IMSA AMSTERDAM

SUSTAINABILITY & INNOVATION

The Cascade Model: balancing ecological risks and economics in the Wadden Sea area

Overview of a "model under development"

Janne van den Akker
Tammo Oegema
Hein Sas

July 2007
NAWV398

(translation: Eva Klok, May 2008)

Contents

page

1. Introduction

In 2003–2004, IMSA Amsterdam developed the Cascade Model in order to elucidate the Wadden Sea controversy. This model played an important role in the advice by the Advisory Group on the Wadden Sea Policy (also called Meijer Commission) to the Dutch government. The ideas and methodology behind the model and the calculations were published in Dutch in 2007. Obviously, the Cascade Model is "work under development".

The Dutch Nature Conservation Law which implements the European Birds and Habitat directives, serves a.o. to protect the Wadden Sea and the coastal zone of the North Sea. For nearly each and every (economic) activity that is to take place in these areas, a permit is required under this law. In the process of getting a permit, the state of the art in scientific knowledge plays an important role. The legalities of the law, however, make it difficult to compare and assess in an integral way the various activities in the same area/timeframe. The Cascade Model is an attempt to facilitate such a comparison. It has proven its effectiveness in ranking the relative degrees of harmfulness of various activities in the Wadden Sea.

The present report explains what the Cascade Model aims to achieve and how it is done. Full details of all eight activities under study are available in Dutch only.

In a densely populated country like the Netherlands, human activities in vulnerable nature reserves are quite common. Unlike those abroad, all Dutch nature protection areas are cultural landscapes with a certain degree of naturalness, in which people have lived and recreated since history. It is not easy to assess the impact of human activities on natural values; and it is even more problematic to decide which activity has the greatest influence and might need to be restrained. Balancing activity A, which disturbs the quietness, and activity B, which negatively affects the water quality is like comparing apples and oranges. Even so, this is exactly what the Cascade Model is meant to do: enabling a comparison by converting the impact of all activities on the ecosystem (including morphology) into one variable. Whether or not an activity can be tolerated is then to be determined by advancing knowledge on the resilience of the ecosystem.

In chapter 2 of this report we outline the Cascade Model itself, the history behind it and its results. Chapter 3 depicts the quantitative form (the “methodology”) of the model, systematically describing the impact of interventions in the ecosystem of the Wadden Sea. In the Dutch report , chapter 4-11 deal with eight different activities in detail.

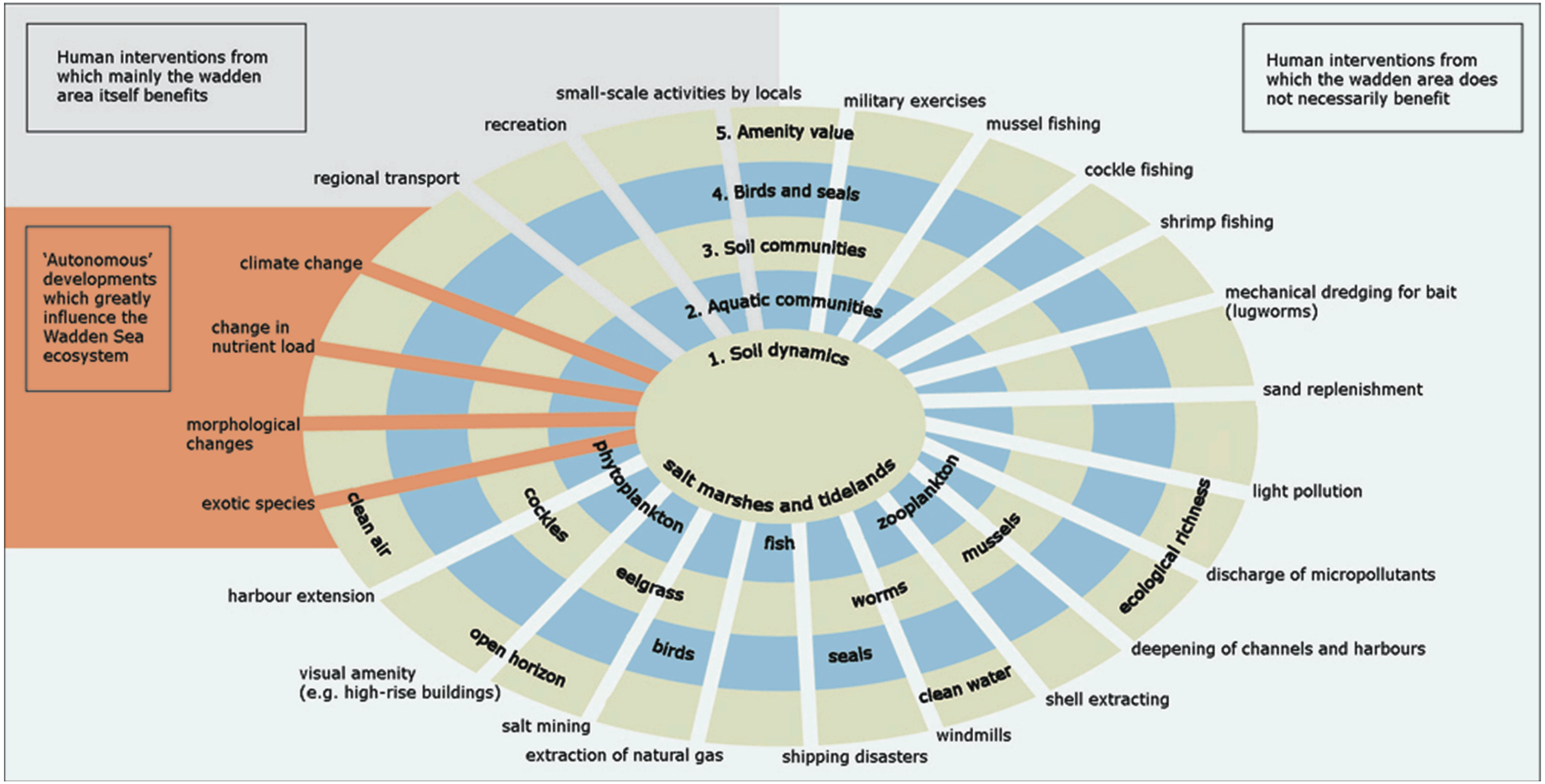
The following persons have contributed to the development of the Cascade Model within IMSA: Wouter van Dieren, Hein Sas, Tammo Oegema, Janne van den Akker, Kim Nackenhorst, Martijn Lodewijkx and Sven Drillenburg Lelijveld. The Advisory Commission consisted of W. J. Wolff (State University of Groningen, now retired), H.J. Lindeboom (Alterra, now part of Imares), B.J. Ens (idem; now working for SOVON Bird Research) and A.P. Oost (Dutch National Institute for Coast and Sea, RIKZ). We would also like to thank all those who have contributed to elaborating the first sketches, as well as those who have constructively criticised our calculations and often offered us excellent ideas for further developments.

