Ex Ante Analysis of a Hypothetical International Road Construction Project

REMEDE

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This presentation reflects the authors' views alone.

Presentation structure

- Introduction
- Initial Evaluation - the Impact Event
- Quantifying Debits from Environmental Damages
- Quantifying Credits from Remediation
- Uncertainties
- Conclusions

Introduction

Objectives of the Case Study

- Providing an example of an *ex ante* analysis of environmental liabilities associated with a hypothetical infrastructure construction project.
- Application of resource equivalency analyses to a hypothetical construction of an international road in northeastern Poland, in *ex ante* context
- Illustration of how habitat equivalency analysis (HEA) can be used to contrast the potential environmental damages associated with two alternative routes of road
- Illustration of application of habitat scalars in resource equivalency.
- Illustration of a probabilistic approach to estimating expected environmental damages in *ex ante* situations.

Initial Evaluation - the Impact Event

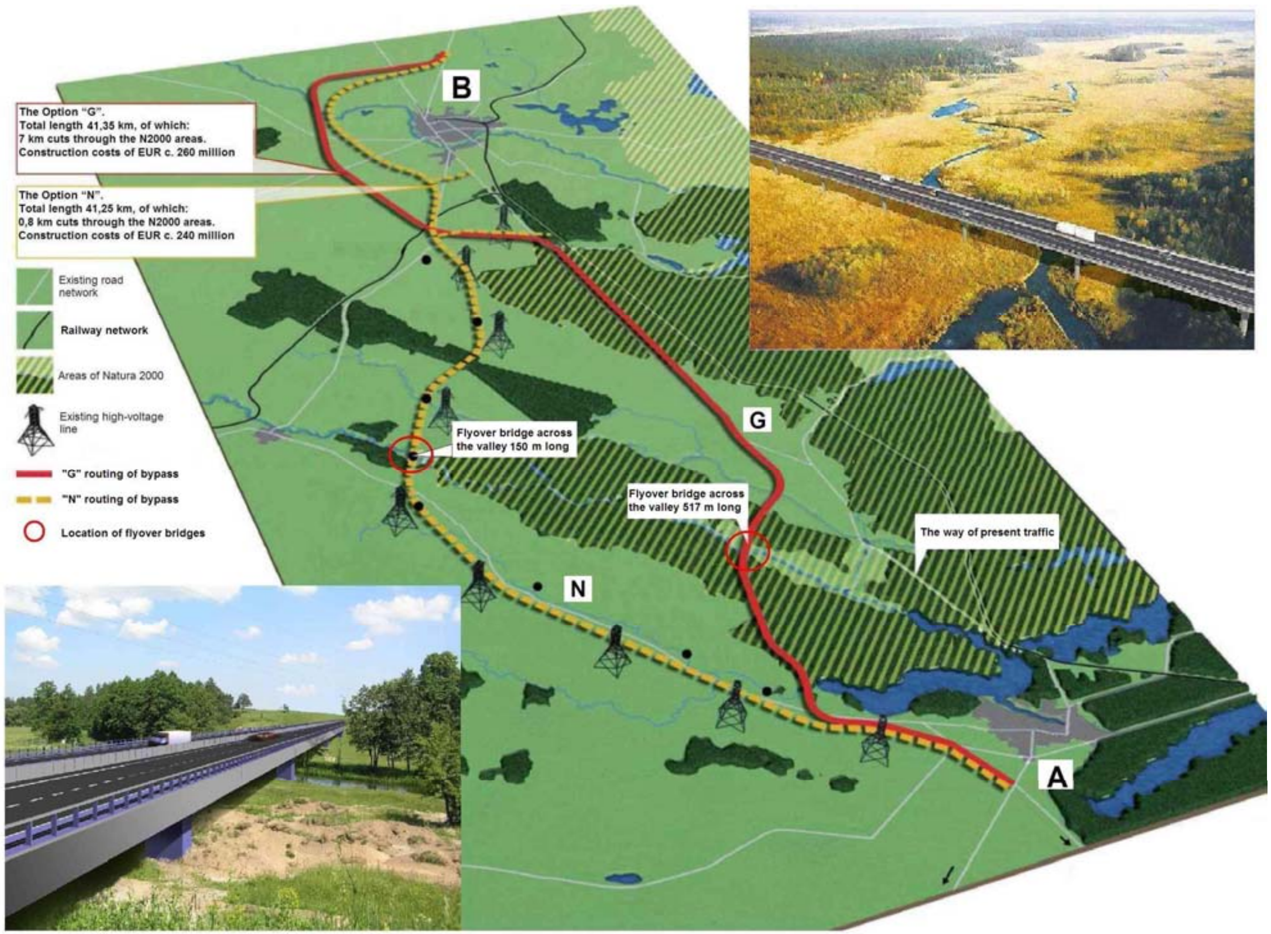
Description of the Incident – the hypothetical case

- The case study involves the anticipated environmental damage associated with construction of an international highway
- Specifically, a highway bypass is planned that would link two cities: City "A" and City "B"
- Two alternative routes are proposed, „G" and „N"
- Route "G" would involve construction of the road through pristine wetlands in a river valley
  - Two Natura 2000 sites
  - Construction of an elevated causeway some 500 m in length above the wetlands and the river valley
- The alternative route, "N", would bypass the Natura 2000 sites and would be constructed within a pre-existing corridor containing electrical lines

Initial Evaluation – the Impact Event

Description of the Incident

Hypothetical road construction alternatives linking City A and City B



Initial Evaluation - the Impact Event

Description of the Incident - the hypothetical case

Key characteristics of the alternative construction routes

Characteristics	Route "G"	Route "N"
Length of river valley at crossing (m)	500	130
Length of elevated bridge/causeway at river crossing (m)	517,34	150,00
Total road length (km)	41,35	41,25
Length of road within Natura 2000 sites (km)	12	1
Construction costs (million EUR)	260	240

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Area characteristic and protected areas

- A “Primeval Forest” SPA site covering nearly 120,000 ha
- A “Habitats” SAC site, covering over 120,000 ha, proposed as a SCI
- A "Primeval Forest"/Important Bird Area of EU Importance, covering nearly 135,000 ha.

- The Primeval Forest is an extensive complex of relatively dense, old-growth forest.
- It lies on a postglacial, sandy plateau 100-140 m asl., with relatively numerous preserved glacial basins and post-glacial lakes and bogs.
- Water bodies totaling 5% of the site surface
- The majority of the site (*c* 85%) is covered by forests, with a few open patches used for agriculture, mostly as grasslands.
- Coniferous forests prevail, predominantly pine stands. There are also patches of well preserved wet and swampy coniferous forests growing on bogs
- The lowest, very wet places in the river valley and around the lakes are typified by riparian wetlands.

Initial Evaluation – the Impact Event

Preliminary Identification of Affected Habitats and Species

Vegetation and habitats of the area

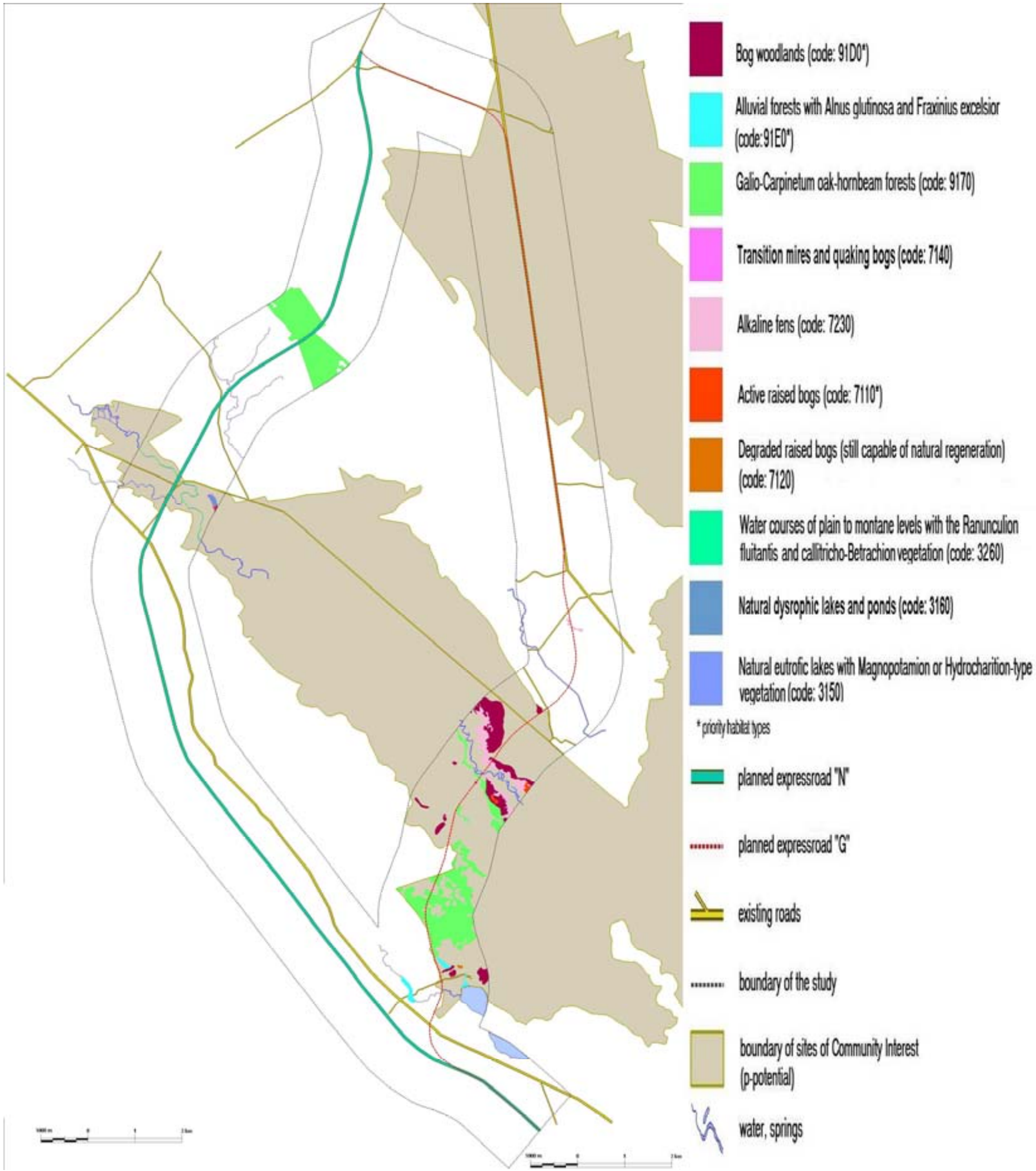
- An extensive network of wetland habitats within the river valley are included within the Natura 2000 network as part of the Special Protection Area “Primeval Forest” under Directive 79/409/EEC.
- Twenty four habitat types of community importance (including 8 priority habitats) listed in Annex I of the Habitats Directive cover *c* 17% (204 km2) of the area of Primeval Forest.
- Extensive patches of bog woodland (code 91D0*), mixed pine-birch stands, and other bog and fen habitats (codes 7110, 7140, 7150, 7210, 7230) highlight the importance of the site for listed habitats.
- Most of the peatland area is covered by vegetation types included in Annex I of the EU Habitats Directive.
- Approximately 100 ha (more than 15% of the valley) is occupied by „alkaline fen” (EU habitat code 7230) with sedge-moss rich fen vegetation.
- Nearly 300 ha are covered by „bog woodland” (habitat *91D0), a priority vegetation type.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Vegetation and habitats

