals are formed and, in the spring, the pre-spawning and spawning shoals migrate back to spawning areas (Parmanne 1990).

4.4.1 Herring migrations

According to tagging studies (Parmanne 1990), old (>2 years) herring migrate farther from the spawning grounds and younger individuals remain in the nearby pelagic areas. In the Gulf of Bothnia, i.e. the Bothnian Sea and Bothnian Bay, herring migrate mostly within the Gulf, though some individuals have been found from the southern Baltic Sea (Bergström et al. 2006). Within the Bothnian Sea, herring migrate from coast to coast (Parmanne 1990, Bergström et al. 2006). On the Swedish side of the Gulf, bottom topography is more uneven and adult herring concentrate there to feed on the slopes (Parmanne 1993). In the spring, many of those herring return to the eastern coast to spawn (Parmanne 1993). In the Gulf of Finland, the old herring migrate to the northern and southern Baltic Proper, while young individuals stay in the Gulf (Aro 1989, Parmanne 1990). In the Baltic Proper, different herring stocks mix and the food conditions set the feeding grounds of the fish, so that a shortage of food drives the shoals southward (Parmanne 1990 and references therein). The fast-growing “sea herring” may even migrate to Bay of Gdansk and the Bornholm Sea (Parmanne 1990, R. Parmanne, pers. comm.). The herring stock in northern part of the Archipelago Sea migrates partly to the Bothnian Sea and the one in the southern part migrates southward to the Baltic Proper (Kääriä et al. 1999, J. Kääriä, pers. comm., R. Parmanne, pers. comm.).

The mixing of the stocks in the Baltic Proper leads sometimes to enhanced gene flow among the spawning stocks as individuals from one area spawn with another stock (Parmanne et al. 1994). The Baltic herring can be divided to three genetically separated stocks: western, southern and northern stocks (Jørgensen et al. 2005).

4.4.2 Homing behaviour

Observations from herring tagging studies indicate that herring return to same areas where they have spawned (Parmanne 1990, Kääriä et al. 1999, Bergström et al. 2006). Herring have homing behaviour in the Atlantic Ocean and the Baltic Sea; return to the spawning areas is, however, not very precise (Hourston 1982, Wheeler & Winters 1984, Aro 1989, Parmanne 1990). Tagging experiments from Archipelago Sea gave evidence that herring return to the large archipelago area, but not necessarily to specific sites (Kääriä 1999). Recovery distances varied from 7 to 140 kms. In the Bothnian Sea, herring spawning in the Öregrund coast returned to the same spawning grounds after migrations to the east, north and south within the Bothnian Sea (Bergström et al. 2006). Similar results have been found in other studies in the Baltic Sea as well (e.g. Parmanne 1990, Kääriä 1999 and references therein). In the Atlantic, herring return to spawning grounds varying from 40 to 100 km from the tagging area and the homing rate has been estimated to 90 % (Wheeler & Winters 1984).

Retention to littoral areas may cause the imprinting to the spawning area around the spawning site (Kääriä 1999). Another explanation to homing behaviour is adaptation to certain salinity level (Griffin et al. 1998, Kääriä 1999).

4.5 Blue corridors of Baltic herring

Connectivity through passive transport is commonly enhanced between areas connected by unidirectional water flow, but also adult fish may ease their swimming effort by the use of concurrent water flows (Aro 1989). Such routes, or linkages, between populations that are of particular importance for the maintenance of a species have been referred to as “blue corridors” (Martin et al. 2006).

The general pattern in water flows of the Baltic Sea comes from the Coriolis Effect and Ekman dynamics (Myrberg & Andrejev 2006). The outcome is an anti-clockwise cyclonic circulation along the Baltic coastlines. Myrberg and Andrejev (2006) and Myrberg et al. (2006) have described the general water flow characteristics in the northern Baltic Sea. In Finland, the circulation comes from the Gulf of Finland, through Archipelago Sea and along the coast of Gulf of Bothnia. The persistency of this circulation is about 20-60% and depends on wind direction (Myrberg et al. 2006). Opposite wind direction, blowing from the North-East, turns the water flows to south and east, though mainly in the surface layer. In the deeper water, wind direction has lesser significance. In the Gulf of Bothnia, two within-gulf anti-clockwise circulations exist, one in the Bothnian Sea and the other in the Bothnian Bay. South of Åland, southward water flows dominate. The fastest mean water flows in the cyclonic circulation are on the eastern coast of the Bothnian Sea, ca. 5-8 cm s-1 in the surface water layer (Myrberg & Andrejev 2006). In narrow elongate sounds, the water flows can easily reach velocities over 50 cm s-1 (Myrberg et al. 2006).