2. The Cascade Model in the Wadden Sea discussion

For years on end, it had been impossible to reach scientific consensus on the effects of several -much debated- human activities in the Wadden Sea, such as mussel and cockle fishing, the extraction of natural gas, and recreation. Because of the complexity of the ecosystem, scientists and knowledge institutes have – as usual – specialised in part of the system, such as fish, shellfish or morphology. As a result, ecologists investigating the impact of one human activity on all compartments of the ecosystem often work in teams. A team that can investigate the effects of various human activities is much harder to form, though. And the summum of complexity is attempting to assess all the effects of various activities simultaneously on the ecosystem.
Without comparing the effects of human interventions, however, it is impossible to decide which activities should be limited or stimulated with priority – and to decide on the priorities of scientific research.

For this purpose, we have developed a system that can analyse ecological risks: the Wadden Sea Cascade Model (figure 1). It serves to compare the influence of human interventions on the ecosystem of the Wadden Sea area, by converting them into a three-dimensional vector and eventually in one single value.
The Cascade Model combines various scientific disciplines. In the course of 2003, scientifically based so-called "dossiers" were drawn up for a number of interventions in the Wadden Sea area, and the first "scores" were given. The Advisory Commission (W.J. Wolff, B.J. Ens, H.J. Lindeboom and A.P. Oost) commented on the set-up of the model and the first results. This process has resulted in quantified dossiers for *eight* activities.
These results have been made available to the participants of the Fryske Akademy In January 2004, 25 Wadden Sea experts met in the so-called Fryske Akademy Consultation, where they ranked *fifteen* human activities (see § 2.3) according to their impact on the ecosystem of the Wadden Sea. This had never been done before on such a scale.

Figure 1: The Wadden Sea Cascade Model: ecological "rings" and the effects of various interventions (source: IMSA Amsterdam)



2.1. The theory behind the Wadden Sea Cascade Model

The model is designed to make an inventory of human activities and objectify their relative effects on the ecosystem of the Wadden Sea. It is a communication model, meant to underpin a scientific discussion. The notion of a "cascade" implies that, ecologically speaking, the mudflats consist of a *series of mutually dependent layers*. Basically this ecosystem can be described in five successive rings. Chapter 3 gives a more detailed description of the arithmetic method.

The Wadden Sea area is defined by a system of inter-tidal mudflats and tidal lands: the soil dynamics (ring 1). This is the basis for the next ring, which again determines the successive ring, etcetera.
The second ring consists of the aquatic communities or the so-called primary production of phytoplankton and zooplankton as well as the animals feeding on it, such as fish and shrimps. In the third ring, we find the soil communities: all creatures on and in the moving seabed that feed on the plankton, for example shellfish and lugworms. The fourth ring is the spectacular fauna of the Wadden Sea: the birds and seals which, again, feed on the previous rings. The fifth ring encircles these four rings. It is formed by mankind, enjoying the Wadden Sea, being (able to be) there: the amenity value. Note: our only concern here, are the effects on the ecosystem. Economic factors, the purpose and need of an activity or emotional and/or fundamental arguments fall currently outside the scope of the model.