Distribution of habitat types listed in Annex I of the Habitats Directive (92/43/ECC) within the study area



Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Rare and threatened species

Flora:

- Species protected by the EU HD (Marsh Saxifrage *Saxifraga hirculus*, Fen Orchid *Liparis loeselii*, Lady's Slipper Orchid *Cypripedium calceolus*), and
- Dwarf Birch *Betula humilis*, Jacob's Ladder *Polemonium caeruleum*, Adder's Mouth Orchid *Malaxis monophyllos*, Slender Cotton-grass *Eriophorum gracile*, Cotton Deergrass *Baeothryon alpinum*.
- Musk Orchid *Herminium monorchis*,

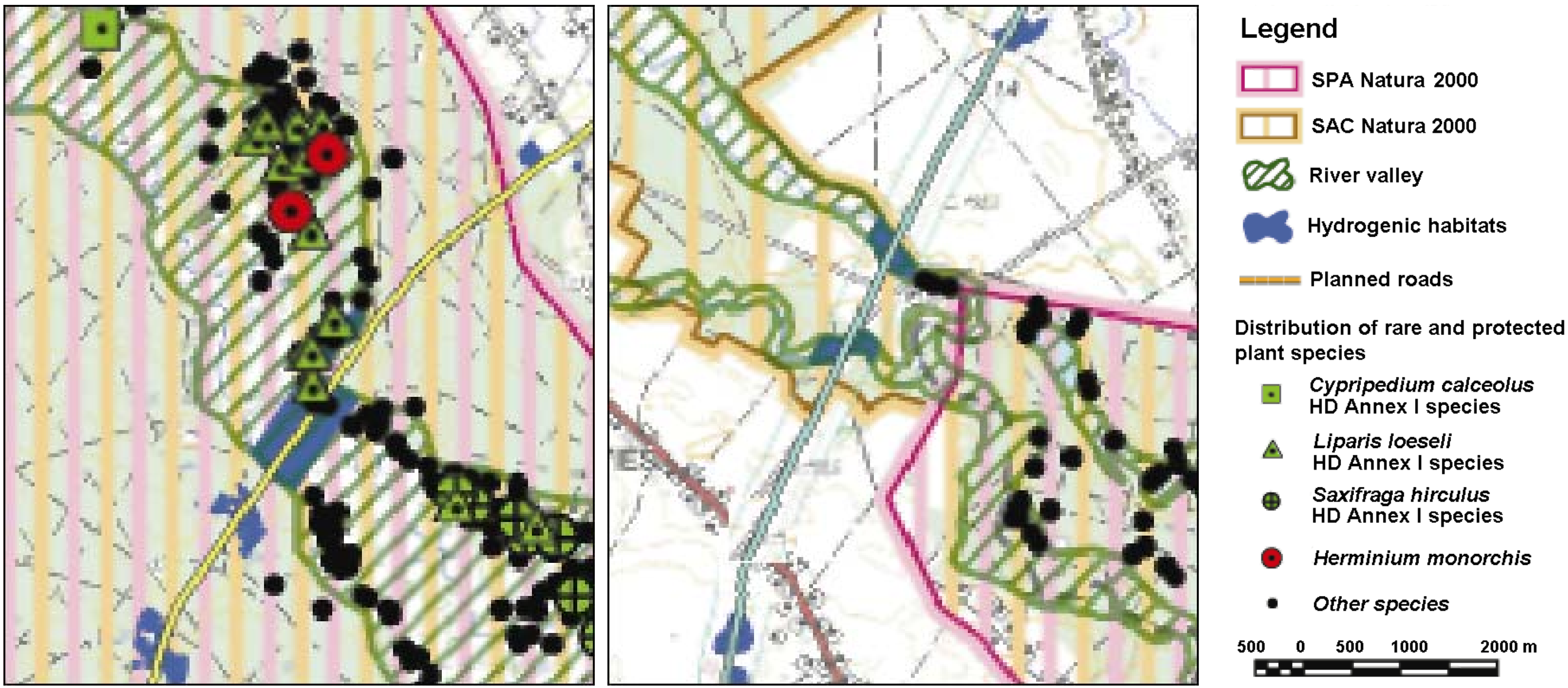
- The open fens of the River valley are a last resort for many plant species that are endangered in Poland and the rest of Europe.
- It accommodates the most numerous and best-preserved Polish populations of two EU Habitat Directive species: *Liparis loeselii* and *Saxifraga hirculus*.
- The valley is the only site in Poland where Musk Orchid *Herminium monorchis* occurs.
- As many as 14 vascular plant species are included in the Polish Red Data Book of Plants (e.g. *Eriophorum gracile, Carex chordorrhiza, Baeothryon alpinum, Herminium monorchis*),
- 32 species of vascular plants, mosses and liverworts are listed in the Polish „red list” (e.g. *Meesia triquetra, Paludella squarrosa, Tomentypnum nitens*),
- 75 species are under protection in Poland.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Rare and threatened species

Occurrence of rare and protected plant species in at river crossing sites for Route "G" and Route "N"



Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Rare and threatened species of the area

Fauna:

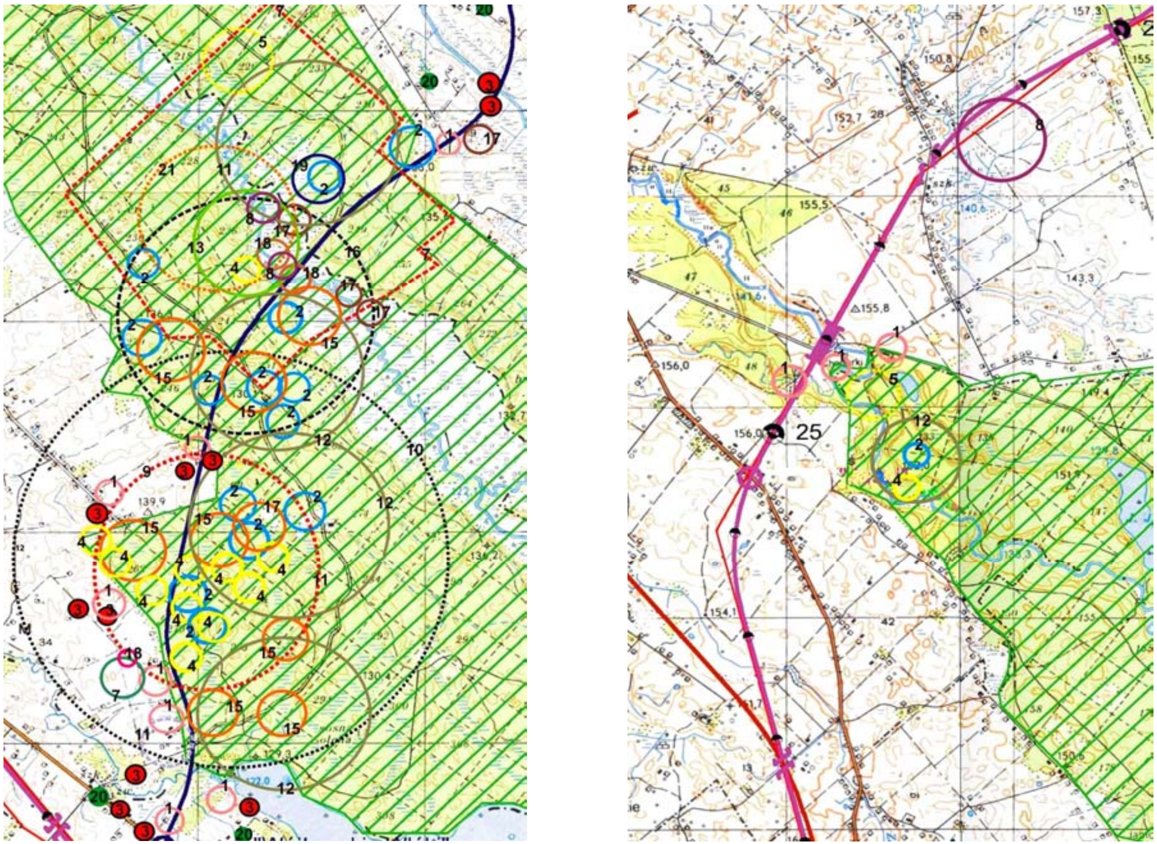
- In Primeval Forest SPA at least 42 breeding bird species listed in Annex I of the WBD
- 12 species included in the list of threatened birds in the *Poland's RDB of Animals* of 2001
- For 8 of Annex I WBD species, the Primeval Forest is one of the 10 most important breeding sites in Poland, supporting >1% of their national populations
- Primeval Forest also provides breeding habitat for a number of rare raptor species such as Short-toed eagle, Black kite, Red kite and White-tailed eagle.
- It is home to five species of mammals listed in Annex II of the Habitats Directive: wolf (26-28 ind., 5% of Poland's population), lynx (16 ind., 8% of country population), otter, beaver, and pond bat
- Local population of elk is of considerable importance, counting for c. 150 ind.
- Together with other neighbouring natural forests, it represents the largest continuous forest tract in NE Poland, and is of key importance in maintaining populations of lynx and wolf in CE
- Two amphibian, one reptile, and four fish species listed in Annex II of the Habitats Directive also occur in the Primeval Forest area.
- Further, 11 invertebrate species of community importance are found within the proposed SAC