In the Bothnian Sea and the northern Archipelago Sea, adult herring migrate mainly northward (Aro 1989, Bergström et al. 2006), which may indicate the use of water flows in the migration. The herring stock in the southern Archipelago Sea has clear southward migration after two years of staying in the Archipelago Sea area (Parmanne 1990, Parmanne 2001). There is, however, no indication whether the shoals use specific inlets to enter or exit the sea area. To date, there is no direct evidence, if adult herring use water flows in their migrations. However, spawning migrations of sea trout seem to follow the Baltic cyclonic circulation; the northward migration follows the eastern coast, while the southward migration follows the western coast (Aro 1989).

Blue corridors have usually been associated with larval transport (e.g. Roberts 1997, Nielsen et al. 1998, Hinrichsen et al. 2003). Even though larval retention or drifting seem to be more active choice than previously thought (Lazzari et al. 1993, Urho 1999, Cowen et al. 2000, Smith et al. 2001, Hindell et al. 2003), water flows may affect herring larval distribution (Lazarri & Stevensson 1992). In the case of Baltic herring, the movement of young-of-the-year larvae to nursery grounds in inner bays and, at later stage, to pelagic to juvenile feeding grounds may be due to either water flows transporting larvae or active swimming (Raid 1985, Urho & Hildén 1990, Parmanne 2001). Parmanne et al. (1997) speculate that fronts, currents and upwellings are significant to larvae and juvenile herring. Observations of larvae moving out from vegetation to open water at night (Romare & Bergman 1999), retention to estuaries (Urho 1999) or migrations from the littoral to the pelagic zone at a given stage in the metamorphosis (Urho & Hildén 1990), as well as differences in the number of migrating larvae depending on moon phase (Gaudreau & Boisclair 2000), indicate that migration may to large part be active, making use of existing water flows in the transport.

4.6 Geographical localisation of herring EFHs

The geographical locations of herring spawning grounds were identified from a literature survey and from sites used for trapnet fishery (Hurtta 1984, Anonymous 2007 a). Trapnets are used specifically for herring fishery in littoral (<10m) areas, when spawning shoals come to the spawning grounds (Ojaveer et al 2003). Thus, the trapnet fishing sites indicate sites that are frequented by spawning herring at a regular basis and known to fishermen. The literature studies included scientific studies, reports from different coastal areas, reports from environmental impact assessments and expert judgements. The amount of spawning grounds located by the method is surely an underestimation of the reality, but may serve as a rough indicator of the situation. In addition, known herring spawning sites may be further added to the analysis (Anonymous 2007 b).

4.7 Comparison between herring and Natura 2000 sites

The distribution of Natura 2000 sites is relatively continuous along the Finnish coastline (Table 5). There are in total 62 00 km^2 of water areas in the Natura 2000 network in the Finnish territorial waters of the Baltic Sea (Table 5). As there are altogether 52 483 km2 territorial waters in Finland (within 12 nm boundary), the proportion of Natura 2000 sites in Finnish territorial waters is 13%. Many of the Natura 2000 sites cover inner bays and estuaries, which have poor water quality due to high nutrient and sediment loads and are therefore not suitable as spawning habitats. The inner bays have, however, significance to herring as nursery areas for juveniles (Kääriä & Sorakunnas 1999, Parmanne 2001). How much of the Finnish territorial area is really used as spawning grounds by herring remains to be studied. For example, the Archipelago Sea is known to be an important breeding region for herring (Parmanne 2001), but only a few spawning grounds have been found in the area (Kääriä et al. 1988, Rajasilta 1992, Anonumous 2007 b).

4.7.1 Methods for analysis

Identified herring trapnet sites along the Finnish coastline were compared to the Natura 2000 network (Table 5) and the proportion of trapnet sites within Natura 2000 areas was calculated (Table 6). It was considered that all Natura 2000 sites may at least support herring populations because activities that may harm habitat quality are restricted or forbidden, such as dredging and marine construction. Enhanced habitat quality is also likely to stabilize local ecosystems, which may provide support for increased larval survival, growth rate and population density. Already now, enhanced water quality near coastal cities can be seen to results in restored spawning grounds for herring, for example off Helsinki (Niinimäki et al. 2004).

4.7.2 Results

According to this survey, there are big differences among sea areas in how well herring trapnet sites coincide with Natura 2000 sites (Table 6). In the Bothnian Sea and the Bothnian Bay, 40-50% of the trapnet sites and known spawning grounds are situated within Natura 2000 areas. There is a rather continuous chain of elongate Natura sites along the coast of the Gulf of Bothnia, which may explain the result. The Natura 2000 network in the region contains many estuaries, which may serve as nursery grounds for the larvae. Thus, linkages of spawning and nursery grounds among Natura sites are probably relatively well covered in the Gulf of Bothnia.