Outside the five rings, we have grouped the (human) activities. The purpose of the study was to give each of these activities a score, depending on the impact on the ecosystem (the five rings).

The activities reflected in the figure, have been described as they were taking place in the 2003-2004 period or as they could take place in a realistic scenario. This scenario is based on interviews with Wadden Sea experts. The descriptions of these activities, the dossiers, are partly quantitative and partly qualitative, and are meant to underpin a scientific discussion about the acceptability / admissibility of activities in the Wadden Sea area.

The interventions in the area consist of exogenous factors (in red), practices that are linked closely to the area (in grey), and practices that can be accepted as well as prohibited (light green). The radiuses in the figure indicate that interventions can have an influence on each and every ring. *The model converts the influence of interventions systematically and consistently into scores per ring and in a total score.* To this end, indicators (such as the area of mudflats that fall dry, fish, birds and seals) have been defined for each ring, and are mentioned in those.

For each intervention, we have defined its effects on the indicators *in three different dimensions*: the surface area that is being influenced by the intervention (0-100 percent of the Dutch Wadden Sea area), how long this influence lasts (0-1 century), and the intensity of the influence (0 = no influence, 1 = total destruction).

In consultation with the Advisory Commission, IMSA Amsterdam has attributed weight factors to each indicator and to each ring. This has made it possible to assign a score to varying interventions and thus to compare their effects on the ecosystem of the Wadden Sea. The data used for these calculations have been collected in dossiers, drawn up by IMSA Amsterdam in close collaboration with the Advisory Commission.

2.2. Result according to the dossiers

As an example, we here present the calculation for the intervention of climate change (defined as a rise in temperature).
As a result of climate change, some 21 km^2 of mudflats (1.8% of the total Wadden Sea area) will gradually (time score 0.5) disappear (intensity 1).
Score for ring 1 (mudflats): 1.8% x 0.5 x 1 = 0.009.
This is one fifth of the total score (five rings with equal weight):
sub-score 1/5 x 0.009 = 1.8×10^{-3}.
We have no data concerning the influence of climate change on the aquatic communities, but our estimate for the effect on ring 2 is 0.
Disappearing mudflats will result in a loss of soil communities, which gives a score of 6.7×10^{-3} on ring 3.
This in turn affects the bird populations: a score of 9.3×10^{-3} on ring 4.
Resulting in part of the natural value disappearing, which translates into a score for the amenity value of $2,3 \times 10^{-3}$.
This comes down to a total score for all rings of well over 20×10^{-3}.

We did not make dossiers for all interventions, partly because of a lack of time, but especially because of a lack of data. Applying the method to the available dossiers, has resulted in the following scores (state of affairs at the end of 2003).

