BALANCE Interim Report No. 18

A practical guide to Blue Corridors

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<tr><td>1</td><td>Final report</td><td>JYR</td><td>JYR</td><td>19/12-07</td></tr>
<tr><td>0</td><td>Draft report</td><td>AR</td><td>JYR</td><td></td></tr>
<tr><td></td><td>Front page illustration</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Key words

BALANCE;</td><td colspan="3">Classification

☒ Open

☐ Internal

☐ Proprietary</td></tr>
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Distribution	No of copies
BALANCE Secretariat	3 + pdf
BALANCE partnership	20 + pdf
BSR INTERREG IIB Joint Secretariat	1
Archive	1

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0 PREFACE

Why plan for connectivity?

Marine areas do not exist in a vacuum – they are all linked to other areas on land or in the sea. This linkage is important both for the movement of organisms, but also for the connection and exchange of ecological processes. It is therefore important not only to consider the extent, values, and management of individual areas, but also to start thinking about the role of a single area in a network (natural or planned by humans) of areas. By starting to make such network planning, the possibility that individual areas actually fulfil their goals (conservation, resource management, or other defined goals) will increase.

Several international directives and conventions (e.g. the EU birds and habitats directive, the HELCOM and OSPAR regional seas conventions, and the convention on biological diversity CBD) call for the establishment of *networks* of protected areas. What does a network mean? There are many different systems and opinions on this, but most definitions on networks of protected areas include the concepts of representativity and ecological coherence (see below). Connectivity among protected areas is an essential part of ecological coherence.

This report is a product of the EU BSR INTERREG IIIB co-financed project "BALANCE". One of the tasks in the BALANCE project has been to evaluate the concept of **blue corridors**, i.e. the routes through which different areas are connected (the concept is described in more detail later in the report). In another report we have reviewed and discussed the literature on blue corridors in some detail (BALANCE 2006a). Other reports from the BALANCE project present other stages of marine spatial planning, e.g. landscape modelling, analysis of representativity and ecological coherence, and stakeholder analyses. These reports (listed at the back of this report) should be consulted for details of other steps.

For more information of the "BALANCE" project and for an electronic copy of this report, please go to www.balance-eu.org and for more information of BSR INTERREG, please go to www.bsr.interreg.net.

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December 2007

1 PLANNING FOR CONNECTIVITY THROUGH BLUE CORRIDORS

The purpose of this report is to give an introduction to the subject of blue corridors, and to give some examples and recommendations on how to work with the subject in practical marine spatial planning. The focus of this report is on the planning of marine protected areas (MPAs) in the Baltic Sea (figure 1), but hopefully some of the ideas presented here can also be useful for other planning processes, and in other areas.

The report describes a variety of analyses and data sources that may be used to plan for blue corridors and thereby improve connectivity between sites. Many of these are time and data intensive, and will not likely be available to the average marine planner. However, we do not want to scare the reader away – almost any kind of analysis, no matter how simple, of blue corridors and connectivity is probably a step forward from the practices used today, and may improve on the management of MPAs. We therefore urge the reader to keep an open mind to the concept, and to consider if there is any of the steps and methods we propose that may be practical for his/her special case.

This report is aimed at anyone with an interest in practical marine conservation planning. In particular, we hope that it may be useful for practicians in governmental agencies (transnational, national, regional or local) and especially to help implementing international and regional conventions and agreements asking for ecological coherent MPA networks.

Figure 1. The Skagerrak, Kattegat and the Baltic Sea as seen from space. The image is used by kind permission of the SeaWiFS Project, NASA/Goddard Space Flight Centre and ORBIMAGE.

1.1 Outline of the report

The report follows a scheme that we believe may be a useful way to systematically go through connectivity planning in the marine environment.The outline of this scheme is presented in a graph on the next page. The report follows this outline, and for each step in the scheme, discusses possible questions, data sources and analyses.

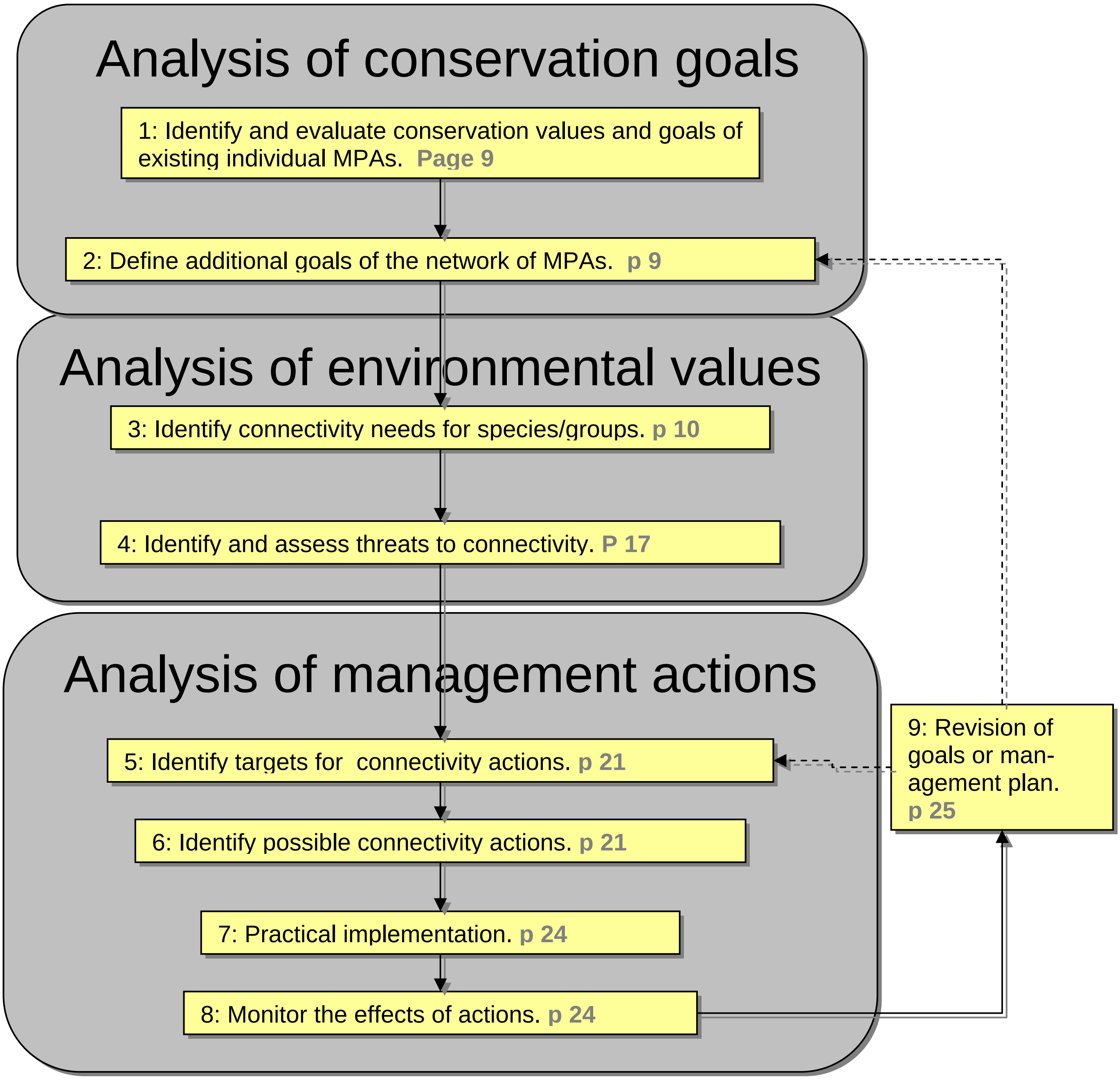

Figure 2: An outline for a possible scheme for a systematic analysis of connectivity between marine areas. This scheme also forms the outline for this report.

2 BUT FIRST SOME INTRODUCTORY EXPLANATIONS…

On land, much of conservation work has been directed toward individual species. In the BALANCE project, we emphasize the protection of habitats as an important way forward in marine nature conservation: by preserving the habitats we may preserve also the species living in them.

2.1 Linking species to habitats and areas – the importance of connectivity

Some species migrate over long distances, meaning that their habitat is not a fixed location or is only so during a certain part of their life cycle. Many species are also dependent on several different habitat types during their life. In such cases the population dynamics in one place may be driven by factors in another place.

In any area there will be a turnover of species. Populations are seldom in steady state: some species will from time to time go locally extinct, either as a result of predictable long-term processes or as a result of random events. The risk that local extinction occurs depends on the size of the habitat. The bigger the habitat and the larger the population, the smaller is the risk that local population dynamics lead to extinction within the habitat. After a species has disappeared form an area, it may recolonise the area again after some time. The species assemblage in one place therefore depends on both the characteristics of the habitat and how populations within the habitat are interconnected with other similar habitats separated in space. Thus in order to ensure the long-term survival of a species, the connectivity of habitats may be as important as the quality and quantity of the individual habitat.

For some species and/or habitats, the exchange of individuals between sites may be occurring in both directions. Population exchange may also be unidirectional, meaning that individuals only move from one site or type of habitat to another, but not in the opposite direction. Such sites or habitats (sometimes called source areas or source habitats in the scientific literature) are obviously particularly important and should be given priority in conservation.

The fact that the long-term survival of species and population depends on healthy habitat occurring over large areas is the reason for the importance of ensuring connectivity between sites, which is the theme of this report.