In the Gulf of Finland, however, Natura 2000 areas cover herring trapnet sites and known spawning grounds relatively discontinuously. Some large Natura sites (e.g. the Pernajanlahti bay) cover many trapnet sites and spawning grounds, while there are long gaps in the Natura 2000 network along the coast. For example, the coast from Kirkkonummi to Porvoo (about 100 km, including cities Espoo, Helsinki and Sipoo) does not have any marine Natura 2000 sites. According to Parmanne and Sjöblom (1988 a b), the sea areas between Tammisaari-Inkoo and Sipoo-Ruotsinpyhtää are the most productive spawning grounds on the northern side of the Gulf of Finland. Both of these areas are relatively well covered by large Natura 2000 sites. Therefore, in the Gulf of Finland, the connectivity of spawning and nursery grounds among Natura sites is estimated to be regionally weak, but locally good within the large Natura sites.

The Archipelago Sea and waters around Åland have the most productive herring spawning grounds in the Finnish coast line (Parmanne 2001). However, according to this survey, the Natura 2000 network covers only 6-11% of the trapnet sites and known spawning grounds in these areas. In Åland, the Natura sites are rather small resulting in an almost random overlap between trapnet sites and spawning grounds and Natura 2000 sites. In the Archipelago Sea, trapnet sites and spawning grounds are in the inner archipelago, while Natura 2000 sites are mostly in the outer archipelago. Thus, Natura sites do not enhance herring populations in the Archipelago Sea and the waters around Åland.
The *nursery grounds* of Baltic herring were not investigated separately in this survey, but according to previous studies (Urho & Hildén 1990, Kääriä & Sorakunnas 1999, Rajasilta et al. 1999, Parmanne 2001), herring larvae use larger areas as nursery grounds than as spawning grounds and these are often situated in inner archipelago, bays and estuaries. Because many Natura 2000 sites are in such areas, the nursery grounds may be covered at least as well as the spawning grounds.

The quality of pelagic areas as *feeding grounds* depends on the abundance of large zooplankton, which is linked to the salinity patterns of the Baltic Sea (Flinkman et al. 1998). The adult feeding grounds are pelagic and even less overlapping with Natura 2000 sites than the ones nearer the coastline. The young herring (<2 years) stay closer to the coastal areas and may, thus, benefit of the sites covering coastal waters. Large MPAs, such as Natura 2000 sites in national parks (the Bothnian Bay, Archipelago Sea, Ekenäs and Eastern Gulf of Finland), the Quarck, and archipelagos of Seksmiilari, Uusikaupunki, Kirkkonummi, Söderskär-Långören, and Pernaja, cover large pelagic areas, but not far enough from the coast to cover true pelagic feeding grounds. The need for MPAs in EEZ areas (>12nm from coast line) is evident.

In all other sea areas than Archipelago Sea, Natura 2000 sites are mostly SCI sites (under the Habitats Directive), while SPA sites (under Birds Directive) are in minority. Furthermore, almost none of the herring trapnet sites and known spawning sites are within the SPA sites. The SCI sites protect the benthic environment better than SPA sites. In the archipelago areas, littoral-pelagic coupling is an important feature enhancing food webs and productivity. These areas are predicted to support higher densities of larvae, juveniles and adults.

4.7.3 Conclusions

The representation of potential herring *spawning grounds* within Natura 2000 sites depends on the region studied. In the Gulf of Bothnia the coverage is good, in the Gulf of Finland it is very discontinuous, and in the Archipelago Sea and around Åland, it is poor. The *nursery grounds* are expected to be at least as well/poorly covered as the spawning grounds. Despite some pelagic areas within Natura 2000 sites, the *adult feeding grounds* are not covered by the current Natura 2000 network. The results indicate that connectivity should be ensured particularly between spawning and nursery grounds, because the Natura 2000 network may best protect the young, non-fished, life stages. The current Natura 2000 network probably already supports these linkages to some extent, though regional differences are high. By guaranteeing connectivity between spawning grounds and nursery grounds, one may expect to enhance also later life stages. Furthermore, one must separately consider the habitat quality of each site, which is known to affect herring spawning grounds.

The current placing of Natura 2000 sites are mainly covering shallow water areas around islands, in estuaries or along the coastline, while true pelagic MPAs are a rarity. To ensure viable fish stocks in future, MPAs and no-take areas should be established in both coastal and pelagic areas.

Table 5. Designated Natura 2000 sites (both SCI and SPA) in the Finnish Baltic Sea coast.