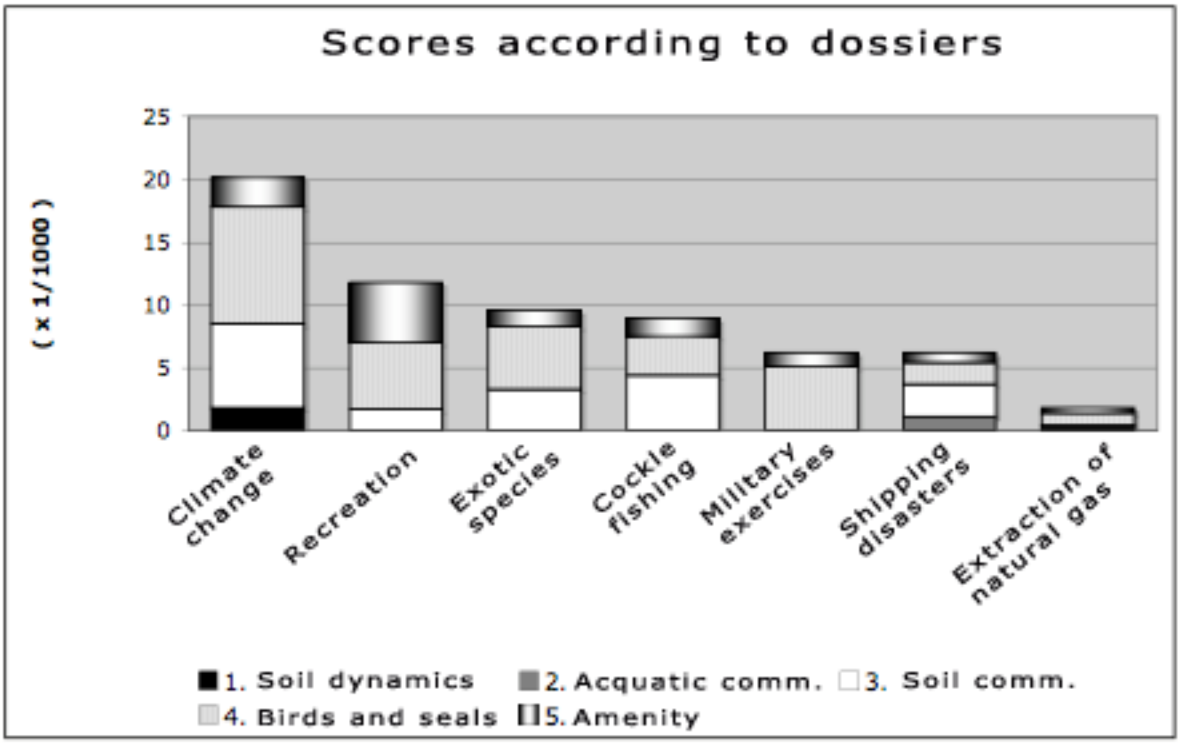


Figure 2: Scores according to dossiers

2.3. Fryske Akademy Consultation: verification of the Wadden Sea Cascade Model

Thirty Wadden Sea experts from all relevant research institutes, universities and ministries were invited to participate on a formal meeting on January 15, 2004. The majority of the invitees from the shellfish sector did not attend, which may have caused a certain bias in the results.

The meeting took place in the Fryske Akademy in Leeuwarden. The purpose of this Fryske Akademy Consultation was to discuss the activities for which dossiers had been and preliminary scores were calculated, assign score together (Delphi method) to each activity and, by doing so, ranking the scores according to their relative effects on the ecosystem of the Wadden Sea. The essence of the results is that they depict the scientific consensus on the relative effects of activities on the ecosystem.

For each ring, the workshop participants assigned a score to the various interventions. By determining the average and spread of the scores, a ranking in influence and an impression of the uncertainties therein emerged. The ranking, the uncertainties and the discussions have been summarised in the workshop report (IMSA 2004, Account Fryske Akademy Consultation (in Dutch)). When workshop participants felt they lacked expertise regarding a certain intervention, they did not assign a score, but placed a question mark.

The final results are represented in figure 3. The red bars are the total scores per activity, averaged over all participants. Note that they are based on the first four rings, which represent the physical ecosystem. During the discussion, it was decided to leave out the scores on ring 5, the amenity value, as the participating experts felt they lacked sufficient scientific insight on this.

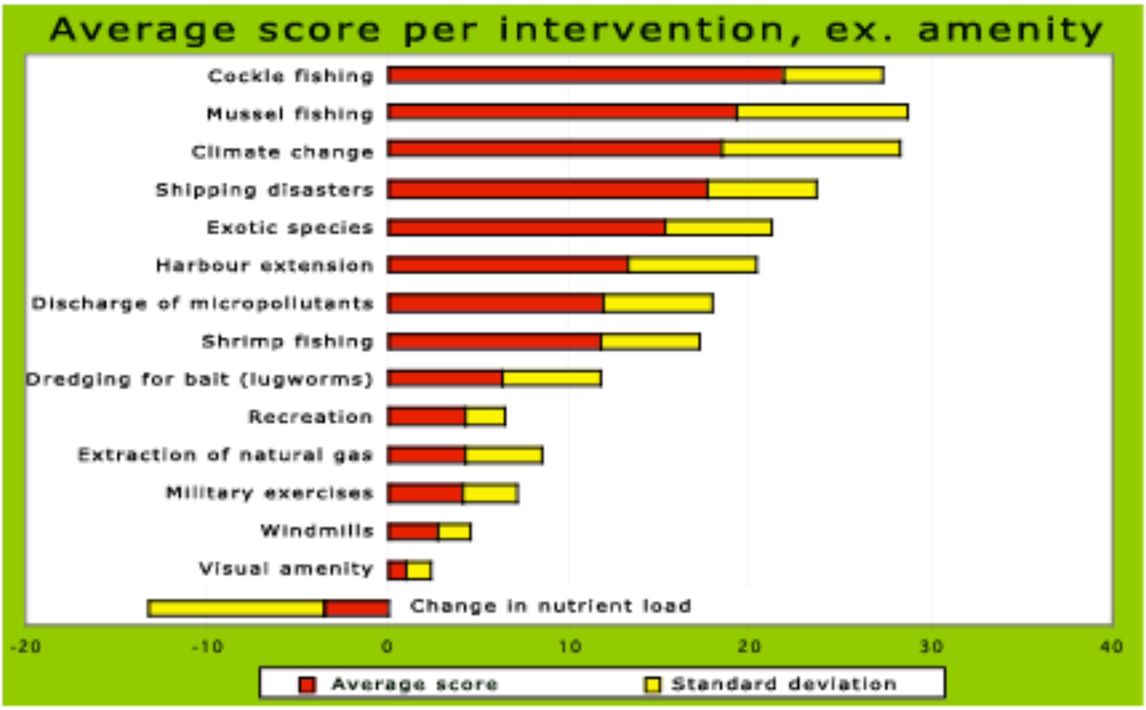


Figure 3: Average score per intervention, with standard deviation

The yellow bar in figure 3 represents the standard deviation. It shows for instance that there is more agreement between the experts about the effects of cockle fishing than about those of climate change.