2.2 What causes and hinders connectivity?

The exchange of individuals between sites is may be difficult to quantify, whether or not the organisms are subjected to passive dispersal or self-motile. However, the exchange between sites is not only a matter of the physical distances: some environments may be more or less hostile to cross - like water for terrestrial species or land for aquatic species. Barriers may be natural or created by humans. Spatially separated habitats can also be interconnected by corridors, which facilitate an efficient population exchange between two sites. Corridors can be routes that intersect barriers like valleys, rivers, etc. They can be attractive routes to follow for migrating organisms because of food, water, shelter etc. In the marine environment corridors may be very concrete physical features, such as coastlines, sandbanks or deep channels, Blue corridors can also be defined by optimal water temperature, salinity, oxygen condition. In case of passive dispersal corridors may be defined by prevailing winds or in the marine environments by currents. Corridors can also emerge from human activities such as shipping (ballast water). In this latter case, it may have negative effect s as it serves as a stepping-stone for invasive species.

In this manual we will use the following definition of a blue corridor:

> ***A blue corridor** is a route of particular importance for the population exchange between locations and of importance for the maintenance of biogeographical patterns of species and communities. Blue corridors are shaped by interplay between the biological characteristics of a species, the physical/chemical characteristics of an area, and the geographical location of habitats. Blue corridors can therefore either be concrete physical features or the preferred or realised route of spread of a species*

2.3 Some definitions:

Throughout this manual we use some terms that may require a definition:

Connectivity is the opportunity for dispersal and migration of individuals of different species within and between areas.

Marine landscape. In general, the marine landscape is the geographical distribution of marine environments. In the BALANCE project, an important task has been to identify various types of marine landscapes and to produce maps how these are distributed in the Baltic Sea and Kattegat.

A **network**. of MPAs may in its simplest form be a list of individual MPAs designated through a certain process (or several processes). Commonly, however, MPA networks are defined as being composed of individual MPAs that are physically discrete and have separate management structures and regimes, but that are interlinked and together meet objectives (e.g. representing a full range of ecosystems and habitat types in a biogeographic region) that single MPAs cannot achieve on their own. Here we are more concerned with a coherent network (se below),

Ecological coherence means that the MPA network:

1. Interacts with and supports the wider environment,
2. Maintains the processes, functions and structures of the intended protected features across their natural range; and
3. Function synergistically as a whole, such that the individual protected sites benefit from each other in order to achieve the other two objectives
4. Additionally, an ecologically coherent network of MPA should:
5. Be designed to be resilient to changing conditions.

Fragmentation is the breaking up of a habitat, ecosystem, or seabed type into smaller parcels. **Fragmentation** causes transformation of nature types and habitats, an important current process in marine landscapes as more and more exploitation occurs.

2.4 The role of corridors on land vs. corridors in the sea

The biological value of corridors has long been discussed. In terrestrial landscapes there is now good experimental and observational evidence supporting the hypothesis that corridors, in certain landscapes, at certain times and for certain species, can direct the dispersal of individuals and influence a range of population characteristics in a variety of organism groups. In the sea the application of corridors will most likely be suited to particular marine landscapes, habitats and species. In the marine environment, some marine mammals, fishes and invertebrates in some marine landscapes use migration pathways. This has been demonstrated for e.g. Harbour porpoise, Spiny lobster, Blue crab, Sea turtles and Cod. These pathways, or blue corridors, are could be secured e.g. through management actions or protection. However, there is as yet little direct evidence demonstrating the utility of *protected* marine corridors in marine conservation, i.e. areas that are protected and managed for the main purpose of enhancing the dispersal of organisms.

Planning of “blue corridors” in the Baltic Sea should focus on functional aspects of ecological coherence, including connectivity, of a network of marine protected areas. Blue corridors may describe both passive dispersal of organisms with currents, and properties (e.g. the geopgraphical distance between protected high-quality habitats) in the marine landscape, which facilitates migration of mobile organisms. Both kinds of corridors might be relevant tools that can be applied in order to achieve the conservation goals.

Blue corridors may differ in how efficient they are in promoting the exchange of individuals between sites. The level of connectivity could be considered as 1) **high** if population exchange between populations efficiently prevents local population dynamics. 2) **Medium** if populations are restored within reasonable time following extinction of subpopulations. 3) **Low** if local sub-population develops with population dynamics being unaffected by regional population dynamics and restoration takes very long time following extinction events. 4) **Non-existing** when endemism develops. At the ecosystem level connectivity describe the degree to which the integrity of the ecosystems is regulated be regional or local processes.

Some examples (conceptual models) of connectivity models and blue corridors are given on the next page (figure 3a-c):

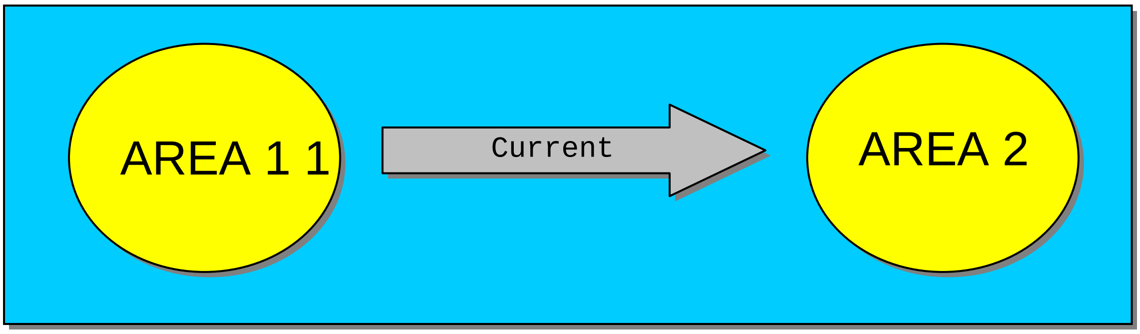

Figure 3a. The simple blue corridor model: water current connecting two areas. The flow speed correlates positively with connectivity: the stronger the flow, the more individuals it transports and the better is their survival.

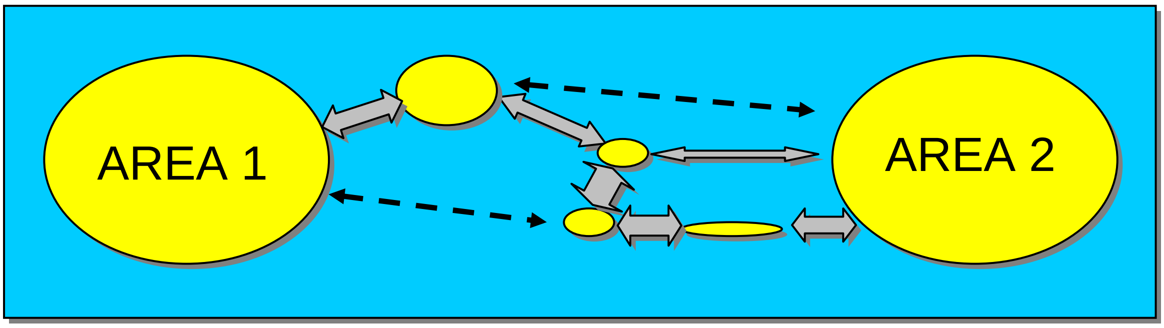

Figure 3b. Stepping-stone model. Patches of habitats between the two reserves serve as stepping stones, by which the species move from area 1 to area 2.

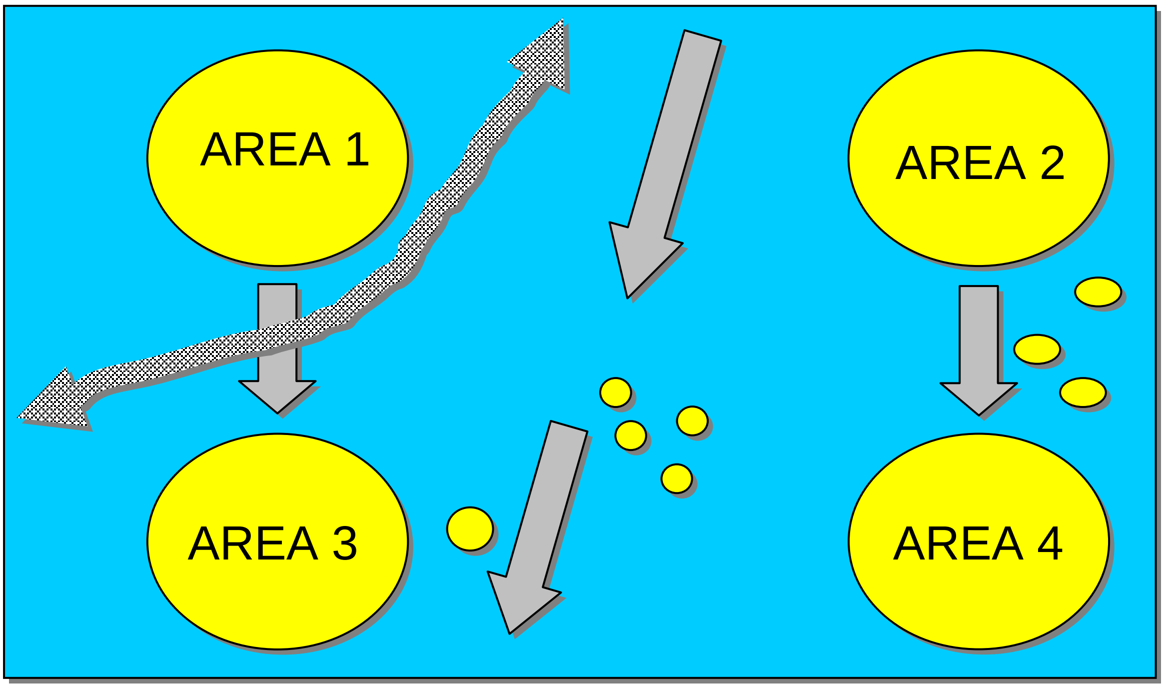

Figure 3c. A schematic network of MPAs with currents (grey arrows),stepping-stones (small yellow patches) and human disturbance (e.g. a shipping route, hatched line). The current enhances connectivity from the areas 1 and 2 to the areas 3 and 4, but inhibits the connectivity between 1 and 2, and between 3 and 4. Stepping-stones between the areas 3 and 4 might ease the migration of organisms between 2 and 3, despite the current.