Area	Natura 2000 sites (km^2 marine area)
Bothnian Bay	740
Bothnian Sea	2340
Archipelago Sea	640
Gulf of Finland	2490
Total	6210

Table 6. Estimated number of spawning grounds of Baltic herring in Finland based on the localisation of trapnet fishing sites (Chapter 6.5). Column 1 shows the total number of sites, and column 2 shows the number of sites that are located within Natura 2000 sites. The data is based on trapnet locations and literature survey. The Natura 2000 sites are, with two exceptions, SCI sites under the Habitat Directive.

Area	Estimated spawning grounds in coastal areas (number)	Estimated spawning grounds within Natura 2000 areas (number)	Proportion (%)
Archipelago Sea	526	31	5.9
Åland	19	2	10.5
Bothnian Sea	868	361	41.6

Bothnian Bay	215	103	47.9
Gulf of Finland	423		31.9
Total	2051	632	30.8

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APPENDIX 1: APPLIED DEFINITIONS OF NATURA 2000 HABITAT TYPES

BALANCE reference: Wennberg & Nöjd (2007)

Sublittoral sandbanks (1110)
Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than on the underlying hard substrata.

Additional description/definition in Sweden: Maximum depth 30 meters.

Estuaries (1130)
Downstream part of a river valley, subject to the tide and extending from the limit of brackish waters. River estuaries are coastal inlets where, unlike 'large shallow bays' there is generally a substantial freshwater influence. The mixing of freshwater and sea water and the reduced current flows in the shelter of the estuary lead to deposition of fine sediments, often forming extensive intertidal sand and mud flats. Where the tidal currents are faster than flood tides, most sediment deposits to form a delta at the mouth of the estuary.

Baltic river mouths, considered as an estuary subtype, have brackish water and no tide, with large wetland vegetation (helophytic) and luxurious aquatic vegetation in shallow water areas.

Additional description/definition in Sweden: Mean sea level outlines the estuary towards land. The annual average stream flow into the estuary is > 2 m3/s.

Coastal lagoons (1150)
Lagoons are expanses of shallow coastal salt water, of varying salinity and water volume, wholly or partially separated from the sea by sand banks or shingle, or, less frequently, by rocks. Salinity may vary from brackish water to hypersalinity depending on rainfall, evaporation, and through the addition of fresh sea water from storms, temporary flooding of the sea in winter or tidal change. Flads and gloes, considered a Baltic variety, are small, usually shallow, more or less delimited water bodies still connected to the sea or have been cut off from the sea very recently by land upheaval. Characterised by well-developed reedbeds and luxuriant submerged vegetation and having several morphological and botanical development stages in the process whereby sea becomes land.

Additional description/definition in Sweden: Lagoons are usually less than 4 meters depth and have limited water exchange with the sea. They do not have major freshwater influx from rivers or streams. They are usually smaller than 25 ha and are both smaller and more shallow than 1160. Rockpools are not lagoons.

Large shallow inlets and bays (1160)
Large indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited. These shallow indentations are usually sheltered from wave action and contain a great diversity of sediments and substrates with a well developed zonation of bentic communities. These communities have generally a high biodiversity. The limit of shallow water are sometimes defined by the distribution of Zosteretea and Potametea associations.

Additional description/definition in Sweden: The limit of shallow water is defined by the depth distribution of macroalge. They are usually larger than 25 ha.

Reefs 1170
Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.

Clarifications:

“Hard compact substrata” are: rocks (including soft rock, e.g. chalk), boulders and cobbles (generally >64 mm in diameter).

“Biogenic concretions” are defined as: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species.

“Geogenic origin” means: reefs formed by non biogenic substrata.

“Arise from the sea floor" means: the reef is topographically distinct from the surrounding seafloor.

“Sublittoral and littoral zone” means: the reefs may extend from the sublittoral uninterrupted into the intertidal (littoral) zone or may only occur in the sublittoral zone, including deep water areas such as the bathyal.

Where an uninterrupted zonation of sublittoral and littoral communities exist, the integrity of the ecological unit should be respected in the selection of sites. A variety of subtidal topographic features are included in this habitat complex such as: Hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields.

Additional description/definition in Sweden: Mussel beds are included if the coverage of mussels are more than 5-10 %. The reef is delimited from the surrounding seafloor when soft bottoms cover more than 50 % or when the biogenic concretions cover less than 5- 10 %. Mean sea level outlines the reef towards land.

Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation (1610)
Glaciofluvial islands consisting mainly of relatively well sorted sand, gravel or less commonly of till. May also have scattered stones and boulders. The vegetation of esker islands is influenced by the brackish water environment and often by the ongoing land upheaval which causes a succession of different vegetation types. Several rare vegetation types (heaths, sands and gravel shores) and threatened species occur.