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Rare and threatened species

Bird species from Annex I of the Wild Birds Directive identified near the river crossings of route "G" and "N"



Legenda:

1	**Woodlark**	*Lullula arborea*
2	**Hazel Grouse**	*Bonasa bonasia*
3	**Red-backed Shrike**	*Lanius collurio*
4	**Red-breasted Flycatcher**	*Ficedula parva*
5	**Pygmy Owl**	*Glaucidium passerinum*
6	**Tawny Pipit**	*Anthus campestris*
7	**Capercaillie**	*Tetrao urogallus*
8	**Marsh Harrier**	*Circus aeruginosus*
9	**Honey Buzzard**	*Pernis apivorus*
10	**White-tailed Eagle**	*Haliaetus albicilla*
11	**Middle Spotted Woodpecker**	*Dendrocopos medius*
12	**Black Woodpecker**	*Dryocopus martius*
13	**White-backed Woodpecker**	*Dendrocopos leucotos*
14	**Lesser Spotted Eagle**	*Aquila pomarina*
15	**Crane**	*Grus grus*
16	**Barred Warbler**	*Sylvia nisoria*
17	**Corncrake**	*Crex crex*
18	**Spotted Crake**	*Porzana porzana*
19	**Tengmalm's Owl**	*Aegolius funereus*
20	**White Stork**	*Ciconia ciconia*
21	**Common Kingfisher**	*Alcedo atthis*

Initial Evaluation - the Impact Event

Preliminary Identification of Potential Damages

Stressors

Examples of anticipated stressors during the construction phase:

- direct loss of habitat from construction
- disturbance of fauna due to human presence, equipment operations, noise and light
- creation of barriers for animal movements -- both for migration and normal dispersal movements
- temporary or permanent changes in hydrology (both groundwater and surface water)
- vibrations from driving piles
- shading from platforms and bridges
- primary and secondary dust from excavation, traffic, and equipment
- air pollution, sedimentation
- altered patterns of water runoff and sediment yields in local drainage basins

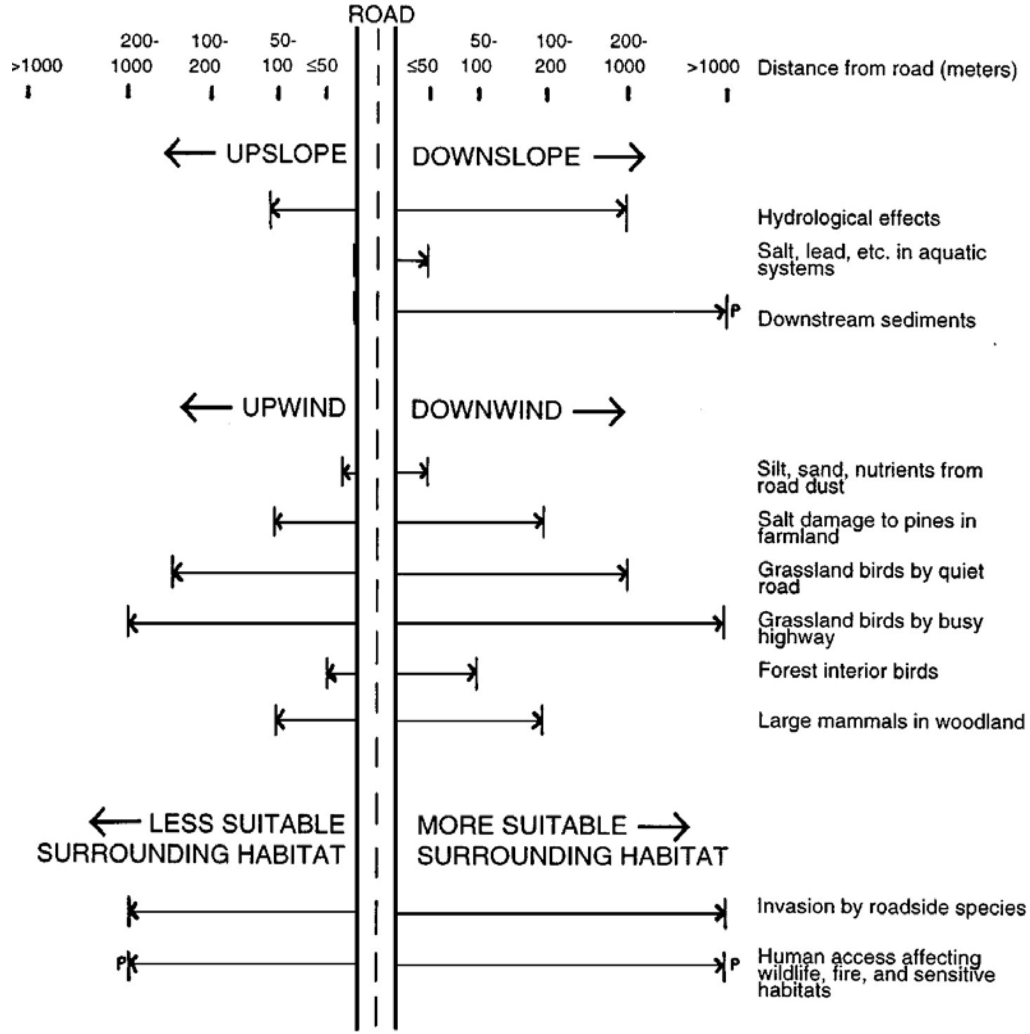
Examples of anticipated stressors during road operations:

- invasion by roadside species
- facilitated spread of pathogens and diseases, as well as of exotic and pest species along road
- increased human access affecting wildlife, fire and other disturbance to sensitive habitats and species
- vibrations caused by heavy traffic
- introduction of traffic or/and increase of traffic intensity and related pollution and risks
- salt and other ice control chemicals
- pollution in road runoff
- noise and light
- accidents with hazardous products

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Stressors



Potential impact zones associated with different stressors.

Initial Evaluation – the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

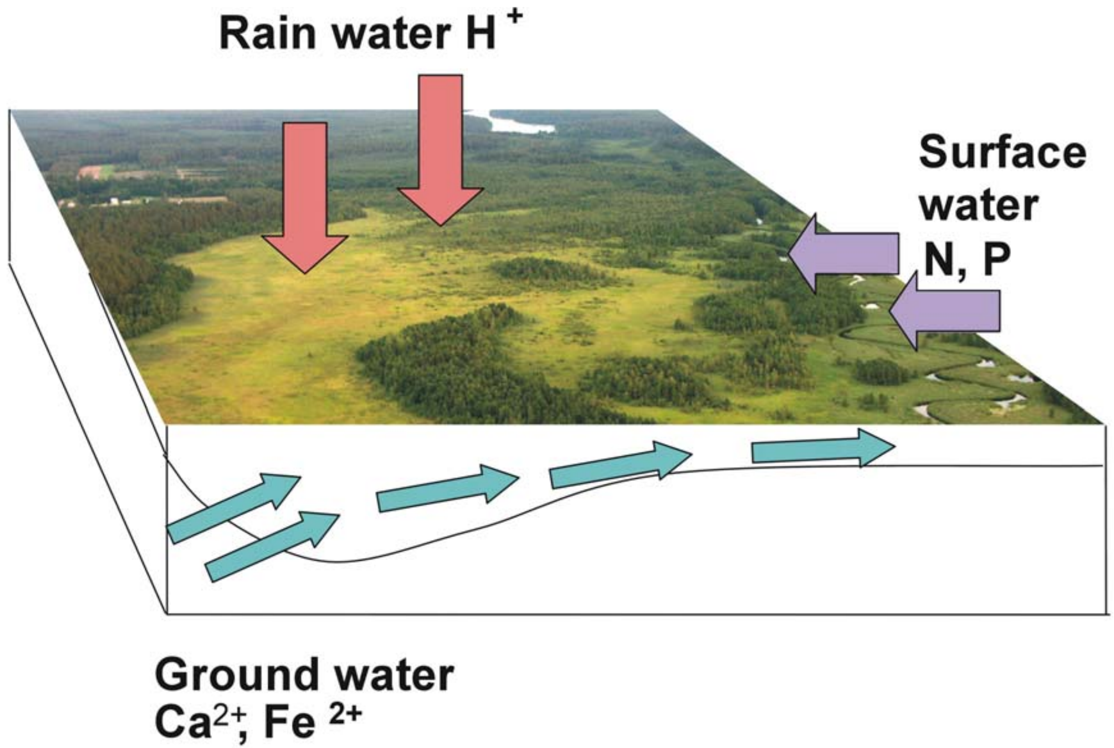
Sensitivity and Fragility of the River Mire Ecosystem