3 PLANNING A COHERENT MPA NETWORK FOR BIODIVERSITY CONSERVATION.

If the assessment and planning for improved connectivity is done in a stepwise process with a defined sequence of actions and decisions, it may be easier both to analyse the individual area, and to compare the conservation effect of including different areas (an important task if a network of areas is analysed). Here is a proposal for such a stepwise decision-making process. Nine decision steps are organized in 3 major blocks. The explanation for each of the decision steps is given in following text with relevant examples (see figure 2).

Define and identify conservation goals

1. Check the goals of existing individual MPAs.
2. Define additional goals to be achieved by a network (if the goals are not specific enough, identify key species or groups to analyse from the connectivity point of view).

Define and identify environmental values and threats

3. Identify the connectivity needs (temporal development) for the species groups listed below:

   a. Species and populations of invertebrates;

   b. Species and populations of plants and algae;

   c. Fish;

   d. Mammals.

4. Identify and assess potential threats and limits of connectivity

   a. Describe water movement;

   b. Assess destruction of habitats (increased fragmentation);

   c. Assess changes in habitat quality (pollution, eutrophication);

   d. Assess over-harvesting of commercial species, leading to lower reproduction and dispersal rates.

Define and identify management actions

5. Identify targets concerning connectivity.
6. Identify the possible actions.
7. Practical implementation (stakeholder involvement, cost assessment, prioritising).
8. Monitor of the effects of the actions.
9. Revise the management plan.

3.1 Define and identify conservation goals

Creating connectivity between MPAs will help to meet the goals of individual MPAs. An example of this could be that an already stated goal for an MPA is to protect a spawning area for fish. However, the same fish stock is also dependent on another area to feed as juveniles (a nursery area). The connectivity of the MPA network including the nursery area will increase the protection of the spawning fish in the original MPA.

3.1.1 Step 1 – Check the goals of existing individual MPAs

The first action of improving the connectivity is to gather information of the goals of existing individual MPAs. Secondly, to combine this with any information of what kinds of species and habitats exist in the MPAs. And thirdly, to gather knowledge about the dispersal patterns of selected species or groups.

If some MPAs do not have explicitly expressed goals, then comparing the fauna and flora may give some indications of the possibility of different MPAs sharing populations, and thus possibly helping each other.

There are many different schemes for setting goals for an MPA. Commonly, overarching goals are combined with more precise objectives and criteria for evaluation. Many feel that it is difficult to formulate such precise statements the first time they try it, but there is much to gain if this could be done for each MPA. Interested readers could consult e.g. the IUCN report “How is your MPA doing” (Pomeroy and others 2004).

3.1.2 Step 2 – Define additional goals to be achieved by network

The second action is to analyse if additional goals can be achieved with an ecologically connected network of MPAs. This could be goals related to values already defined in individual MPAs, but with a greater chance of being met in the entire MPA network. It could also be values not explicitly mentioned in any individual MPA, but mentioned in other policies (locally, nationally or internationally) e.g. protection of widely spread species.

Whether or not such additional goals could be achieved, partly depend on whether or not blue corridors play a significant role for population exchange between the individual areas of interest and other areas. If an initial analysis indicates that the species, habitats or other ecological features are not dependent on (strongly connected to) other areas, focus should be on the individual MPA rather than on the network of MPAs. However, if the species are highly dependent on the exchange between several areas, then a network of MPAs may be necessary to achieve the conservation goals for that species, and the planning for blue corridors would be an important tool for achieving this.

Indicators of the importance of blue corridors could include the following:

1. The MPA in question contains many species with well-known planktotrophic larval stage (see below). If this is the case, passive dispersal of the organisms will play a significant role for the distribution of individual species, in shaping the community composition and/or regulating the level of biodiversity.

2. Current patterns or physical elements in the marine landscape suggests that there exist certain routes of particular importance for population exchange

3. Population exchange between two spatially separated habitats may be more or less unidirectional. In such cases the locations may be referred to as "upstream and downstream" and could be prioritised accordingly.

4. There are indications (from e.g. tagging experiments, or genetic analyses) that there is an exchange of individuals between areas).

***Conclusions about analysis of goals**:*

MPA´s and MPA networks should have clearly formulated goals for management. This helps also in the process of formulating plans of connectivity among areas. Goals are often formulated for a particular area, but goals should also be formulated for systems (networks) of areas.

3.2 Define and identify environmental values and threats

The third action is to define the connectivity needs, e.g. dispersal distance and dispersal mode, for the species and habitats the networks should be designed to protect. A major stumbling block for many planning processes is the lack of detailed biological and ecological data. Although we may always want more and better data, there is already a large body of biological and ecological data available. The challenge is to use it wisely, an to be able to assess it's merits and weaknesses. Also, the planning process should be seen as an iterative, stepwise process that should be regularly be revised to and improved when more data is available.

3.2.1 Step 3 – Identify the connectivity needs

Here we give examples of information that can be used to assess the importance of connectivity. For a more in-depth discussion on this issue, se e.g. the BALANCE literature review on Blue corridors (BALANCE 2006a).

3a. Species and populations of invertebrates

Many invertebrate species disperse via pelagic larvae. This means that they are subject to passive transport via currents and therefore the maintenance of the communities rely on blue corridors.

Basically there are three kinds of larvae: pelagic, littoral and brooded.

1. Pelagic (planktotrophic) larvae, also called meroplankton, drift passively with water flows. Common species are e.g. Blue mussel (*Mytilus edulis, figure*

4a), Baltic tellin (*Macoma baltica*), most of the other bivalves, Spire snail (*Hydrobia ulvae*), barnacles (*Balanus improvisus*), many polychaetes such as *Hedeste diversicolor* and *Marenzelleria viridis*, and echinoderms (such as sea stars and sea urchins, figure 4b).

2. Littoral larvae do not drift in the open pelagic but remain in the littoral zone, either as free-swimming or attached to substrates. These species include, for example, Mud snail (*Hydrobia ventrosa*) and the snail species of fresh water origin.

3. The third group, brooded larvae, are carried by their mother e.g. crustacean taxa, such as the decapods (*Palaemon adspersus*, *Carcinus maenas* and *Crangon crangon*, figure 4c), *Gammarus*-amphipods and all the isopods (e.g. *Jaera spp*. and *Idotea spp*., figure 4d).

Figure 4a. Mytilus edulis – a species with pelagic larvae and passive dispersal depending on dominating currents. Photo: DHI • Water • Environment • Health.

Figure 4b. Echinus esculentus – a species with pelagic larvae and passive dispersal depending on dominating currents. Photo: Orbicon

Figure 4c. Crangon crangon – a species with brooded larvae, where the mother carries the young in the early life stages. Photo: Orbicon.

Figure 4d. Idotea balthica – a species with brooded larvae. Photo: The Natural Heritage Service, Finland.

The first step is to identify which species that are likely to migrate as adults and which species that are most likely to disperse as larvae. For the species that are not likely to migrate as adult, the next step is then to identify what type of larvae these species have. In the context of blue corridors the pelagic larvae are of special importance. Although the duration of pelagic phase is limited from few days to some weeks, most of the species are able to postpone the larval phase if settlement is not possible. This enables the larvae to find proper habitat for settlement relatively far from the source area. Depending on the water flow larvae may drift even tens of kilometres (see Table 1).

Table 1. Examples of dispersal distances of some common Baltic Sea invertebrate species. The dispersal distances are estimates, based on genetic and behavioural studies. Modified from table 11 in the BALANCE coherence report (BALANCE 2007c).

Species	Substrates	Salinity	Photic depth	Dispersal distance	Notes and references
Mytilus edulis (Blue mussel)	bedrock, hard bottom complex, sand (west from Pomeranian Bay)	>5 psu	Non-photic and photic	100km	Reproduction limited in salinities <5psu, Distribution whole Baltic Sea, except the Bothnian Bay.
Macoma balthica (Baltic tellin)	Sand and mud	>5 psu	Non-photic and photic	100km	Tolerates salinity of 4 psu. Distribution whole Baltic Sea, except the Bothnian Bay.
Idotea baltica (an isopod)	Bedrock and hard bottom complex	>5 psu	Photic	25km	Distribution whole Baltic Sea except the Bothnian Bay.

Some species may be highly mobile as adults. From genetic point of view even low migration between two areas is able to prevent genetic differentiation, but from the view of coherent MPA network the migration potential of species needs to be rather high. Species known to swim relatively large distances (kilometers) as adults include all mobile crustaceans and the polychaete *Marenzelleria viridis*. Also migrations by clinging to drifting plants, debris and wood, known as rafting, is common for many species with low mobility, such as bivalves, snails and crustaceans.