Additional description/definition in Sweden: The marine environment in connection to the islands is included in the habitat. Sublittoral sandbanks (1110) or reefs (1170) in connection with the esker islands are included in the esker islands habitat (1610). The esker islands are higher prioritised than Baltic islets and small islands (1620).

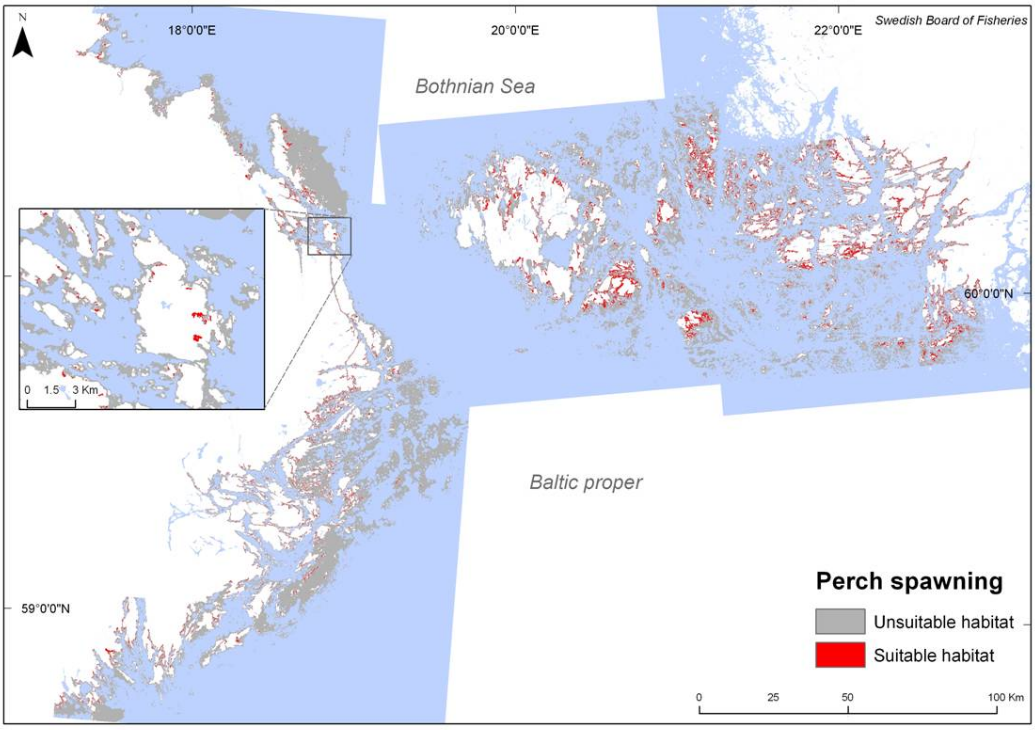
Boreal Baltic islets and small islands (1620)
Groups of skerries, islets or single small islands, mainly in the outer archipelago or offshore areas. Composed of Precambrian, metamorphic bedrock, till or sediment. The vegetation of boreal Baltic islets and small islands is influenced by the brackish water environment, the ongoing land upheaval (in areas with intense land upheaval) and the climatic conditions. The vegetation types are influenced wind, dry weather, salt and many hours of sunlight. Land-upheaval causes a succession of different vegetation types. Bare bedrock is common. A lot of small islands have no trees. The vegetation is usually very sparse and consists often of mosaic-like pioneer vegetation communities. On some islands the species diversity is increased by nitrogenous excrement from birds. Many of the plants are xenophytic and lichens are common. Temporary or permanent rockpools are common and these are inhabited by a variety of aquatic plant and animal species. Boreal Baltic islets and small islands are important nesting sites for birds and resting sites for seals. The surrounding sublittoral vegetation is also included in the type 1620.

Additional description/definition in Sweden: The Baltic islets and small islands (1620) are higher prioritised than reefs (1170).