- It is important to understand that integrity of this peatland ecosystem relies on the interconnectivity of hydrological and vegetations processes
- Plants determine what type of peat will be formed and the nature of its hydraulic properties
- Site hydrology, in turn, determines which plants will grow, whether peat will be created, and decompositional processes.
- Peat structure and the physical relief determine how the water will flow and fluctuate.
- These close interrelationships imply that when any one of these components changes, the others will be affected as well
- The river mire in the study area is categorized as a sloping mire, where the water level forms an inclined plane and water flow is mainly horizontal
- Percolation mires are found in areas where the water supply is large and very evenly distributed over the year
- As a result, the water level in the mire is almost constant, dead plant material reaches the permanently waterlogged zone quickly, and is subject to aerobic decay only for a short time.

Initial Evaluation – the Impact Event

Preliminary Identification of Affected Habitats and Species
Potential Impacts Associated with the Road Project

Sensitivity and Fragility of the River Mire Ecosystem



Initial Evaluation – the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

Potential Impacts to Fauna

- **loss of supporting habitat and increased mortality from vehicle collisions with vehicles**
- **decreased densities in areas adjacent to the road as a result of increased disturbance which reduce habitat quality**
- **increased fragmentation of animal populations because of the barrier effects of roads.**
- **changes in composition of vertebrate communities in areas adjacent to the road, resulting from differential effects of factors on particular species groups, e.g.:**
  - proportional decrease in abundance of large-bodied birds, mainly top-level predators (including raptors) which are more vulnerable to disturbance and habitat fragmentation than small birds,
  - proportional decrease in abundance of small vertebrates (rodents, amphibians) which are most vulnerable to collision mortality and are main prey for other species,
  - facilitated spread of pathogens and diseases, as well as of exotic and pest species along roads,
  - proportional increase in abundance of opportunistic, scavenger species (e.g. red fox, raven) searching the roadsides for corpses of collision victims and exerting a higher predation pressure on adjacent areas

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

Potential Habitat Impacts

- **considerable and far-reaching changes in freshwater habitats caused by:**
  - substantially altered patterns of water runoff and sediment yields
  - increased chemical pollution and light pollution,
- **a considerable reduction of the effective habitat due to**
  - decrease of the habitat quality,
  - road avoidance or reduction of usable habitat near roads
  - noise disturbance
- **direct habitat destruction**
  - complete habitat destruction
  - direct damage from vibrations
  - direct damage from shading

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

Landscape fragmentation, ecological integrity, and ecological connectivity

- The pSAC or existing SPA, which are likely to be directly affected by bypass roads serve as the dispersal corridor for large mammals (mainly wolf, lynx and elk).
- This dispersal route is recognized as the main corridor of international importance, the main tract supporting the connectivity of continuous forest tracts of South Baltic basin (Lithuania, Latvia, Belarus, Russia) and fragmented forests of Central Europe.
- One of the main requirements for proper functioning of wolf and lynx populations is the maintenance of long-distance dispersal movements of individuals.
- If routing “G” is selected, running through the pSCI, the substantial increase in traffic volume on road sections placed in dispersal corridors is likely to seriously impair dispersal possibilities.
- Animals not only avoid busy roads but also suffer heavy mortality while crossing them.
- Limiting the dispersal possibilities would reduce the probability of animals to colonise new areas. cause the isolation of local populations and expose them to higher risk of decline and extinction.
- Preventing dispersal may be a particularly important threat for the lynx population of northeastern Poland, which is almost isolated from the bulk of the Baltic basin population.
- Road mortality is invariably identified as one of the most important sources of lynx mortality across Europe. Additionally, lynx numbers in Poland have been declining since 1989.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

Eco-hydrological effects

- The water in the sand layer underneath the peat layer will be under pressure from the weight of the road.
- Because the weight-bearing capacity of the peat is low, all construction will be built on the sand layer beneath it.
- The effect will lead to increased water flow from the edges of the valley to the centre,
- Pumping experiments have shown that – if the drainage is strong enough - large amounts of water will be even drained away from the upper layers through 'almost impermeable' layers of several m thicknesses.
- Even if the drainage is relatively moderate, it will result in compaction of the peat and increase resistance for water flow.
- Short-cutting the groundwater flows will result in lowered groundwater pressure along the river. This will lead to an increasing effect of more eutrophic surface water from the river.
- The processes are likely to lead to both an increase of eutrophic and acidic wetland species at the cost of red list alkaline fen species.
- From the existing information it is very difficult to predict whether construction of the bridge could permanently change the peatland's hydrological regime.
- Possible outcomes of Route G may include irreversibly affecting the River's percolation fen.
- A direct effect that may be expected is compaction of the peat, as rather irreversible process which results in increased resistance for water flows.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project

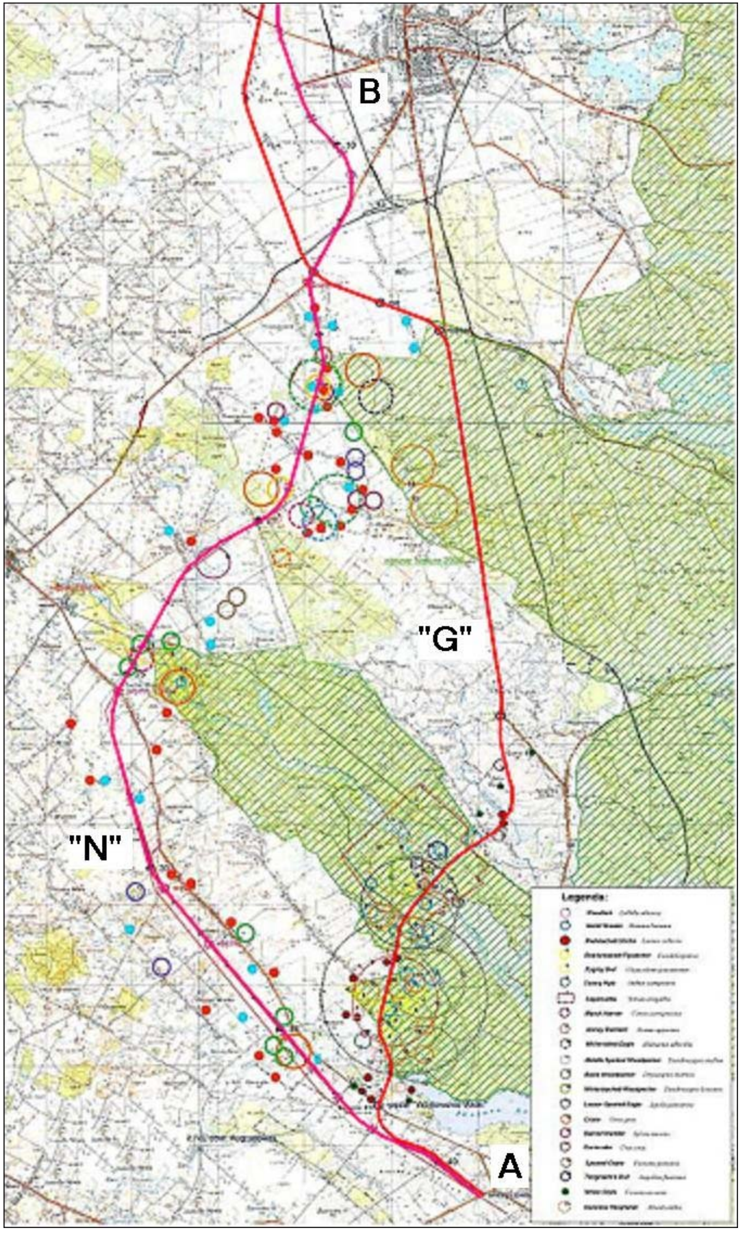
Impacts on birds

- Our assessment of impact takes into account only those nesting sites which are located within 750 metres from the planned routes.
- The two variant routes of the planned expressway were examined along stretches between the points where they diverge in the south to the point where they converge in the north.
- Between these points, both routes follow entirely different courses. Variant G is about 24 km long, and Variant N about 25 km. long
- For the sake of comparison, the number of bird species and individual birds identified along each variant was recorded and listed.
- On this basis, it was possible to determine the average number of bird species and bird individuals found along every 1 km of each variant.
- To highlight the natural differences between the variants even more, each species was assigned a numerical value depending on its degree of threat on a continental scale (SPEC), and
- points were awarded for each species for its flexibility regarding habitats and its conservation quality.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project