3b. Species and populations of plants and algae

Dispersal of vascular plants and macroalgae may be either by spores or seeds, or by drifting adults. The potential for migration for the first two cases are very much species-specific ranging from centimetre to kilometre scale, whereas the latter case depends on the storms to detach the plant and water currents to transport them to new areas (Table 2).

The planktonic lifespan varies from group to group. As for other groups of planktonic organisms the motility of the organisms themselves is unimportant for the large-scale spread. Typical swimming speeds for brown and green algal spores with flagellates are less than 1 mm/s, which is insignificant compared to common current speeds. However, the swimming ability of the propagules may be very important for their ability to choose the site where they will attach.

Spore dispersal capacity is controlled by a number of factors like current speed and direction, release height from parent plants, sinking rate, swimming speed and duration, time span were settling capability remain, vertical transport by turbulence and the concentration of propagules. Turbulent transport models predict that that suspension times for spores of most seaweeds are likely to be less than 1 week, and that their dispersal in typical near shore currents is limited to distances of several kilometres.

The longevity of the pelagic stage is the prime predictor of the dispersal range and species-specific differences suggests which species that benefits from the network rather than the individual MPA. Below is listed some examples from the literature on planktonic longevity including knowledge of reproduction period and dispersal time for selected common algal species in the Baltic Sea.

Table 2: Examples of larval traits important for the analysis of connectivity for some macroalgae occurring in the Baltic (including the Kattegat). *Modified from the BALANCE coherence report (BALANCE 2007c).*

Species	Dispersal mode	Spore dispersal length	Reproduction season	Distribution
Laminaria saccharina	Spores			Medium-shallow water
Laminaria digitata	Spores			Medium-shallow water
Laminaria hyperboria	Spores	Motile spores: 1 day Suspended spores: many days Survival: > 40 days	October-April	Medium-shallow water
Fucus vesiculosus	Spores and "floating"		March-August	Medium-shallow water
Fucus serratus	spores		Autumn	Shallow water
Fucus spiralis	Spores and "floating"		Summer	Very shallow water
Halidrys siliquosa	Spores and "floating"		Winter	Shallow-medium
Enteromorpha intestinalis	* spores and gamets	** Motile spores: 8 days	Summer	
Odonthalia dentata	* spores and gamets	** Motile spores: 8 days	Summer	

Most plants and algae can survive long distance transport if they are detached as adults, provided that they are maintained in the photosynthetic zone, and will contribute to connectivity if they carry reproductive structures or have alternative vegetative reproduction. Species like Bladder wrack (*Fucus vesiculosus*, figure 4a*)*, Spiral wrack (*Fucus spiralis)*, knotted wrack (*Ascophyllum nodulosum)*, Sea oak (*Halidrys siliquosa)* and Wireweed (*Sargassum muticum)* have a ability to disperse by drifting. Some algae species can retain capability to grow and reproduce for a long time and transport distances of 500 km and more are recorded. The quick dispersal of Wireweed since its introduction in southern England in 1973 to Norway in 1984 and later in the Limfjord and down the Swedish west coast is an excellent example of the dispersal capacity using floating vegetative branches. However, not all macroalgae, such as crust-forming red algae (figure 4c), are capable of using floating vegetative branches and depend solely on spore dispersal.

The vascular plants in the Baltic Sea depend either on transport by animals or floating as seeds and adult plants for long distance dispersal. The farthest-reaching vascular plant of marine origin in the Baltic Sea, the eelgrass (*Zostera marina*, figure 4d), produces seeds in the southern Baltic Sea, whereas in the Gulf of Finland the low salinity prevents the sexual reproduction and it increasingly propagates vegetatively. A similar shift to increasing vegetative reproduction is also seen in other marine species in the Baltic Sea, which makes them potentially more vulnerable to extinction in these areas. Sexual reproduction of freshwater vascular plants may function up to approximately 6 psu salinity.

Figure 4a. Fucus vesiculosus – a brown seaweed dispersing through spores and by using floating vegetative branches. Photo: The Natural Heritage Service, Finland.

Figure 4b. Enteromorpha intestinalis – a green macroalgae dispersing by spores and by drifting fragments of adults. Photo: The Natural Heritage Service, Finland though the picture is from a shore in the Kattegat.

Figure 4c. Crust-forming red algae are depending on dispersal by spores. Photo: Orbicon

Figure 4d. Zostera marina – a plant species, which can reproduce both by seeds and through vegetative growth. Photo: The National Environmental Research Institute.

3c. Fish

The movements of fish larvae and adults are strongly species-specific (Table 3). There are almost as many different adaptations of fish as there are species in the Baltic Sea. Generally, there are pelagic and littoral spawners, river and freshwater spawners. Several Baltic species, such as pike (*Esox lucius*), whitefish (*Coregonus lavaretus*) and trout (*Salmo trutta*), have both populations spawning in freshwater and populations spawning in the Baltic Sea. Some species carry their off-spring until hatching, such as pipefishes and the viviparous blenny (*Zoarces viviparus*).

Pelagic eggs and larvae can drift passively by currents. However, as soon as the fish develop fins they are capable of changing their position in the water column and, thus, are able to change to different water layers and choose direction of water flow. Therefore, care is needed when estimating the role of currents in the movement of fish. Also, the low salinity in the Baltic Sea may affect the ability of larvae to spread. For example, the eggs of turbot (*Psetta maxima*) and flounder (*Platichthys flesus*, figure 5a) are pelagic in fully marine environments but are demersal in the inner parts of the Baltic Sea.

Common species with pelagic larvae are cod (*Gadus morhua*) and sprat (*Sprattus s. sprattus*). During spawning periods cod normally gather around stone reefs, ship wrecks etc., but in the Baltic proper they prefer the deeps, e.g. Bornholm Deep and Gotland Deep. From here the hatched larvae most likely migrate towards littoral waters along the German and Polish coast. Sprat larvae have been seen to actively stay in the surface layer and may thereby be transported by surface currents. On the other hand, herring (*Clupea h. harengus*) is a pelagic species, but spawns in the littoral zone and its larvae probably remain in the coastal areas by active selection of water flows.

The larvae of many freshwater species that spawn in coastal lagoons and bays (e.g. Pike *Esox lucius* figure 5b, Perch *Perca fluviatilis*, Pikeperch *Sander lucioperca*, cyprinids) are demersal and remain in the vegetation until they reach a certain size. These species usually migrate comparatively short distances even as adults. Genetic analyses support these observations as populations are often strongly structured.

Figure 5a. Pleuronectes platessa – the species spawn in relative deep water in the central Kattegat and the eggs float with the currents to shallow near-shore habitats. Photo: Orbicon

Figure 5b. Esox lucius – a freshwater species common in the Baltic Sea. It usually migrates only small distances from the original spawning area. Photo: The Swedish Board of Fisheries.

Populations of river-spawning species (e.g. Smelt *Osmerus eperlanus*, Salmon *Salmo salar* and some of the Whitefish *Coregonus lavaretus*) usually show a homing behaviour to their spawning sites, whereas outside the spawning season they may be mixed along the coast or in the sea. Thus, when considering blue corridors, the link between the feeding and spawning grounds is important for a number of species. (BALANCE 2007a)

In most cases, it is unknown how much populations from different spawning sites mix with each other. Strong genetic population differentiation has been observed among several species that have been studied (e. g. pike, perch, whitefish), while no differentiation has been observed in others (e. g. turbot). In a management context, populations exhibiting genetic differentiation should be treated as separate entities.

Table 3. Mobility estimates for some common Baltic fish species (From Table 4 in BALANCE 2007a). 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

3d. Mammals and birds

Marine mammals and birds move actively and may cover large areas during their migrations. In the Baltic Sea, grey seal (*Halichoerus grypus*), ringed seal (*Phoca hispida botnica*), harbour seal (*Phoca vitulina*), and harbour porpoise (*Phocoena phocoena*) are relevant objects when estimating connectivity between separate areas. Grey seals migrate long distances within and between Baltic regions. Ringed seals occur in the northern parts of the Baltic Sea, with main occurrence areas in the Bothnian Bay, the eastern Gulf of Finland and the Gulf of Riga. Ringed seals also occur in the Archipelago Sea to a lesser extent. Adult Baltic ringed seals appear to be quite stationary. However, no genetic differentiation has been found between different breeding subpopulations within the Baltic Sea, which indicates that there is gene flow between distinct breeding areas. Based on these results, migration seems to occur between all subpopulations to some extent. Both seal species have been observed more and more commonly in the rather densely populated inner archipelago, although their resting, breeding and molting sites are mainly remote skerries at the margin of the open sea.

The distribution of marine mammals in the Baltic depends on several factors, including food availability, ice cover, suitable sites for reproduction and molting. The availability of peaceful resting sites and the prevention of human disturbance, have a local impact on the distribution of marine mammals.

Birds can be a significant part of the marine ecosystem and it is useful to estimate the connectivity of MPA network also by marine birds. However, the blue corridors concept cannot be applied to them as they migrate by flying. There exist much literature on bird migratory routes in the Baltic Region.

***Conclusions about analysis of connectivity needs**:*

Although detailed information on connectivity needs of species and populations often is missing, there is basic information available on the reproductive biology (larval vs direct development) and migration ecology of many species. This information can at least be used to make initial analyses if connections to other areas are likely to be important to the population processes of the area of interest. Also, the planning process should be seen as an iterative, stepwise process that should be regularly be revised to and improved when more data is available. In situations where the area contain many species with different reproductive modes, the are several options for selecting which species to use for the connectivity analysis:

a) The species for which the goals of the area are formulated (i.e. the decision on which species is important is made beforehand);

b) The species which are ecologically most important (e.g. keystone or habitat-forming species);

c) The species with the most stringent need for connectivity design (with the reasoning that if the connectivity for this species is ensured, then the connectivity for other species should be ensured too);

d) or just any species for which good data are available.