The most important recommendation of IMSA Amsterdam to the Advisory Commission for the Wadden Sea Policy as a result of this consultation is the following.

From the stance of efficient nature management (excluding amenity value), in research, policy making as well as regulation attention should be focussed on activities which have a large impact on the ecosystem: cockle fishing, mussel fishing, climate change, shipping disasters and the increase/spreading of exotic species (such as the Japanese oyster).

For the activities with an average impact (harbour extension, emission of micro-pollutants, shrimp fishing and dredging for bait (lugworms) additional research is important in order to reduce uncertainties and to gain better insight in their effects.
Activities with a relatively small impact are visual amenity, windmills, gas extraction, military exercises, recreation and a reduced input of nutrients.

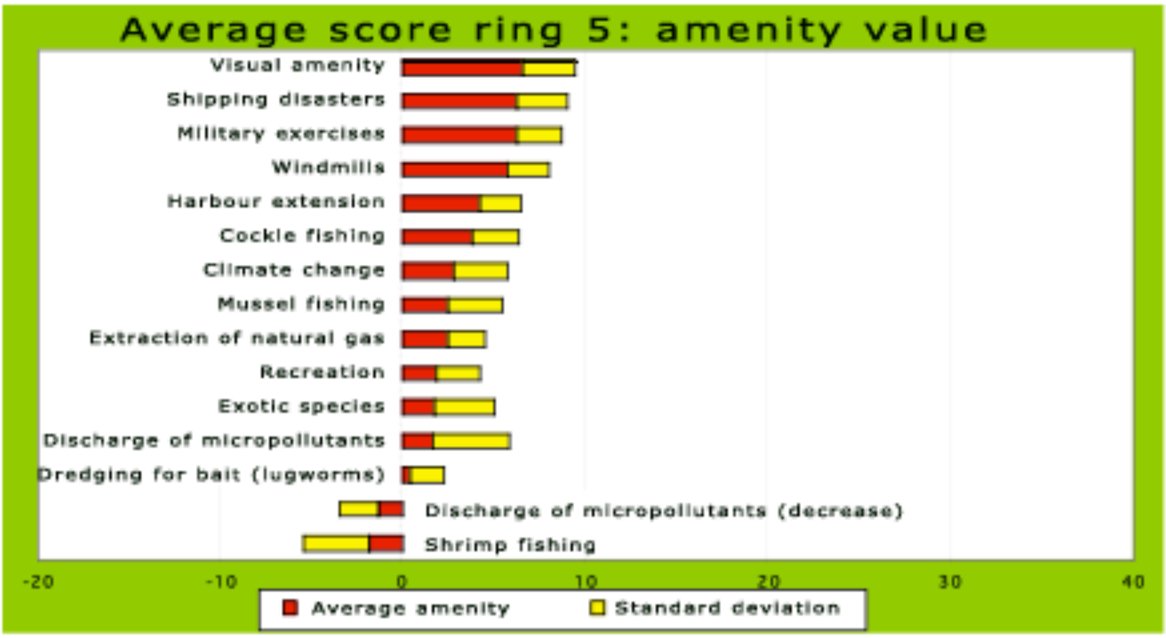


Figure 4: Average scores for ring 5 in the Wadden Sea Cascade Model (amenity value) and the relevant standard deviation

3. The Cascade Model: methodology

3.1. System boundaries

The model concerns the impact of human interventions on the nature protection area (or the ecosystem) of the Wadden Sea. We aim to identify the effects of these interventions and to rank them according to their seriousness. The nature protection area of the Wadden Sea has been defined in the third Key Planning Decision Wadden Sea.

In concrete terms, these system boundaries imply the following.

- In principle, all interventions which have been mentioned more than once by our interviewees or which are mentioned in the Key Planning Decision Wadden Sea are taken into account.
- Interventions which are taking place outside the area defined in the Key Planning Decision, but which have a major influence on the area, are taken into account as well (this is the "external influence" mentioned in the Key Planning Decision).
- Interventions are judged according to their impact (negative as well as positive) on the whole ecosystem of the Wadden Sea, thus:
  - effects on the physical ecosystem, i.e. all (essential and scientifically underpinned) effects of a physical, chemical and biological nature (for which the right indicators need to be identified, see below)
  - effects on the amenity value of the ecosystem for mankind.

In the relevant literature a discussion is taking place whether or not the amenity value should be considered as one of the effects on the ecosystem. Since it is part of the collective good (the natural area) and is playing such a prominent role in the discussions regarding the Wadden Sea, it is no option to leave it out of our model. This is also the opinion of the Dutch Council for the Rural Area.