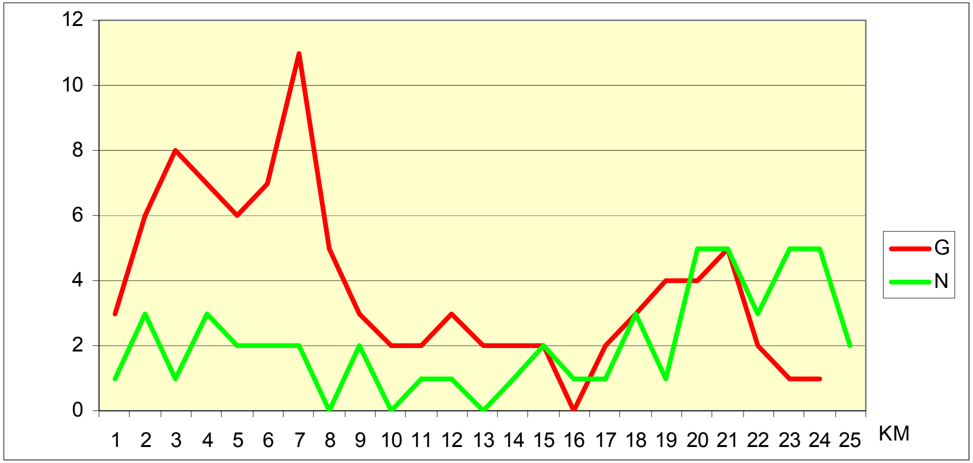
Impacts on birds

Distribution of WBD Annex 1 bird species along Routes G and N.

Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

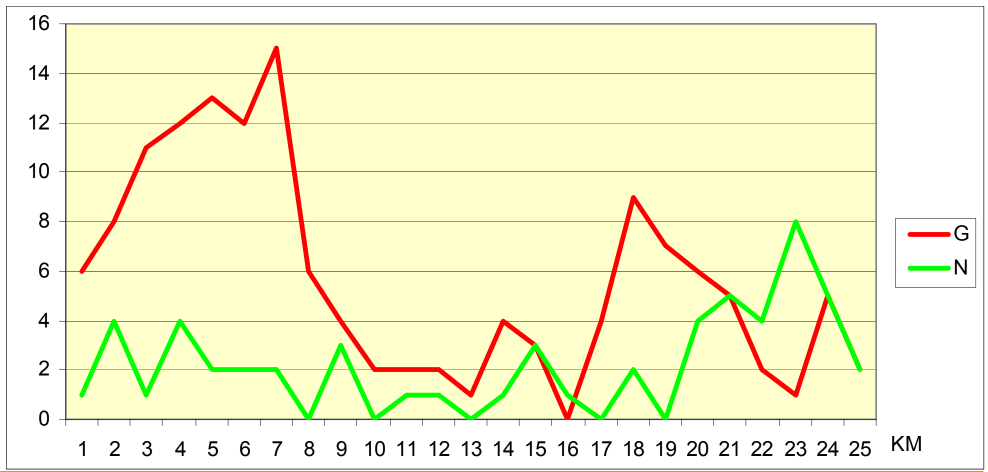
Potential Impacts Associated with the Road Project



Impacts on birds

Number of <u>species of birds</u> of the WBD Annex I, identified along the two alternative routes counted on each km of the routes.

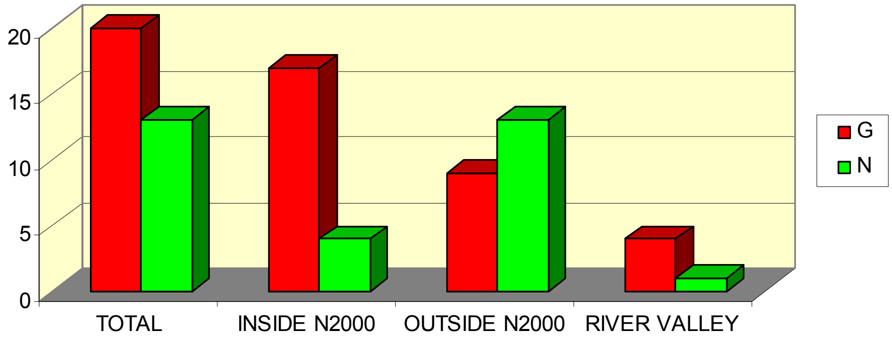
Number of <u>birds individuals</u> of the WBD Annex I species identified along the two alternative routes and counted on each km of the routes.



Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

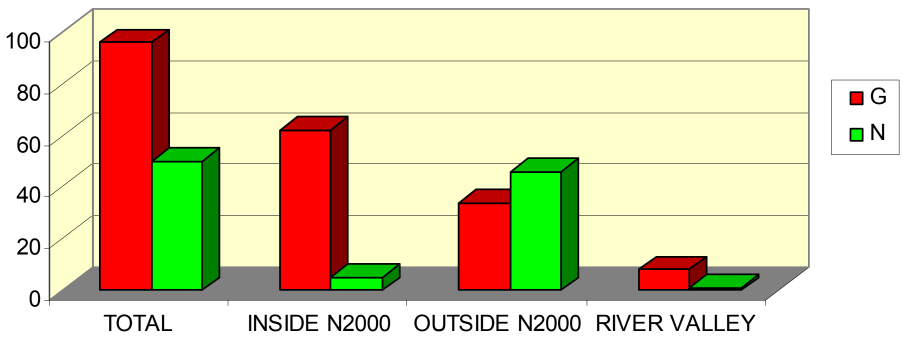
Potential Impacts Associated with the Road Project



Impacts on birds

Number of nesting species of Annex I of the Wild Birds Directive in a 1,5 km wide buffer along either side of the routes

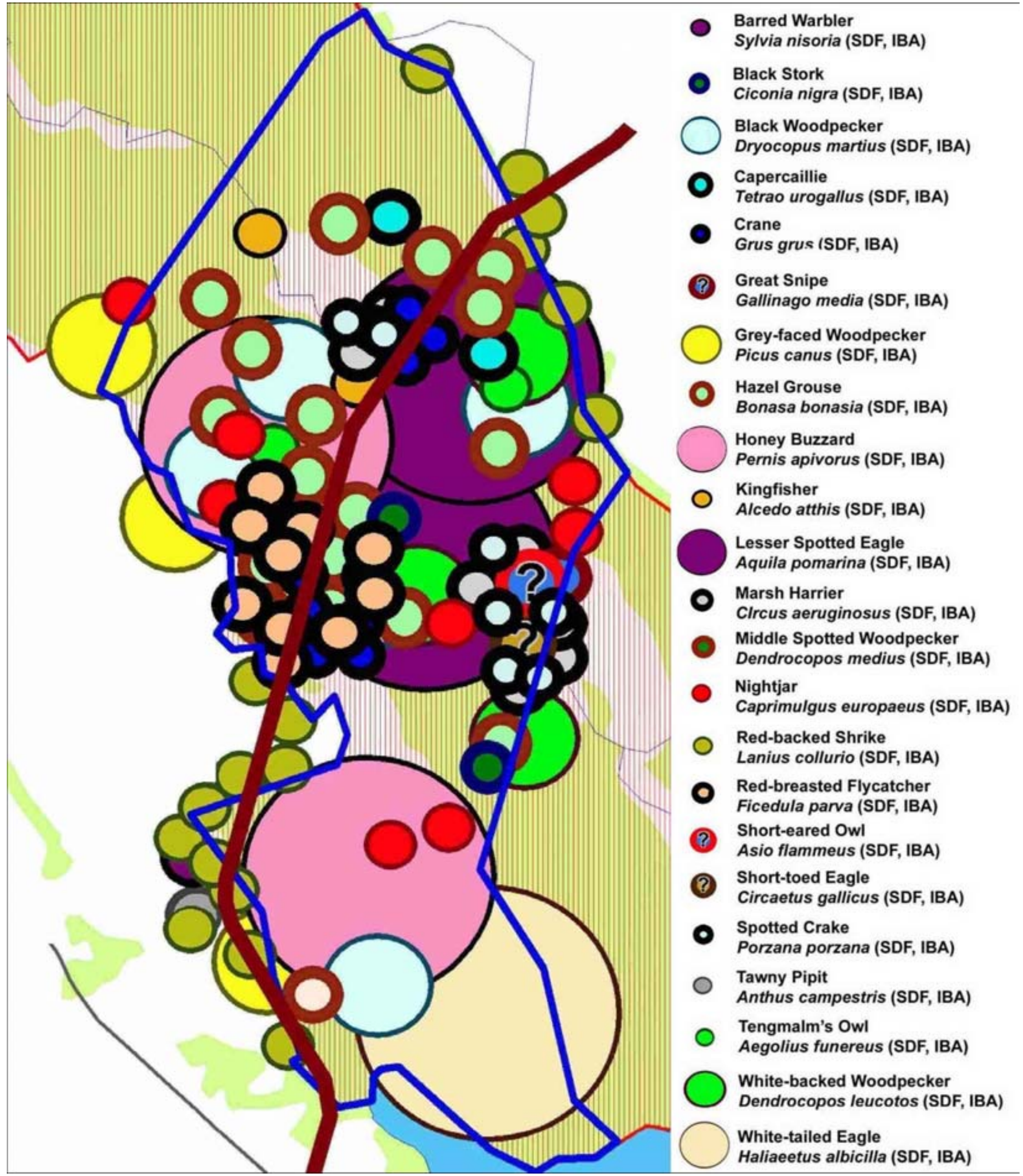
Number of individuals of nesting species of Annex I of the Wild Birds Directive in a 1,5 km wide buffer along either side of the routes.