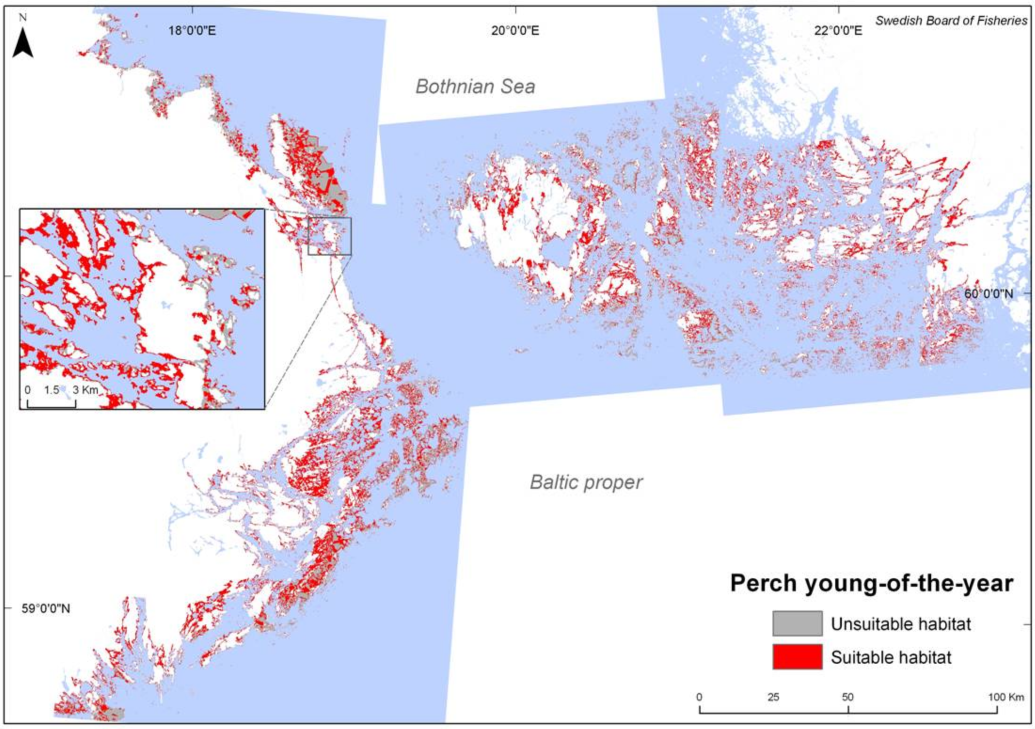
APPENDIX 2: AVAILABLE MAPS OF FISH HABITATS IN BALANCE PILOT AREA 3

BALANCE reference: Bergström et al. (2007)