The model only deals with the *ecological* effects of interventions; not with their value (in economic terms or not) for human society. Therefore, it does not aim to prioritize between interventions, as this would implicate the possibility to weigh their effects on the ecosystem with their purpose. This is a next step, though, which requires separate research.

3.2. Cornerstones of the method

The forementioned sets out the conditions the method has to comply with.

- It needs to give a – preferably quantitative – score for each human intervention to be taken into consideration, thus creating a ranking order.
- It has to be possible to include both negative and positive effects of an intervention.
- It needs to do justice to all main characteristics of the ecosystem of the Wadden Sea (including the amenity value).
- It needs to be transparent, i.e. it should be clear which assumptions and choices are underpinning the scores per intervention.
- It needs to call for discussion.

The area in which human interventions and their effects are to be charted is, as stated above, the (Dutch) part of the Wadden Sea that has been designed as a nature protection area in the Key Planning Decision Wadden Sea (2400 km^2, half of which consist of tidal lands; see Quality Status Report 1999).

Our point of departure is that there are four aspects – all of which are explained briefly hereunder – which determine the impact of interventions. We then define how the score per intervention is to be expressed mathematically. And finally, we elaborate on how the various indicators are to be made operational, and we give a concrete, numerical example.

The four aspects are: *the parts of the ecosystem, the degree of influence, the weighing factors, and the time span of the influence.*

- The *parts of the ecosystem*, or the rings on which an intervention has an impact are (see figure 1: The Wadden Sea Cascade Model)[1]:
  1. the dynamics of the soil of the Wadden Sea
  2. the aquatic communities
  3. the soil communities
  4. the communities that are not permanently tied to soil or water, particularly as birds and seals
  5. the amenity value.

[1] There is no separate ring for water quality. We assume that a bad water quality would manifest itself in the biological indicators of rings 2 – 4.

We number the rings with the index i, which goes from 1 to 5. We use the symbol W_i to indicate the weight, the importance, that we give to ring 1 when calculating the total score. All rings have an equal weight of one fifth.

- An intervention has a certain *degree of influence* on the indicators of each ring. The symbol for these indicators is a_{ij}. The index i stands for the ring, the letter j stands for the indicators (to be determined) within this ring. By means of desk research and interviews with experts we have assessed the degree in which an intervention affects these indicators. For the harm done to the morphological variables in ring 1, the criterion is: disappeared. For the organisms in rings 2 and 3: dead. For the birds and seals in ring 4: disrupted or chased away from the Wadden Sea. For ring 5: the human perception is disrupted. We divide the degree of harm done by the volume of the total population or by the total of the indicator in question in the –undisturbed – Wadden Sea. The a_{ij} are, therefore, relative numbers (fractions), that go from 0 (no influence) to 1 (maximum influence). Since we assume that most human interventions cause some harm, the sign a is positive in case of harm. The sign a therefore becomes negative if an intervention has a positive influence on the ecosystem of the Wadden Sea.

- Since not all indicators need to have an equal weight, we have assigned a specific *weight factor* w_{ij} to each indicator. These weights have been determined in such a way that their sum per ring equals 1. The box in the next paragraph gives an overview of all these weight factors.

- The *time span of the influence* (symbol t) is to be assigned per ring i and per indicator j. We assume that the maximum time span of an intervention is one hundred years (thus, the final year being 2103)[2]. We distinguish between repetitive and single events. The repetitive ones happen every year. Research is needed to determine whether or not their impact lasts throughout the year. If not, then this needs to be accounted for by multiplying one hundred years by that part of the year in which the intervention usually happens. In case of a single event, we need to account for the variation in the intervention over its duration. We express the time span of the intervention as a fraction of one hundred years. Therefore, this scale goes from 0 to 1 as well.

[2] In a method such as this, it is necessary to choose a limited time span to prevent repetitive interventions (that happen every year) from dominating single events (limited in time and impact), even when such a single event is quite serious and prolonged. The time span of one hundred years seems long enough to do justice to all the important effects.

We assume the influence per intervention to be proportional to the factors a, w and t. The subscore per ring (index i) is calculated by multiplying the factors a_{ij}, w_{ij} and t_{ij} per indicator (index j) and, subsequently, adding them up over j. Therefore, the formula for the sub-score S_i per ring will be:

$$S_i = W_i * \Sigma_j a_{ij} * w_{ij} * t_{ij}$$

of which:

- W_i = the weight of ring i
- a_{ij} = the intervention indicators j in ring i
- w_{ij} = the weight of indicator a_{ij}
- t_{ij} = the time span in which the intervention influences the indicator a_{ij}.

To get to the total score, we add up all the subscores S_i per ring.