3.2.2 Step 4 – Identify and assess potential threats and limits of connectivity

When the dispersal characteristics of one or several focal species have been defined, then the fourth step is to identify if it is likely that the dispersal needs are met, and if not, what may limit the dispersal.

4a. Describe the water movement

The blue corridors concept is closely linked to free passage of species through a water area, and accordingly for species that disperse with larvae or spores to the water flow between the areas. Naturally, the connectivity for such organisms between two sites increases with higher water flow to “downstream” areas. For organisms subjected to passive dispersal the outcome is entirely determined by current patterns. Whereas active movement along blue corridors may be recorded by observing the behaviour of the species of interests (typically adult fish), quantification of passive movements along blue corridors requires some kind of modelling if costly sampling programs are to be avoided. Population exchange between two sites depends on prevailing current patterns and on mixing of water masses, which dilutes a patch of drifting organisms along the blue corridor. The time for the movement of water between two sites should not exceed the longevity of the planktonic phase of the organism of interest, otherwise more MPAs are needed or more “stepping stones” in between. As exemplified later in this report these questions may be answered by using hydrographic models to predict exchange of water between two sites.

As currents may be influenced by human activities (offshore constructions, outflows of cooling waters from power or waste water treatment plants, regulation of rivers, dredging of coastal lagoons etc.) it is essential to quantify the consequences in terms of changes in water exchange. If a construction increases the time for the water to move between two MPAs, introducing new MPA´s in between may compensate for such an effect, which may serve as stepping-stones. Alternatively, the size of existing MPA´s could be increased, thereby increasing the input of planktonic organisms to be transported along the corridor.

4b. Assess destruction of habitats (increased fragmentation)

Connectivity between two sites via water flow or via stepping-stones can be reduced, if habitats, either in the ends or in the middle, are altered or destroyed. Logically, if the habitat in either end of the blue corridor is destroyed, the connectivity is prevented for the number of species relying on that specific habitat. However, if the habitat is destroyed in the middle of the blue corridor this does not necessarily lead to destruction of the blue corridor but may reduce the connectivity as it takes more time for slowly-advancing species to survive the increased gap between the two stepping stones. Such slowly advancing species are, for example, snails and small fish with littoral larval development.

Examples of underwater habitat destruction may be dredging of bays and lagoons, destruction of eelgrass meadows by sand extraction, bottom-trawling soft-bottom communities, creating new shipping routes, establishing harbours or marinas, leading warm water outflow from waste water plants or from industry to a coastal area, altering the water flow or quality in rivers and their catchment areas and changing otherwise the water quality of lagoons and bays. These activities will change the species composition in an area via multiple mechanisms and often lead to destruction of the original habitat.

4c. Assess changes in habitat quality (pollution, eutrophication)

In many cases human activities lead to reduced quality of a habitat. A well-known process is eutrophication, which in a number of ways can change the quality of a habitat (figure 6a-c). In first phases of the process, increased nutrient input increases the biomass of phytoplankton or filamentous macroalgae, which increases turbidity in the water. The decreased light affects harmfully the visually preying fish and bird species, and decreases photosynthesis on the bottom. In the second phase, the great biomass of phytoplankton dies and forms organic layer on the bottom, which temporarily increases the benthos (bottom-living fauna). However, the biological and chemical activities consume oxygen from the bottom (hypoxia), which reduces the amount of species capable of surviving in the altered conditions.

Figure 6a. Zostera marina – a habitat forming perennial species, which used to be a dominant species in large areas of the Baltic Sea. Here in an area with little eutrophication. Photo: The National Environmental Research Institute.

Figure 6b. Zostera marina – With increased eutrophication opportunistic the biomass of annual species such as filamentous macroalgae will increase and out-compete perennial species. Photo: The National Environmental Research Institute.

Figure 6c. The degradation of large amounts of biomass requires oxygen and can cause oxygen depletion, which, in turn, kill higher organisms. Photo: The National Environmental Research Institute.

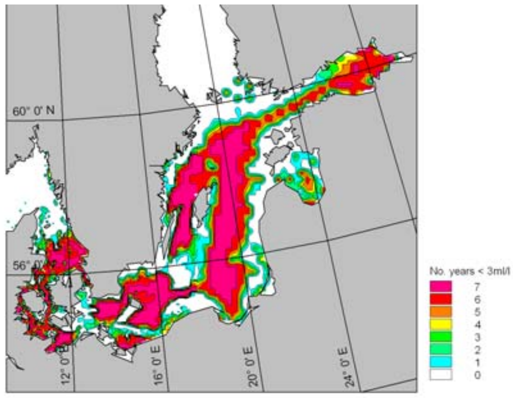

Figure 6d. Eutrophication can cause habitat fragmentation within the Baltic Sea. Modelled distribution of frequency for extent of minimum oxygen condition, showing the number of years within seven years (2000-2006) where minimum bottom oxygen is below 3 mlO_2/l for at least one day. DHI • Water • Environment • Health.

During summer months, eutrophication in the Kattegat and in many parts of the Baltic (e.g. around Bornholm) will lead to total oxygen deficiency, anoxia, which is toxic environment to living organisms (except some bacteria, figure 6d). Hypoxia, anoxia and reduced light availability affect the connectivity of two areas, but the magnitude of the effect depends on the species. For instance, bottom-migrating species cannot move through hypoxic or anoxic areas and visual predators probably avoid areas of low visibility. The reduced light availability decreases the depth of the photic zone in the stepping zone areas and may therefore affect particularly plant species and the phytobenthic community.

Other types of pollution (e.g. toxins, oil-spills) can also destroy or decrease the ability of a site to function as a stepping-stone. Therefore, when the consequences of pollution in an areas is analysed, it is important to consider not only the threats to values within that area, but also the consequences for the connectivity between other areas.

4d. Assess over-harvesting of commercial species, leading to lower reproduction and dispersal rates
Connectivity of populations among sites is also affected by the population size in itself. Many commercial fish species are harvested at a rate that keeps populations at levels too low to ensure their long-term maintenance. If harvesting takes place in important migration routes that has a large impact on the population dynamics, then this must be taken into account when designing the network of MPAs. Although MPA for biodiversity networks may contribute to the conservation of these stocks, they alone are unlikely to provide adequate population protection, unless they reach a very large size. For example, MPA networks may contribute to the maintenance of commercial fish stocks through the protection of spawning and nursery habitats, and they may also locally decrease mortality if the MPA encompasses fishing restrictions. However, due to the high level of potential mortality of commercially harvested species (fish and others), protected areas for fisheries management should be seen as one tool among several in resource management, which should be influenced by and complemented by other actions. This emphasizes the need for a good level of cooperation between nature conservation managers and marine resource managers.

***Conclusions about identification of threats and limitations to dispersal**:*
This step is essential in order to formulate concrete actions. Natural and human processes may contribute to limiting the dispersal. Preferably, the consequences for the connectivity in MPA networks of any human activity or construction should be assessed.

Human disturbances may be physical (e.g. construction, exploitation) or chemical (pollution, eutrophication). Information of the extent of human activities is probably easier to find than information on the biological characteristics of dispersal.

3.3 Define and identify management actions

Identifying quantitative targets may be the most difficult part in the process to improve and ensure connectivity. Only for very few species do we yet have information enough to make numerical predictions of consequences for populations from different actions. However, from the analysis of the goals, the biological values and the threats described in previous sections, it should be possible to identify which values (e.g. which populations, species or habitats) should be targeted for management actions, evaluation and monitoring (as described below). Targets could then be formulated not towards measurements of connectivity per se, but rather towards actions taken to ensure connectivity, e.g. “protection of area X from activity Y before 2009”, where Area X is e.g. a stepping stone area and activity Y is a threat to the habitat quality for which there is information suggesting that it may alter the necessary qualities for connectivity. In many cases, agencies prefer to formulate outcome-oriented targets rather than action-oriented targets (for many reasons, one of which is that it is often easier to get stakeholder acceptance for outcome-oriented targets), but if outcome-oriented targets cannot be formulated because the necessary level of information is missing, action-oriented targets might be better than not formulating any targets at all.

3.3.1 Step 5 – Identify specific targets concerning connectivity

Tools for such analyses include the outcomes from fisheries models and from the sets of models called population viability analysis (PVA models). As mentioned earlier another tool may be quantitative predictions dispersal via prevailing current patterns, which can give information on the probable distance travelled by larvae, both large-scale and small-scale. An example of such an analysis is made in the BALANCE project (see the case study in chapter 4). This concerns the dispersal range of the hard bottom biota within the Kattegat area and between selected MPA across the entire Baltic Sea.

3.3.2 Step 6 – Identify the possible actions

Once the goals and targets of the network of MPAs and the threats to them are identified, the possible management actions should be identified. In the previous section we identified four main threats to connectivity:

1) Limiting water movements
2) Destruction of habitats
3) Changes in habitat quality
4) Over harvesting with resulting low population densities

The analysis outlined in the previous steps should identify which of these threat categories that are most vital to address for meeting the goals and targets for the network of MPAs. The actions to counter the threats can be addressed within the MPA system, or with general regulations not specific to the MPA areas. This may imply that more protected areas may be necessary, that existing MPAs should be enlarged, or that MPA management plans should be updated. It may also imply that general regulations for marine activities should be changed to better meet the purposes of the MPA system. In most ways, the knowledge, methods and regulations used to ensure connectivity are no different than what is already used in marine environmental planning. The difference is the additional emphasis not only on effects on the area where the threat occurs, but also on its effects on other areas.