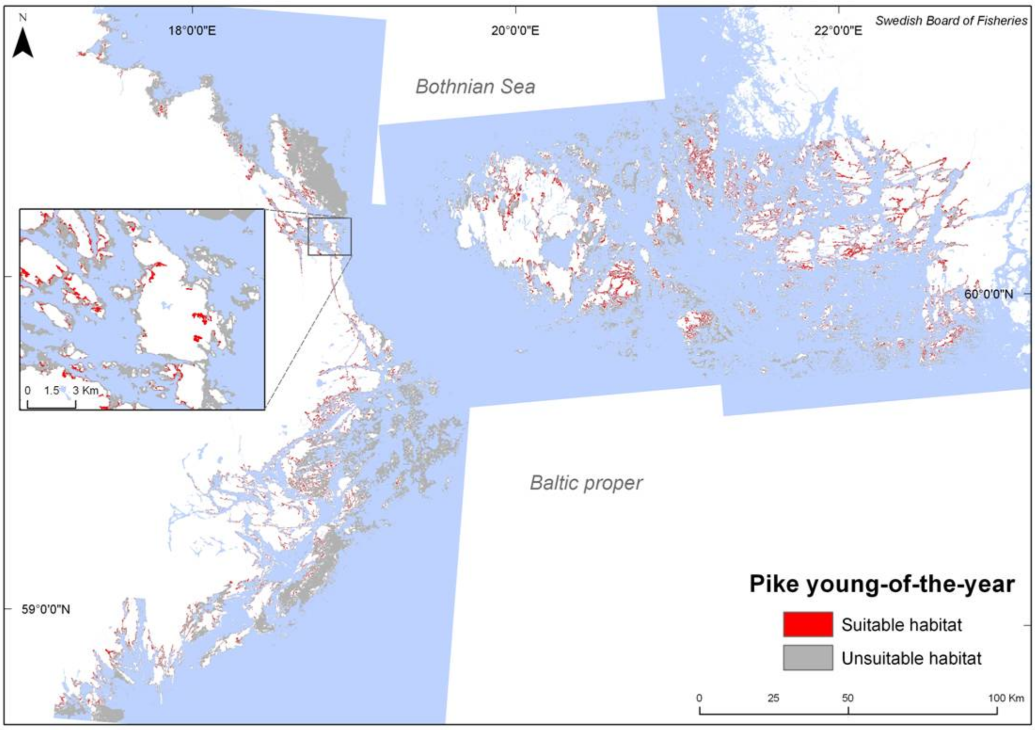
Perch spawning areas



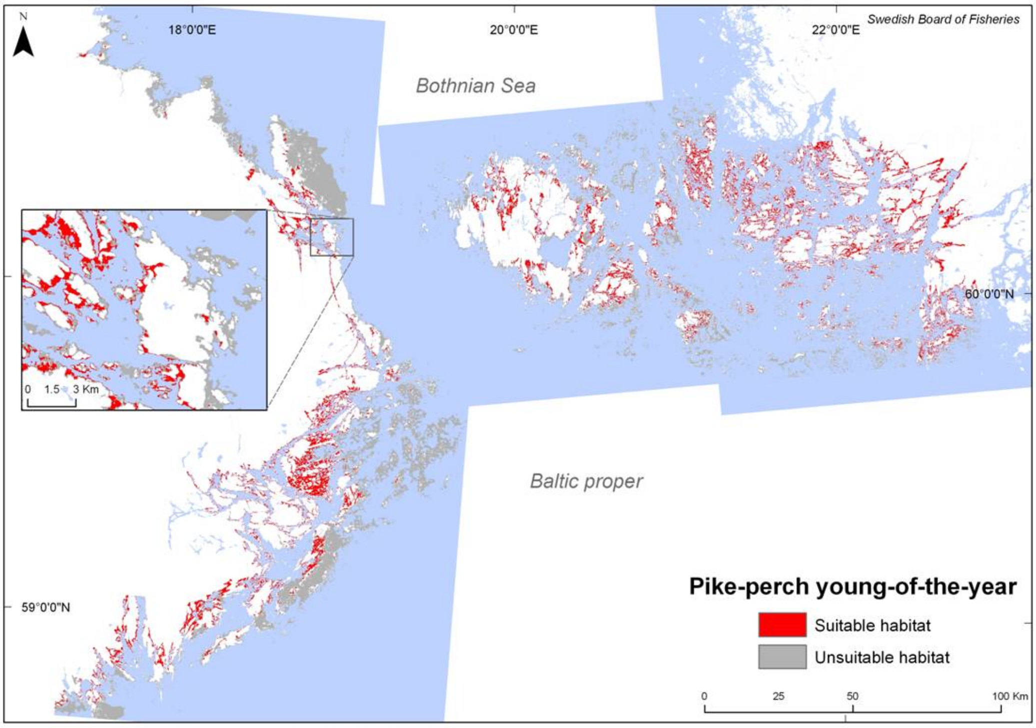
Perch young-of-the year



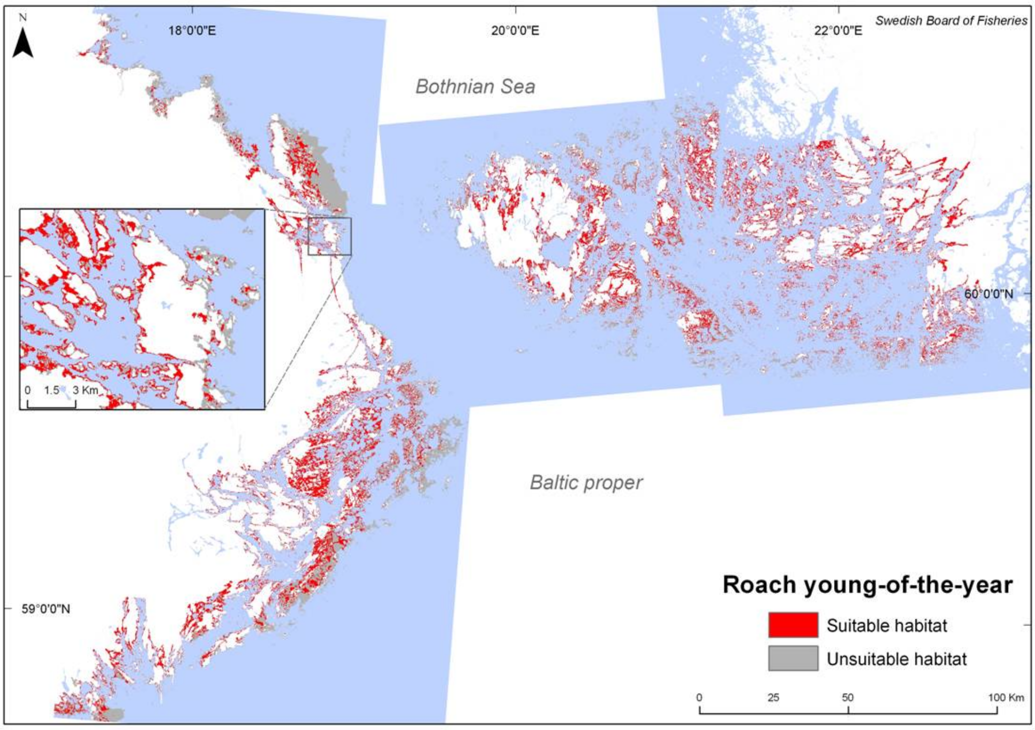
Pike young-of-the year



Pike-perch young-of-the year



Roach young-of-the year



About the BALANCE project:

The BALANCE project aims to provide a transnational marine management template based on zoning, which can assist stakeholders in planning and implementing effective management solutions for sustainable use and protection of our valuable marine landscapes and unique natural heritage. The template will be based on data sharing, mapping of marine landscapes and habitats, development of the blue corridor concept, information on key stakeholder interests and development of a cross-sectoral and transnational Baltic zoning approach. BALANCE thus provides a transnational solution to a transnational problem.

The work is part financed by the European Union through the development fund BSR INTERREG IIIB Neighbourhood Programme and partly by the involved partners. For more information on BALANCE, please see www.balance-eu.org and for the BSR INTERREG Neighbourhood Programme, please see www.bsrinterreg.net

The **BALANCE Report Series** includes:

BALANCE Interim Report No. 1	"Delineation of the BALANCE Pilot Areas"
BALANCE Interim Report No. 2	"Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea – an interim strategy"
BALANCE Interim Report No. 3	"Feasibility of hyperspectral remote sensing for mapping benthic macroalgal cover in turbid coastal waters of the Baltic Sea"
BALANCE Interim Report No. 4	"Literature review of the "Blue Corridors" concept and its applicability to the Baltic Sea"
BALANCE Interim Report No. 5	"Evaluation of remote sensing methods as a tool to characterise shallow marine habitats I"
BALANCE Interim Report No. 6	"BALANCE Cruise Report - The Archipelago Sea"
BALANCE Interim Report No. 7	"BALANCE Cruise Report - The Kattegat"
BALANCE Interim Report No. 8	"BALANCE Stakeholder Communication Guide"
BALANCE Interim Report No. 9	"Model simulations of blue corridors in the Baltic Sea"
BALANCE Interim Report No. 10	"Towards marine landscapes of the Baltic Sea"
BALANCE Interim Report No. 11	"Fish habitat modelling in a Baltic Sea archipelago region"
BALANCE Interim Report No. 12	"Evaluation of remote sensing methods as a tool to characterise shallow marine habitats II"
BALANCE Interim Report No. 13	"Harmonizing marine geological data with the EUNIS habitat classification"
BALANCE Interim Report No. 14	"Intercalibration of sediment data from the Archipelago Sea"
BALANCE Interim Report No. 15	"Biodiversity on boulder reefs in the central Kattegat"
BALANCE Interim Report No. 16	"The stakeholder - nature conservation's best friend or its worst enemy?"
BALANCE Interim Report No. 17	"Baltic Sea oxygen maps"
BALANCE Interim Report No. 18	"A practical guide to Blue Corridors"
BALANCE Interim Report No. 19	"The BALANCE Data Portal"
BALANCE Interim Report No. 20	"The reproductive volume of Baltic Cod – mapping and application"
BALANCE Interim Report No. 21	"Mapping of marine habitats in the Kattegat"
BALANCE Interim Report No. 22	"E-participation as tool in planning processes"
BALANCE Interim Report No. 23	"The modelling *Furcellaria lumbricalis* habitats along the Latvian coast"
BALANCE Interim Report No. 24	"Towards a representative MPA network in the Baltic Sea"
BALANCE Interim Report No. 25	"Towards ecological coherence of the MPA network in the Baltic Sea"
BALANCE Interim Report No. 26	"What's happening to our shores?"
BALANCE Interim Report No. 27	"Mapping and modelling of marine habitats in the Baltic Sea"
BALANCE Interim Report No. 28	"GIS tools for marine planning and management"
BALANCE Interim Report No. 29	"Essential fish habitats and fish migration patterns in the Northern Baltic Sea"
BALANCE Interim Report No. 30	"Mapping of Natura 2000 habitats in Baltic Sea archipelago areas"
BALANCE Interim Report No. 31	"Marine landscapes and benthic habitats in the Archipelago Sea"
BALANCE Interim Report No. 32	"Guidelines for harmonisation of marine data"
BALANCE Interim Report No. 33	"The BALANCE Conference"

In addition, the above activities are summarized in four technical summary reports on the following themes 1) Data availability and harmonisation, 2) Marine landscape and habitat mapping, 3) Ecological coherence and principles for MPA selection and design, and 4) Tools and a template for marine spatial planning. The BALANCE Synthesis Report "Towards a Baltic Sea in balance" integrates and demonstrates the key results of BALANCE and provides guidance for future marine spatial planning.