This results in the formula for the total score S per intervention:

$$\mathbf{S} = \Sigma_i S_i = \Sigma_i \Sigma_j W_i * a_{ij} * w_{ij} * t_{ij}$$

S is a number without dimension. The maximum score is 1. In this case, the entire ecosystem of the Wadden Sea is dead, disrupted or has disappeared, at least over a period of the next hundred years.

We are aware of the fact that many aspects of this methodology strongly simplify reality and that they are the product of normative choices. Especially the choice of the weights is purely normative. This means that each and every one of us is free to choose his own weights. However, we have tried to distil a general sense of the relative importance of the indicators from our interviews with various experts, and to express this in their weights. We realise, though, that not everyone involved would do this the same way.

3.3. Elaboration of the methodology and numerical example

Hereunder, we explain in detail how we have determined the scores for the impact per ring, i.e. how we have defined the indicators a and their weight factors w. We discuss them per ring. The numerical examples are based on a hypothetical intervention. The following table gives an overview of the indicators and their weight factors.

Table: Overview of weight factors and indicators

Rings	Weight per ring	Indicators per ring + criteria	Weight of indicators
1. Soil (mudflats, tidal lands, trenches)	1/5	Mudflats: surface area (1199 km^2) Tidal lands: surface area (82 km^2)	0,5 0,5
2. Water communities	1/5	Phytoplankton: biomass/dead Zooplankton: biomass/dead Fish: biomass/dead or gone	0,33 0,33 0,33
3. Soil communities	1/5	Eelgrass: biomass/dead Mussels: biomass/dead Cockles: biomass/dead Worms: biomass/dead Vegetation on tidal lands: biomass/dead	0,2 0,2 0,2 0,2 0,2
4. Birds and seals	1/5	Birds: numbers/dead or gone. Species: ▪ eider duck (characteristic) ▪ oystercatcher (characteristic) ▪ red knot (characteristic, winter) ▪ curlew (shy) ▪ grey plover (high Wadden Sea) Seals: grey and common, numbers/dead or gone	 0,1 0,1 0,1 0,1 0,1 0,5
5. Amenity value	1/5	Numbers of "disrupted" people, because of: ▪ no clean water/air ▪ no open horizon ▪ no quietness ▪ decrease in ecological diversity: score ring 4	 0,25 0,25 0,25 0,25

Ring 1: The dynamics of the Wadden Sea soil

With the dynamics of the Wadden Sea soil we mean: the interaction of water and sediment which sustains the system of inter-tidal mudflats and tidal lands. Without these, the unique character of the Wadden Sea would be lost. We therefore presume the area of mudflats and tidal lands to be the best measure for these dynamics. Consequently, we choose a relative decrease in the areas of mudflats and tidal lands in the Dutch part of the Wadden Sea as indicators for the impact of an intervention in ring 1. We estimate the total Dutch area of mudflats at 1199 km^2 (Louters 1994) and the total Dutch area of tidal lands at 82 km^2 (Dijkema, 2003). We give both indicators the equal weight of a factor 0.5, and the entire ring, as stated before, the weight of 1/5.

Arithmetic example on the basis of a hypothetical intervention

If the intervention would cause, over a period of thirty years, a loss of one hundred km^2 of mudflats and of ten km^2 of tidal lands, then the sub-score for ring 1 would be:

S_1 = 1/5 x 30/100 x (0.5 x (100/1199) + 0.5 x (10/82)) = 1/5 x 30/100 x 0.10 = 0.006

In this example, the factor 1/5 represents the weight of the ring, the factor 30/100 the time span of thirty years in the maximum period of one hundred years, and the factors 0.5 the importance of the mudflats and the tidal lands within the ring.

Ring 2: The aquatic communities

The factors determining the influence of an intervention in this ring are the presence and the health of water-bound biota. As indicators we choose the impact of the intervention on the biomasses of the populations (dry weight) of phytoplankton, zooplankton and fish, relative to the total of the Wadden Sea populations. We give them all an equal weight, so one third each. We aim to determine the relative influence of the intervention on the populations, which means that we do not need the data for the total biomass. We give the ring as a whole a weight of 1/5.

Arithmetic example
If our intervention would cause, over a period of twenty years, a decrease in the total Wadden Sea phytoplankton biomass of 15%, in the zooplankton biomass of 30% and in the fish biomass of 3%, then the sub-score for ring 2 would be (rounded off):

S_2 = 1/5 x 20/100 x (0.33 x 0.15 + 0.33 x 0.30 + 0.33 x 0.03) = 1/5 x 20/100 x 0.16 = 0.006

Again, the factor 1/5 represents the weight of the ring, the factor 20/100 the time span of twenty years in the maximum period of one hundred years, and the factors 0.33 the weight of phytoplankton, zooplankton and fish populations within the ring.