Initial Evaluation - the Impact Event

Preliminary Identification of Affected Habitats and Species

Potential Impacts Associated with the Road Project



Distribution of territories of Annex I Bird Directive species along Route G

Initial Evaluation - the Impact Event

Temporal extent of damage

Temporal extent of damage

- The construction period for both alternatives - 24 months.
- Direct effects associated with construction (noise, dust, equipment) - last for 2 years, with recovery within 1 years.
- Habitat losses caused by the road, once constructed, are anticipated to continue in perpetuity.

Primary remediation undertaken

- We assume that no primary remediation will be undertaken as part of the project.
- Equivalency methods is applied to determine the scale of offsetting mitigation that would be required for each of the two road alternatives.

Initial Evaluation - the Impact Event

Preliminary Identification of Potentially Affected Services

Primary impact zone Road belt of 60 m wide	Secondary impact zone Road buffer zone 2 km wide
Permanent loss of protected plants, including loss of individuals and loss of supporting habitat	Temporary loss of avian breeding habitats
Permanent loss of avian breeding habitats	Temporary loss of avian feeding sites
Permanent loss of avian feeding sites	Temporary loss of mammalian habitat
Permanent loss of mammalian habitats	Temporary loss of amphibian habitat
Permanent loss of amphibian habitats	Temporary loss of reptile habitat
Permanent loss of reptile habitats	Temporary loss of fish habitat
Permanent loss of fish habitats	Temporary loss of insect habitat
Permanent loss of insect habitats	Temporary loss of habitat integrity and connectivity
Permanent fragmentation of habitats and landscapes	Temporary loss of GHG sink (sequestration) ability
Permanent change of hydrological regime along the road	Temporary loss of recreation usage
Loss of hydrological stability of fens	Temporary separation from arable fields
Decrease in the hydraulic conductivity of the substrate	
Permanent fragmentation of agricultural land	

Quantifying Debits from Environmental Damages
Approach

- Habitat equivalency analysis (HEA) is used to compare potential environmental damages between the two road alternatives
- Although a number of potential habitat types would potentially be affected by the construction project is high, HEA analysis is simplified by pooling similar habitat types into five discrete assemblages
- For **Forest Habitats**, three habitat groups were evaluated:
  - bog forests (inclusive of the bog woodland assemblage, habitat code 91D0)
  - alluvial forests (inclusive of alluvial forests with *Alnus glutinosa* and *Fraxinius excelsior*, habitat code 91E0)
  - oak forests (inclusive of Galio-Carpinetum oak-hornbeam forests, habitat code 9170)
- For **Wetland Habitats**, individual habitat types were pooled into two general assemblages:
  - alkaline fens (inclusive of alkaline fens and transition mires, codes 7230 and 7140)
  - common wetlands (e.g., habitat code 3260)

Quantifying Debits from Environmental Damages
Approach

- HEA approach considered damages within both
  - a primary impact zone (the roadway and the road belt itself), and
  - a secondary impact zone (a buffer extending 1 km on either side of the road).
- Road construction could adversely affect a number of different ecological services, hence a variety of service metrics could be used to describe debits (and credits).
- Rather than apply individual metrics to different potential categories of service loss, we employed an overall habitat-integrity metric to describe changes in services.
- This metric describes an overall habitat integrity, and considers both impacts to local flora and fauna, potential hydrological impacts to wetland habitats, and habitat fragmentation/connectivity.
- Although semi-qualitative metrics that rely on professional judgment may not be ideal, particularly in *ex post* analyses, use of such metrics may be warranted in certain *ex ante* analyses for which quantitative data on environmental damage may not be available.
- Habitat scalars are employed in the HEA to provide for equivalency scaling between habitat assemblages.
- Uncertainties in potential future outcomes are considered in this *ex ante* case by performing a probabilistic analysis of alternative scenarios.

Quantification of Service Losses

Service Loss Assumptions by Habitat Type and Impact Zone: Route G

Habitat Type	Damaged Area (ha) By Impact Zone		Service Loss By Impact Zone		Duration of Loss During Construction (years)	Recovery Period (years)	
	Primary	Secondary	Primary	Secondary		Primary	Secondary
Forest							
Bog	1	79	100%	50%	2	None	5
Alluvial	0	15	na	50%	2	None	5
Oak	5	167	100%	50%	2	None	5
Wetland							
Alkaline Fens	1	35	100%	50%	2	None	5
Common Wetland	1	7	100%	50%	2	None	5

Quantifying Debits from Environmental Damages

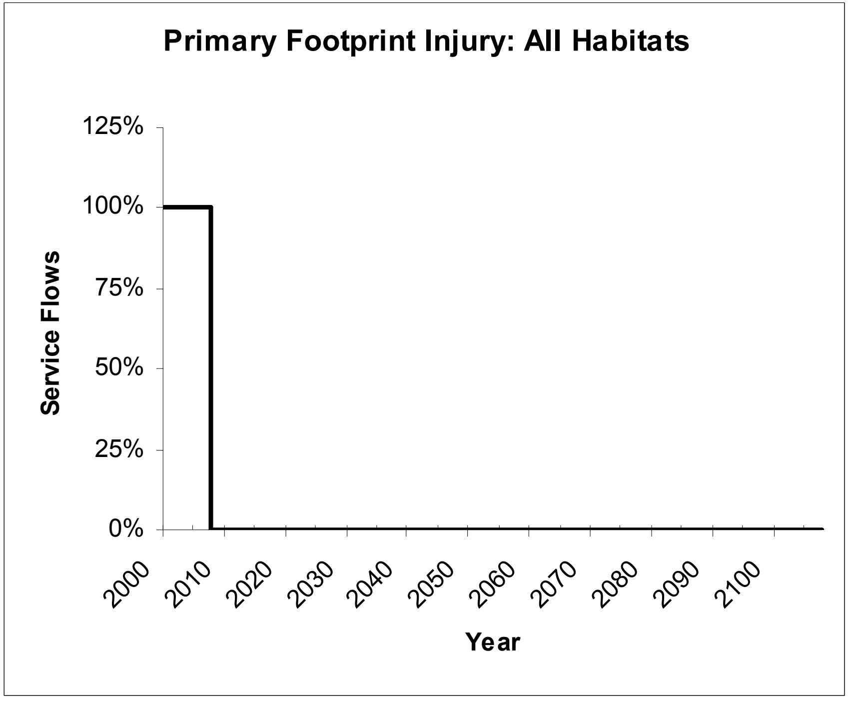
Quantification of Service Losses

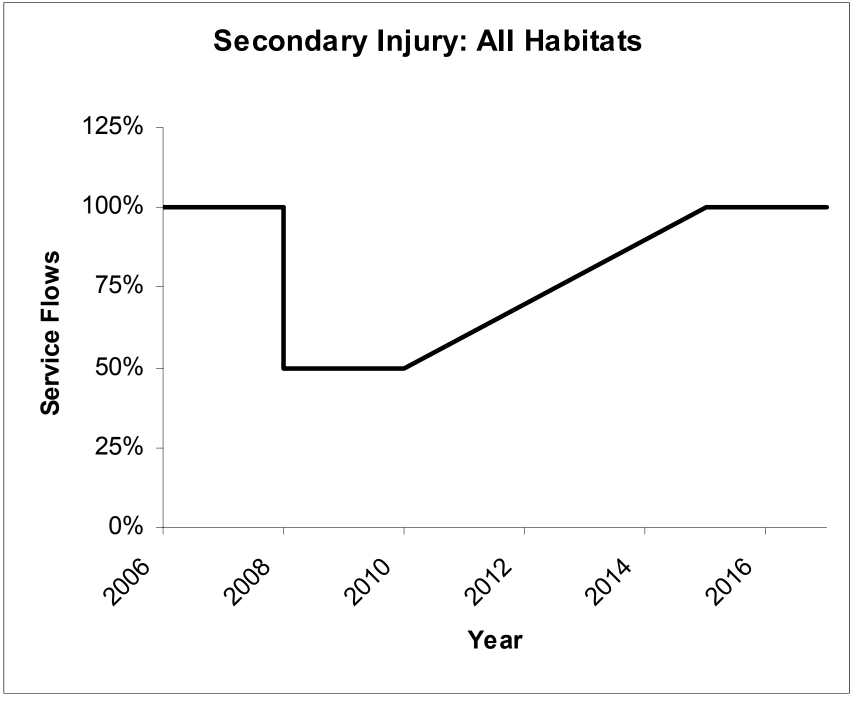
Service Loss Assumptions by Habitat Type and Impact Zone: Route N

Habitat Type	Damaged Area (ha) By Impact Zone		Service Loss Impact Zone		Duration of Loss During Construction (years)	Recovery Period (years)	
	Primary	Secondary	Primary	Secondary		Primary[1]	Secondary[2]
Forest							
Bog	0	0,4	na	50%	2	na	5
Alluvial	0	5	na	50%	2	na	5
Oak	4	139	100%	50%	2	None	5
Wetland							
Alkaline Fens							
Common Wetland	0,1	8	100%	50%	2	None	5