6a. Limiting water movements

As already mentioned, many organisms in the sea disperse with planktonic larvae. There are at least three stages to this larval phase: When the larvae are released into the water, when the larvae are transported longer distances with currents, and when larvae finally settle on to the substrate in an area. Altering the large-scale current patterns is hardly within the reach of managers, and therefore there is not much that managers can do to influence this part of connectivity directly. However, analysing the potential dispersal distance of different species, and making sure that there are appropriate habitats available within the average distance of larval spread of a species is an important management action.

However, small-scale current alterations may influence both the initial (release of larvae) and the last part (settlement of larvae) of the larval dispersal. Therefore, management actions may include an analysis of the local impediments to water movement: have jetties, shore protection installations, large-scale dredging or other constructions changed the water movement in a negative way for larval settlement, and can local regulations against such detrimental constructions be formed? Research on the mechanisms of larval ecology is intense, and we may expect much useful information to marine nature conservation to come from this field in the future.

6b. Destruction of habitats

The destruction of habitats is a major threat to the marine environment globally, as well as within the Baltic Sea (figure 7a-b). Destruction of habitats (both within and outside MPAs) may prevent proper connectivity between MPAs, It is important not only to analyse the habitats that are specifically mentioned in the goals of individual MPAs, but also other habitats that are essential in the life cycle of species that are in focus for conservation in at least some MPAs in the network. In the absence of detailed information about the habitat requirements of many species, the precautionary approach often suggested is to protect a *representative* network of habitats, i.e. that all types of habitats should be protected in all biogeographical areas. The issue of representativity is important, and covered in other reports from BALANCE (e.g. BALANCE 2006b).

6c. Habitat quality

Even though habitats may exist on several spatial scales, as suggested in the previous section, the quality of the habitats must be such that they can function as habitats for the focal species: just ensuring that they exist is not enough. For this purpose, an analysis of threats to the quality of habitats must be done. The threats may be local, in which case actions against them my well be through MPA regulations. Many other threats (e.g. toxins, eutrophication, and unsustainable fisheries) are often large-scale, and the success of the MPA network is dependent on other general environmental policies. In this context, the status reports of regional, national and international monitoring programmes may be important. Such reports may give information about the quality of the focus habitats in general, or even on the status in particular areas. From the individual MPA perspective, it would be beneficial if sampling locations were situated within MPAs, but this must be evaluated against the general purposes of the monitoring programme, which may call for a different layout. Also, if MPAs and in particular MPA networks are seen as a tool to contribute to good environmental status, not only within the individual sites, but for the whole ecosystem, the national an international monitoring programmes may be important.

Figure 7a. Marine aggregate extraction may destruct specific habitats locally. Photo: The Danish Spatial and Environmental Planning Agency.

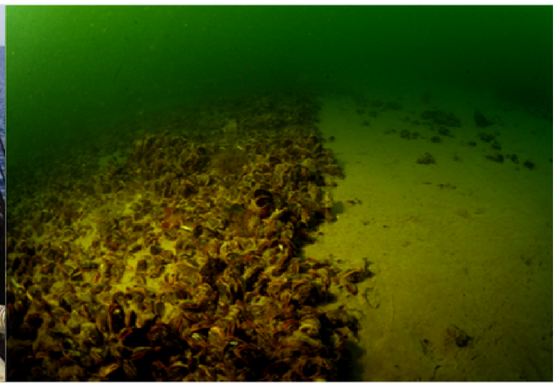

Figure 7b. Dredging for blue mussels cause destruction of habitats and requires informed management to avoid over harvesting. Photo: Environmental Centre of Ringkjøbing, Denmark.

6d. Over-harvesting

Habitats may be present in sufficient numbers and of sufficient quality, but the size of the populations will influence the connectivity of populations among sites. Although MPAs for conservation may contribute to the conservation of stocks of fish and other commercial species (through the protection of essential habitats and the local decrease in fishing pressure), it is less likely that these kinds of MPAs by themselves will ensure the production of commercial fish species, unless the network achieves a very large extent. This means that for the protection of commercial species, MPAs for conservation and fisheries management influence each other. The good side of this is that the two conservation tools may complement each other. On the other hand, if there is a poor cooperation between nature conservation managers and nature resource managers, the aim of both groups may suffer.

Conclusions on the identification of actions:

In most ways, the knowledge, methods and regulations used to identify actions to ensure connectivity are no different than what is already used in marine environmental planning. The difference is the additional emphasis not only on effects on the area where the threat occurs, but also on effects in other areas. Data and analyses from other activities (monitoring programmes, resource management) may be important for the management of connectivity among MPAs. Blue corridors can be secured through MPAs (e.g. stepping stones) or more general management between designated sites. A combination of tools is probably the most efficient solution. This means that there is a strong need for close cooperation between different groups of managers e.g. conservation managers and resource use managers.

3.3.3 *Step 7 – Practical implementation*

Practical implementation include elements such as stakeholder involvement, cost assessment and prioritising and although these activities are often the most demanding and time consuming in any marine spatial planning, they are of course essential: these are often the steps that really determines if a MPA will be formed or not.

This process will probably not differ in any fundamental way if the planning is for an MPA “with connectivity” (as part of a network) or for an “independent” MPA. However, and this may of course be important, planning for connectivity and blue corridors may demand more resources (both in terms of finances and in terms of time) because it involves several geographical areas. For example, it a be more demanding to get local support for forming an MPA if it is stated that the main purpose of the MPA is to support protection of the environment in a different area or to support the entire ecosystem. This may be a challenge when working with networks of MPAs versus working with single MPAs. One important difference between planning for an individual MPA and planning for MPAs with connectivity (network planning) is that an individual site might be chosen for it value as an important stepping stone within the whole network, and may as such be chosen before another site with perhaps more intrinsic values (more diverse, more unique). This will probabaly require a different viewpoint not only from stakeholders, but also from managers. From this perspective, it is important to view the purpose of the entire network with the aim to protect the entire ecosystem, and to emphasize this in analyses and policies. This is further described e.g. in the BALANCE report on coherence (BALANCE 2007c).

However, the difficulties should not be exaggerated: with proper formulations of goals and a careful selection of sites, this problem may be lessened. It may even be that a network strategy may strengthen the argument for local spatial planning, as the importance of the local area to a larger environmental (or resource management) goal, e.g. to protect the entire ecosystem and its ecosystem services, is made more explicit.

Conclusions on practical implementation:

The process will probably not differ in any fundamental way if the planning is for an MPA “with connectivity” (as part of a network) or for an “independent” MPA. However, some parts of the implementation, e.g. stakeholder involvement and support, may be more difficult. One way to facilitate the process may be through careful formulation of goals and targets both for individual sites and for the network of sites. It is important to be clear about the role that an individual site may have for the common conservation goals for the network.

3.3.4 *Step 8 – Monitor the effects of the actions*

As much as is possible, the actions should be formulated such that there are some quantified (numerical) targets for each action (see chapter 6). If possible, these targets should be monitored in order to see if the actions are appropriate, efficient and of sufficient magnitude. The numerical targets can be formulated directly in terms of connectivity, e.g., tagging data on fish suggest that a certain number of individuals have migrated from one MPA to another. Targets can also be directed to monitoring the goals (e.g. the geographical extent of a biotope in the MPAs, the number of individuals in target populations). The advantage of the latter approach is that it is directly related to the goals, but a disadvantage is that it is not possible to separate the effects of connectivity-enhancing actions from other conservation actions.

Which methods that should for used for the monitoring is of course dependent on the actions and targets. Although the monitoring program ideally shall be designed to the specific targets for the network of MPAs, in practice monitoring is costly, and it will probably always be important to keep these costs down also for MPA evaluations. Although the NATURA 2000 system requires monitoring of favourable conservation status of the species and habitats listed in the annexes to the directives, it is likely that managers to a large extent also will have to rely on existing (although possibly modified) monitoring programs, e.g. for fisheries management and environmental monitoring. This means that the available monitoring efforts are not necessarily designed to address the formulated goals and targets for the MPA/MPA network. Formulating goals (the purpose of the MPA/MPA network) that cannot be monitored is probably unavoidable, and accordingly the goals will have to be qualitative. Formulating numerical targets than cannot realistically be monitored is more problematic. In practice, available resources for monitoring might therefore also influence how goals and especially targets are formulated.

Conclusions on monitoring:

Monitoring the outcome of actions is important, but depends on how the goals and targets are formulated, and on the resources available for monitoring. In practice, goals and targets must be influnced by the possibility to monitor them.

3.3.5 Step 9 – Revise the management plan

Ideally, if the monitoring of the effects of actions aiming to increase connectivity show that the actions have not been sufficient to fulfil the goals, the management plans will be revised. This is often referred to as adaptive management. Should the monitoring done be continued, but intensified and how (figure 8a.b)? Should additional actions be started? Should some of the actions be terminated as they proved to be inefficient? Have the goals and targets been met, and can the extent of some of the (perhaps costly) actions be decreased?

However, to revise a management plan may also be costly and time-consuming. Formulating the plan for the MPA may have included difficult negotiations and painful compromises. In practice, this means that the benefits of revising the management plan must be assessed against the costs. It is, however, important to remember that it is of course also costly to have a management plan that does not meet the goals.