Ring 3: The soil communities

Here we determine the impact of the intervention on the presence and the health of soil-bound organisms. As indicators we choose: eelgrass, mussels, cockles, worms and the vegetation of the tidal lands (each with a weight of 0.2). Again, we determine the effect of the intervention as compared to the total biomass of the indicators, except for eelgrass, for which we take a surface measure. In order to make our calculation somewhat easier, we presume an equal spreading of the indicator organisms over the Wadden Sea[3]. The ring as a whole is again given the weight of 1/5.

Arithmetic example

If the intervention causes, over a period of twenty years, a decrease in the total worm biomass of 10%, of the mussel biomass of 3%, of the cockle biomass of 2% and of the surface area of eelgrass in the Wadden Sea of 0.5%, then the sub-score comes to (rounded off):

$S_3 = 1/5 \times 20/100 \times (0.25 \times 0.10 + 0.25 \times 0.03 + 0.25 \times 0.02 + 0.25 \times 0.005) =$
$1/5 \times 20/100 \times 0.04 = 0.0016$

Ring 4: Birds and seals

We allege the presence of seals to be equally important to the presence of (all) birds. So, we give both a weight factor of 0.5. For the seals we choose the numbers of individuals in the subpopulations of the grey and the common seal as one indicator. For the birds we choose, for practical reasons, the following indicator species: eider duck (reason: characteristic species), oystercatcher (reason: characteristic species), red knot (reason: characteristic species, winter visitor), curlew (reason: very shy bird) and grey plover (reason: typical for the high Wadden Sea). Again, we look at the numbers of individuals[4]. And, once more, we presume an equal impact of the intervention on all indicator organisms in the Wadden Sea. All indicator bird species are given the weight of 0.10. The entire ring is given a weight of 1/5.

Arithmetic example

If the intervention causes, over a period of fifteen years, a decrease in the total seal population in the Wadden Sea of 4%, of the eider duck of 10% and of the oystercatcher of 2%, then the sub-score comes to (rounded off):

$S_4 = 1/5 \times 15/100 \times (0.5 \times 0.04 + 0.1 \times 0.10 + 0.1 \times 0.02) = 1/5 \times 15/100 \times 0.03 = 0.0009$

[3] This is a justified assumption as long as the intervention in question is spread over a considerable part (several percents) of the Wadden Sea. This is generally the case.

[4] Afterwards, many discussions have taken place regarding the choice of the indicator species, It was stated that both plant- and fish eating birds should be taken into account in order to include all trophic levels of the system.

Ring 5: The amenity value

From the preparatory interviews we have distilled the following indicators for the amenity value of the Wadden Sea: the experience of clean water and clean air, visible ecological diversity (indicated by the presence of birds and seals), an open horizon (no visual disturbance) and quietness. Ecological diversity is the indicator for ring 4. Regarding the other indicators we need to decide which part of the Wadden Sea (the area defined in the Key Planning Decision Wadden Sea) is being regarded as disturbed. In the case of air and water quality this comes down to, respectively, an unpleasant smell and visible pollution of the water (refuse, thick layers of algae, etcetera). In the case of the open horizon, we take into account the visibility of man-made objects in various weather conditions. In the case of quietness, it is the noise made by people and human objects. To calculate the impact of the interventions, we presume that people are equally spread over the Wadden Sea area. We give each indicator an equal weight, being 0.25 per component. Again, the ring as a whole is given a weight of 1/5.

Arithmetic example
If the intervention does not affect the quality of water and air, but causes, over a period of thirty years, a visual disturbance in 10% of the Wadden Sea, a disturbance of quietness in 25% of the Wadden Area, and if ring 4 (the ecological diversity) has a score of 0.0009, then the sub-score is:
$S_5 = 1/5 \times 30/100 \times (0.25 \times 0.10 + 0.25 \times 0.25) + 0.25 \times 0.0009 = 0.0055$

In case an intervention would indeed cause all the above-calculated scores, then the sum would be the following total score (rounded off):

$\mathbf{S} = 0.006 + 0.006 + 0.0016 + 0.0009 + 0.0055 = 0.02$

One could say that this intervention affects 2% of the ecosystem of the Wadden Sea over the maximum period of one hundred years. Since this percentage is relative to *both* the entire Wadden Sea *and* the full period of one hundred years, this is an intervention with a huge impact, even though 2% does not seem to be much.

But since the method is not very precise (the outcome probably has a margin of a factor 2), it would be better to say that some 2% of the Wadden Sea would be affected.

As a rule, we do not account for synergy between the interventions, as this would make the process impossibly complicated. Since most intervention scores will be small, though, it will be possible in practice to add them up, thus making rough combination scenarios.

3.4. Sources

1. Dijkema, K., 2003: Personal communication based on an inventory of tidal lands in the vegetation charts of 1996-2003 of the Dutch Survey Department, 29-9-2003.

2. Louters, 1994: T. Louters and F. Gerritsen, The mystery of the Wadden Sea (original title: Het mysterie van de Wadden), Report RIKZ-94.040, 1994

3. QSR, 1999: F. de Jong et al., Waddenzee Quality Status Report, RIKZ, 1999