Quantifying Debits from Environmental Damages
Quantification of Service Losses

Illustration of service flows for primary and secondary impact zones





Quantifying Debits from Environmental Damages
Quantification of Service Losses

Example HEA Calculations for 3.9 ha of Oak Forest in Primary Impact Zone, Route N

Year	Annual Service Loss	Total Annual Service Loss (ha)	Discount Factor	Total Annual Discounted Service Loss (DSHaYs)
2008	100.0%	3.9	1	4.0
2009	100.0%	3.9	0.97	3.8
2010	100.0%	3.9	0.94	3.7
2011	100.0%	3.9	0.92	3.6
2012	100.0%	3.9	0.89	3.5
2013	100.0%	3.9	0.86	3.4
.	.	.	.	.
.	.	.	.	.
2107	100.0%	3.9	0.05	0.2
2108	100.0%	3.9	0.05	0.2
2108+	100.0%	3.9	0.05	6.6[1]
Total				**134**

Quantifying Debits from Environmental Damages

Quantification of Service Losses

Total Discounted Service Hectare Years (DSHaYs) of Debit:

Route G			
Habitat	Impact Zone		Total DSHaYs
	Primary	Seconda ry	
Forest			
Bog	28	150	178
Alluvial	0	28	28
Oak	188	317	505
Wetlands			
Alkaline Fens	26	66	92
Common Wetland	18	13	31

Route N			
Habitat	Impact Zone		Total DSHaYs
	Primary	Seconda ry	
Forest			
Bog	0	1	1
Alluvial	0	10	10
Oak	134	264	398
Wetlands			
Alkaline Fens	0	0	0
Common Wetland	3	15	18

Quantifying Debits from Environmental Damages

Quantification of Service Losses

Debits Normalized to Bog Forest and Common Wetland:

Route G			
Habitat	Unadjusted DSHaYs	Habitat Scalar	Normalized Debit
Forest			
Bog	178	1	178
Alluvial	28	0,5	14
Oak	505	0,33	168
Total Bog Forest Equivalent			360
Wetlands			
Alkaline Fens	92	15	1 387
Common Wetland	31	1	31
Total Common Wetland Equivalent			1 418

Route N			
Habitat	Unadjusted DSHaYs	Habitat Scalar	Normalized Debit
Forest			
Bog	1	1	1
Alluvial	10	0,5	5
Oak	398	0,33	133
Total Bog Forest Equivalent			138
Wetlands			
Alkaline Fens	0	15	0
Common Wetland	18	1	18
Total Common Wetland Equivalent			18

Quantifying Credits from Remediation

Assumptions for Credits & Scaling Remediation

- Debits from damages to forest and wetland habitats are offset using remediation projects that restore bog forest and common wetland habitat types.
- Habitat credits for these remediation projects were calculated using the credit assumptions
- It was assumed that construction of an offsetting bog forest remediation project would be completed in 2010, and that it will take 100 years for the enhanced habitat to reach full maturity.
- Services were assumed to increase linearly during that time, resulting in a final increase in services of 75% in the year 2110.
- The present value of the increase in services is calculated using the same discounting methods applied to the habitat service debits. Specifically, a 3-percent discount rate is applied on an annual basis, and annual discounted credits are summed over the 100-year life of the project.
- Total remediation credits for the bog forest project projected to be 6.7 DSHaYs per hectare of remediated habitat.
- The remediated wetland is assumed to reach a full service increase of 75% in 20 years. Total credits for the wetland project are 17.4 DSHaYs per hectare.

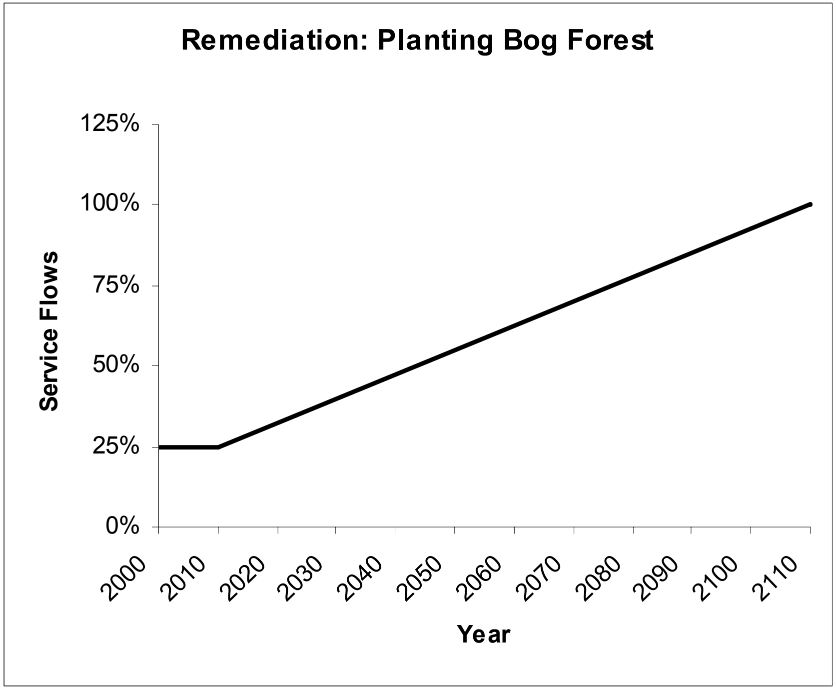
Quantifying Credits from Remediation

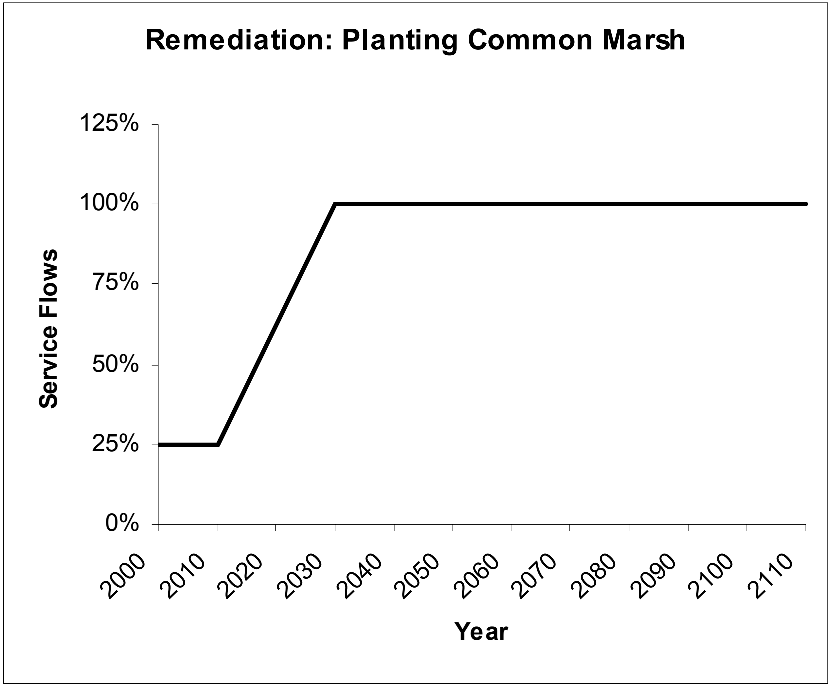
Remediation Credits (DSHaYs) for Each Hectare of Remediated Habitat

Bog Forest	
Assumed year of project completion	2010
Years to full service gain	100
Percent service gain	75%
Final year of quantified benefits	2110
Remediation credits per 1 ha	6,7
Common Wetland	
Assumed year of project completion	2010
Years to full service gain	20
Percent service gain	75%
Final year of quantified benefits	2110
Remediation credits per 1 ha	17,4

Quantifying Credits from Remediation

Assumptions for Credits & Scaling Remediation





Quantifying Credits from Remediation
Scaling Remediation

- Because outcomes are uncertain in this ***ex ante*** application of HEA, two alternative scaling scenarios are presented
- The first scenario, called **base case**, uses the information on debits and credits to calculate the amount of remediation required to compensate for environmental damage
- In the second scenario, a **probabilistic approach** is applied to evaluate potential damages associated with losses to highly scarce alkaline fen habitats

Quantifying Credits from Remediation

Scaling Remediation

Base *Case*

- Our base case uses the results outlined above to calculate the amount of remediation required to offset expected losses
- For Route G, the debit of 360 DSHaYs of bog forest habitat must be offset by pre-unit remediation credits of 6.7 DSHaYs per hectare The required scale of the bog-forest remediation project therefore is 54 hectares (360/6.7 = 54)
- The debit of 1,418 DSHaYs of wetland habitat must be offset by the per-unit remediation credits of 17.4 DSHaYs per hectare The required scale of the common-wetland remediation project therefore is 81 hectares (1,418/17.4 = 81)

Quantifying Credits from Remediation

Scaling Remediation

Base Case, cont.