Figure 8a. Geola – a vessel used for mapping marine habitats in the Archipelago Sea as part of the BALANCE project. Photo: The Geological Survey of Finland

Figure 8b. Gunnar Thorson – one of the vessels applied for monitoring the marine environment in the Kattegat region. Photo: The National Environmental Research Institute, Denmark.

The difficulty of revising the management is probably much less if the rules for revision (e.g. how when and by whom) are laid out already in the management plan. This way different interest groups are prepared for that changes may occur, and under what circumstances revision will start. This may be easy or difficult to present to stakeholders, depending on the circumstances: there may be resistance to constantly changing the regulations, but there may also be a fear of having regulation "written in stone". It may, however, be well worth the effort to have an adaptive revision system included in the management plan.

Conclusions on revision of the management plan:

There is a cost (financial, time, credibility) to change an existing management plan, but it is a waste of resources to have a management plan or a network of marine protected areas that does not achieve the aims of their existence.

For such adaptive management, the rules of how, when, and by whom the plans may be revised should be formulated in the management plan.

4 CASE STUDY – IDENTIFY SPECIFIC TARGETS FOR CONNECTIVITY

This is a study made in the BALANCE project (BALANCE 2007b), with the aim to illustrate if it would be possible to identify specific targets for connectivity within a transnational network of marine protected areas. The study shows how passive dispersal along a blue corridor can be modelled and a spawning locality within one nation's territorial waters can influence populations within another nation's territorial waters.

4.1 Hydrological modelling of planktonic dispersal in the Kattegat

The dispersal of larvae follows the current patterns and disperses in two directions. Note that even though the illustration shows the average conditions during one month (July 2003) there is no dispersal to the southeast through the Sound or to the northeast towards Skagerrak (figure 9).

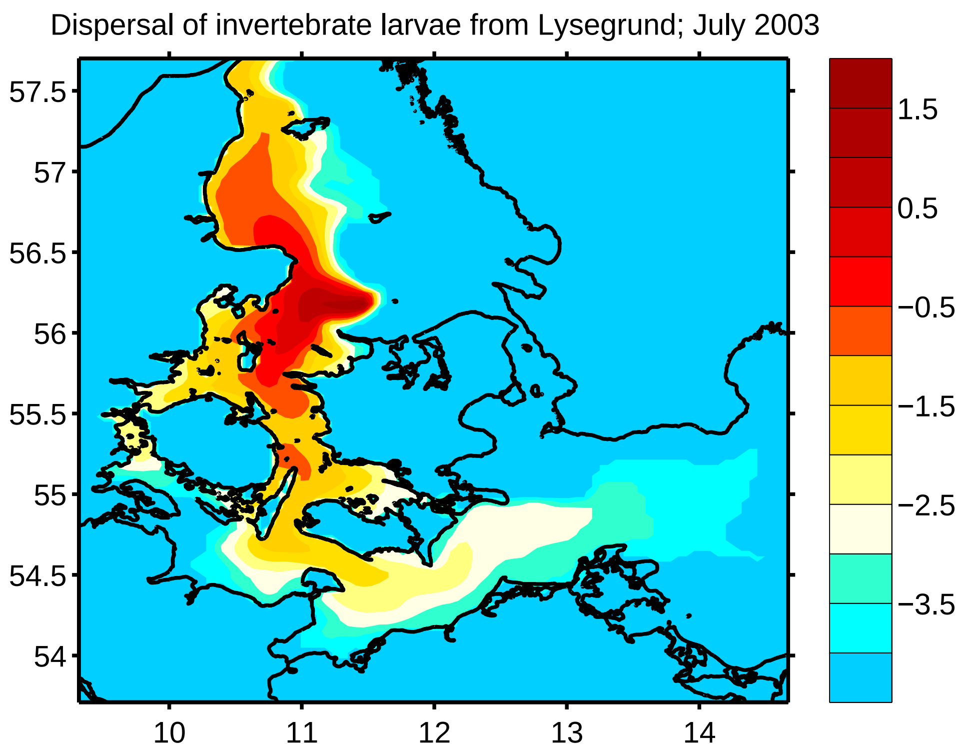

Figure 9. Modelled dispersal of larvae released from a location in southern Kattegat in July 2003. It is assumed that the larvae are released continuously with 20.000 larvae/m^2/day and that they stay pelagic 4 weeks and is subjected to a mortality of 0.2/day. Colour scale shows Log $_{10}$ concentration (number per cubic meter above the bottom).

The difference in dispersal pattern from different locations is also evident when looking at figure 10. The larvae disperses via different routes depending on the location of the site, even though the sites are located close to one another: From the Northern location larvae disperse to the North whereas larvae from localities only about 30-40 km South disperse to the South through the Belt Seas and further toward the Baltic Sea. Such a pattern matches community compositions of the soft bottom fauna, but also community patterns of macroalgae vegetation.

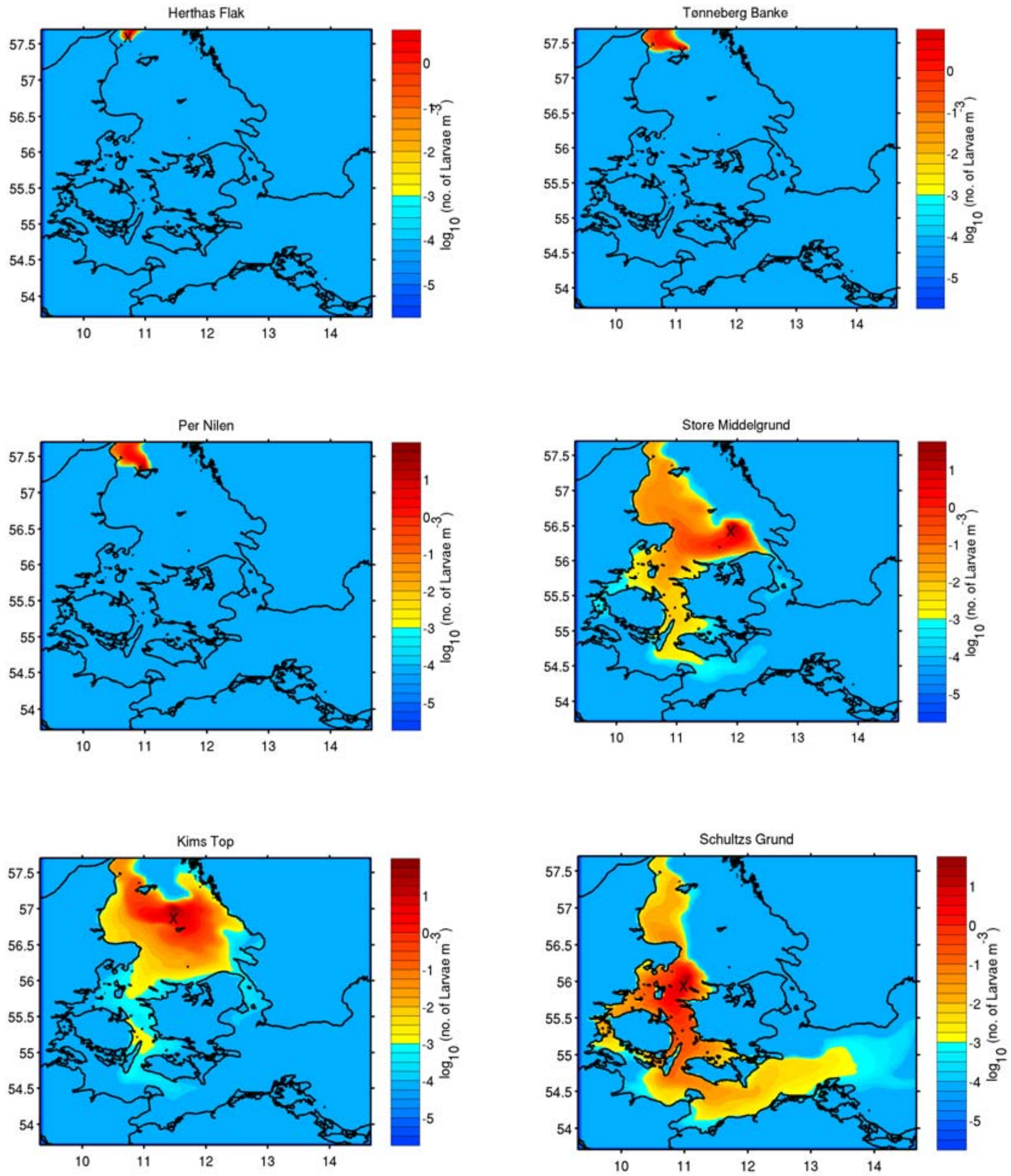

Figure 10. Model results showing an example how a larva released from the position marked X would disperse in the Kattegat. The results are from a model version of COHERENS that covers the region from Northern Kattegat to Southern Baltic Sea. For details of the model, see BALANCE (2007b).

Knowing the sources and sinks of passive dispersal can help prioritising MPA´s and define relevant corridors between them. In the above examples faunal populations in the northern location have apparently no impact on the communities in the central Baltic, whereas populations in the central Kattegat may be highly important as described earlier. If such models are supported by detailed information on the planktonic composition and abundance (or genetic information), it also enables a comparison of the relative connectivity value of individual MPA´s i.e. how much does a site contribute to connecting the MPA network compared to the other MPA´s? For details please see BALANCE (2007b).

Figure 11 shows an example of dispersal at a larger geographical scale, the entire Baltic Sea. In this example it is assumed that there is no decay of the tracer (larvae), which is released continuously. The figure shows the concentration patterns after half a year. This is a model of the maximum range of larval dispersal (the pelagic life stage of Baltic animals never exceeds 6 months). However, it is important to realise that this is a maximum only relevant for a few species and that many species have significantly lower dispersal period. In order for most species/populations inside this area to colonize areas far away stepping-stones are needed along the corridor.

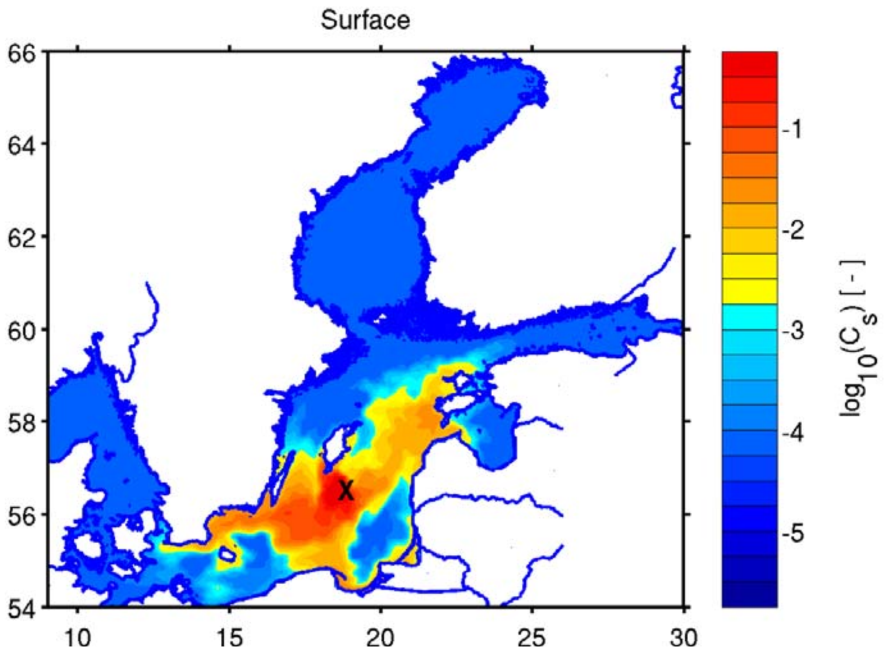

Figure 11. Distribution of a tracer in the surface after 6 months when released continuously from the location marked X. There is assumed no decay of this tracer. The colour show the relative concentration (log10)

Conclusions on modelling connectivity and identify targets

It is possible to model connectivity between sites by linking oceanographic models with ecological or species-specific knowledge, and thus obtain information about how well individual sites within a network are connected.

The study shows how passive dispersal along a blue corridor can be modelled and that one locality within one nation’s territorial waters can influence populations within another nation’s territorial waters.

5 CONCLUSIONS

In order to develop and maintain an ecological coherent network of MPA´s it is important to ensure that the individual MPA´s are connected for the species or habitats for which they are designated. This ecological relevant connection is by BALANCE conceptualised as a "blue corridor" and defined as:

Definition:

***A blue corridor** is a route of particular importance for the population exchange between locations and of importance for the maintenance of biogeographical patterns of species and communities. Blue corridors are shaped by interplay between the biological characteristics of a species, the physical/chemical characteristics of an area, and the geographical location of habitats. Blue corridors can therefore either be concrete physical features or the preferred or realised route of spread of a species.*

5.1 9 steps to planning a connected MPA network

Assessment and planning for improved connectivity can be done in a stepwise process with a defined sequence of actions and decisions building upon existing efforts. It will make it easier both to analyse the individual area, and to compare the conservation effect of including different areas (an important task if a network of areas is analysed). A proposal for such a stepwise decision-making process with nine decision steps organized in 3 major blocks and the conclusions for each step(s) are summarised below:

5.1.1 Define and identify conservation goals

Step 1 – Check the goals of existing individual MPAs.

Step 2 – Define additional goals to be achieved by a network

Conclusions about analysis of goals:

MPA´s and MPA networks should have clearly formulated goals for management. This helps also in the process of formulating plans of connectivity among areas. Goals are often formulated for a particular area, but goals should also be formulated for systems (networks) of areas.

If the goals are not specific enough, identify key species or groups to analyse from the connectivity point of view.

5.1.2 Define and identify environmental values and threats

Step 3 – Identify the connectivity needs (temporal development) for the species groups listed below:

a. Species and populations of invertebrates;

b. Species and populations of plants and algae;

c. Fish;

d. Mammals.

Conclusions about analysis of connectivity needs:

Although detailed information on connectivity needs of species and populations often is missing, there is basic information available on the reproductive biology (larval vs. direct development) and migration ecology of many species. This information can at least be used to make initial analyses if connections to other areas are likely to be important to the population processes of the area of interest. Also, the planning process should be seen as an iterative, stepwise process that should be regularly be revised to and improved when more data is available. In situations where the area contain many species with different reproductive modes, the are several options for selecting which species to use for the connectivity analysis:

a) The species for which the goals of the area are formulated (i.e. the decision on which species is important is made beforehand);

b) The species which are ecologically most important (e.g. keystone or habitat-forming species);

c) The species with the most stringent need for connectivity design (with the reasoning that if the connectivity for this species is ensured, then the connectivity for other species should be ensured too);

d) or just any species for which good data are available.

Step 4 – Identify and assess potential threats and limits of connectivity

a. Describe water movement;

b. Assess destruction of habitats (increased fragmentation);

c. Assess changes in habitat quality (pollution, eutrophication);

d. Assess over-harvesting of commercial species, leading to lower reproduction and dispersal rates.

Conclusions about identification of threats and limitations to dispersal:

This step is essential in order to formulate concrete actions. Natural and human processes may contribute to limiting the dispersal. Preferably, the consequences for the connectivity in MPA networks of any human activity or construction should be assessed.

Human disturbances may be physical (e.g. construction, exploitation) or chemical (pollution). Information of the extent of human activities is probably easier to find than information on the biological characteristics of dispersal.

5.1.3 *Define and identify management actions*

Step 5 – Identify targets concerning connectivity.

Conclusions about identifying targets for connectivity:

It is possible to model connectivity between sites by linking oceanographic models with ecological or species-specific knowledge, and thus obtain information about how well individual sites within a network are connected.

Passive dispersal along a blue corridor can be modelled and that one locality within one nation's territorial waters can influence populations within another nation's territorial waters.

Step 6 – Identify the possible actions.

Conclusions on the identification of actions:

In most ways, the knowledge, methods and regulations used to identify actions to ensure connectivity are no different than what is already used in marine environmental planning. The difference is the additional emphasis not only on effects on the area where the threat occurs, but also on effects in other areas. Data and analyses from other activities (monitoring programmes, resource management) may be important for the management of connectivity among MPAs. Blue corridors can be secured through MPAs (e.g. stepping stones) or more general management between designated sites. A combination of tools is probably the most efficient solution. This means that there is a strong need for close cooperation between different groups of managers e.g. conservation managers and resource use managers.

Step 7 – Practical implementation

Conclusions on practical implementation:

The process will probably not differ in any fundamental way if the planning is for an MPA "with connectivity" (as part of a network) or for an "independent" MPA. However, some parts of the implementation, e.g. stakeholder involvement and support, may be more difficult. One way to facilitate the process may be through careful formulation of goals and targets both for individual sites and for the network of sites. It is important to be clear about the role that an individual site may have for the common conservation goals for the network.

Step 8 – Monitor of the effects of the actions.

Step 9 – Revise the management plan.

Conclusions on revision of the management plan:

There is a cost (financial, time, credibility) to change an existing management plan, but it is a waste of resources to have a management plan or a network of marine protected areas that does not achieve the aims of their existence.

For such adaptive management, the rules of how, when, and by whom the plans may be revised should be formulated in the management plan.

6 REFERENCES

In this report we have chosen not to give direct citations of the primary literature. The interested reader can find a more in-depth coverage of the issues discussed here, including literature references, in the literature review published in the BALANCE project (BALANCE 2006a), and in the other BALANCE reports listed below.

Palumbi , S.R. 2004: *Marine reserves and ocean neighbourhoods: The spatial scale of marine populations and their management.* Annual Review of Environment and Resources 29: 31-68.

Pomeroy, R.S., Parks, J.E. and Watson. L.M. 2004: *How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness.* IUCN, Gland Switzerland and Cambridge, UK. 216 pp.

Balance reports

BALANCE (2006a): Martin, G (ed.) 2006: *Literature review of "blue corridors" concept applicable to the Baltic Sea conditions.* BALANCE Interim Report No 4. 67 pp.

BALANCE (2006b): Andersson, Å. and Liman, A.-S. (eds.) 2006: *Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea.* BALANCE Interim Report No. 2. 19 pp.

BALANCE (2007a): Bergström. L., Korpinen, S., Bergström, U. And Andersson, Å. 2007: *Essential fish habitats and fish migration patterns the Northern Baltic Sea.* BALANCE Interim Report No. 29.

BALANCE (2007b*):*): Bendtsen, J., Söderkvist, J., Dahl, K., Hansen, J.L.S. and Reker, J. 2007: *Model simulations of blue corridors in the Baltic Sea*. BALANCE Interim Report No 9. 25 pp.

BALANCE (2007c): Piekäinen, H. and Korpinen, J. (eds). 2007: *Towards ecological coherence of the MPA network in the Baltic Sea.* BALANCE Interim Report No. 25. 75 pp.

These and other reports from the BALANCE project can be downloaded at www.balance-eu.org/publications

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.