- For both habitats it is assumed, for illustrative purposes only, a remediation cost of Euro 10,000 per hectare.
- This results, in case of Route G, in a cost of Euro 537,000 to offset forest damages and Euro 815,000 to offset wetland damages.
- **The total cost of remediation for Route G, under the base case analysis, is Euro 1,352,000.**
- For Route N, the debit of 138 DSHaYs of bog forest habitat must be offset by the per-unit remediation credits of 6.7 DSHaYs per hectare.
- The required scale of the bog-forest remediation project therefore is 21 hectares.
- The debit of 18 DSHaYs of wetland habitat must be offset by the per-unit remediation credits of 17.4 DSHaYs per hectare.
- The required scale of the common-wetland remediation project therefore is 1 hectare.
- This results in a cost of Euro 206,000 to offset forest damages and Euro 10,000 to offset wetland damages.
- **The total cost of remediation for route N is Euro 216,000.**
- Actual remediation costs for bog forest or wetland remediation are likely to differ, and would be dependent on site-specific factors.
- **Under the base-case analysis, the cost of remediation for Route G is Euro 1,135,000 greater than the remediation cost for Route N.**
- This means it would be cost-effective to choose Route N over Route G, unless the construction costs for Route N are at least Euro 1,135,000 greater than construction costs for Route G.

Quantifying Credits from Remediation
Scaling Remediation

Alternative Case – Probabilistic Approach

- The alternative case analysis considers the potential wide-scale adverse impacts to the function and structure of the sensitive alkaline fens ecosystem
- This broader scale impacts could occur if road construction in this sensitive habitat type affects overall integrity and function of the habitat unit
- Such effects could extend beyond the actual “footprint” of the roadway. E.g., if hydrological changes alter water flows, peat formation, and nutrient cycling, the entire fens could be damaged
- All of these scenarios reflect possible ecological effects of the construction of Route G, which would pass directly through the alkaline fens habitat
- Route N would not pass through the alkaline fens habitat and consequently is assumed to have no impact on the alkaline fens ecosystem

Quantifying Credits from Remediation

Scaling Remediation

Ecological Risk Scenarios

Alternative Scenarios	Scenario Probability	Affected Area (ha)	Perpetuity Service Loss Relative to Full-Function Alkaline Fens	Transitional Period (years)	Habitat Scalar	Additional Normalized Debit (DSHaYs)
Remains as alkaline fens, with biodiversity loss	25%	100	40%	30	15	3 466
Becomes common wetland, with full function	25%	100	93%	30	15	8 087
Becomes common wetland, with 20% loss from reduced biodiversity	25%	100	95%	30	15	8 202
Total	x	x	x	x	x	19 754

Quantifying Credits from Remediation
Scaling Remediation

Ecological Risk Scenarios

- **<u>The first scenario</u>** assumes that the fens continue to function, but that biodiversity losses would extend throughout a broader habitat area (assumed to be 100 ha).
- Such biodiversity losses could occur from migration barriers or changes in the water table. The probability of this scenario is assumed to be 25 percent. The total area of affected alkaline fens habitat is 100 hectares, with an estimated 40% decline in habitat quality associated with biodiversity impacts.
- Losses do not occur immediately at the time of construction, but increase from 0 to 40% during a transition period of 30 years.
- Given the habitat scalar for alkaline fens of 15:1 relative to common marsh, and using the calculations for discounting and normalized debits described above, the total debit from the potential loss of biodiversity is 3,466 DSHaYs.
- This total loss accounts for the 25% probability that this scenario will occur.

Quantifying Credits from Remediation

Scaling Remediation

Ecological Risk Scenarios

- **The second scenario** assumes that hydrological or other habitat function critical to sustaining alkaline fens are disrupted by the presence of the road in Route G.
- Because of these alterations in function, the 100 hectares of alkaline fens habitat shift to become common marsh over a 30 year transition period.
- The common marsh is assumed, however, to be fully functioning. The service loss of 93% is calculated based on the habitat scalar of 15:1 for alkaline fens relative to common marsh. The units of loss are then normalized to common marsh, again using the habitat scalar.
- After discounting, and after accounting for the 25% estimated probability, total losses associated with this scenario are 8,087 DSHaYs.

Quantifying Credits from Remediation
Scaling Remediation

Ecological Risk Scenarios

- **<u>The third scenario</u>** describes service losses associated with the transition of alkaline fens to a degraded common marsh (e.g., the common marsh is degraded relative to fully functioning common marsh because of reduced biodiversity).
- The service assumptions presented in the third scenario resulting in total service losses of 8,202 DSHaYs.
- In addition to the three scenarios, it is assumed that there is a 25% probability that no adverse impacts will occur to the alkaline fens ecosystem.
- **Expected losses from the first three scenarios therefore represent the total expected losses from ecosystem impacts.**

Quantifying Credits from Remediation
Scaling Remediation

Ecological Risk Scenarios

- The total expected value of debit is 19,754 DSHaYs
- Adding these losses to the base case results, total wetland losses associated with Route G increase from 1,418 DSHaYs to 21,172 DSHaYs
- The quantity of required wetland remediation therefore would increase from 81 hectares to 1,216 hectares
- Under the alternative case, the total cost of remediation for Route G would be Euro 12,700,000 (assuming unit costs of Euro 10,000 for illustrative purposes)
- These alternative assumptions regarding potential ecosystem impacts to alkaline fens do not affect the analysis for Route N
- **The cost of remediation for Route G damages is some Euro 12,500,000 greater than the remediation cost for Route N**
- **It would be cost-effective to choose Route N over Route G unless the construction costs for Route N are at least Euro 12,500,000 greater than construction costs for Route G**

Quantifying Credits from Remediation

Scaling Remediation

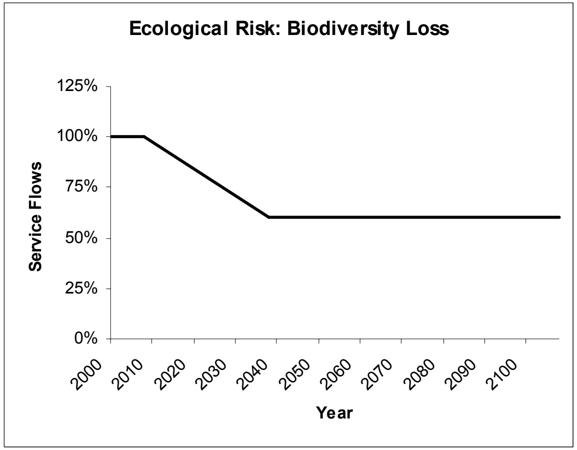
Alternative assumption regarding the habitat scalar for alkaline fens

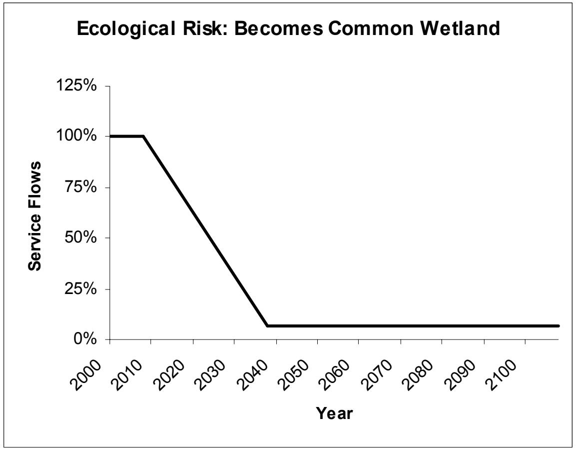
- The habitat scalar of 15 was based in part on the scarcity of sedge moss fens relative to total mire habitat in Poland
- Alkaline fens is included within the category of sedge moss fens habitat, and sedge moss fens is one of many wetland habitats included within total mire habitat
- The ratio of the area of sedge moss fens to total mire habitat is 15
- By comparison, the area of alkaline fens, by itself, relative to total mire habitat is 1:13,222
- **If this ratio is used as the habitat scalar for converting alkaline fens to common marsh, the revised estimate of required wetland remediation would be 1,123,000 hectares**
- **The total cost of remediation for environmental damages associated with Route G would be then be approximately Euro 11 billion**

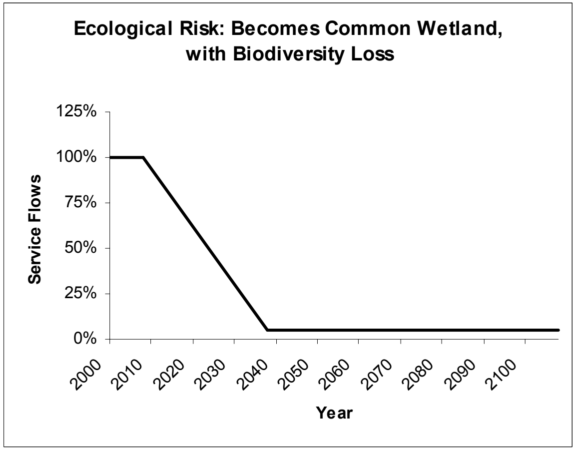
Quantifying Credits from Remediation

Scaling Remediation

Service flows associated with each of the three ecological risk scenarios







Conclusions

- Habitat equivalency analysis (HEA) was used to contrast the potential environmental damages associated with two alternative routes of a hypothetical international highway
- Application of HEA on an *ex ante* basis enabled to compare the cost effectiveness of the two alternatives considering the environmental externalities associated with anticipated future environmental damage
- Under a simple base case, environmental damages for Route G were somewhat greater than for Route N
- When considered potential wide-scale ecosystem damages using a probabilistic approach, environmental damages for Route G were considerably greater than for Route N
- When this probabilistic approach was expanded further to consider the relative scarcity of the extremely rare alkaline fen habitat that could be lost, environmental damages increased considerably to over Euro 1 billion
- This case study illustrated how HEA could be applied in an ex ante case involving infrastructure development
- The case study illustrates application of habitat scalars in resource equivalency
- Finally, the case study illustrates a probabilistic approach to estimating expected environmental damages in *ex ante* situations