TOPCONS marine spatial planning tool

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1 Summary

This report describes the TOPCONS marine spatial planning tool prototype and the work flow that it supports. The software platform and the TOPCONS software itself are described. The prototype was alpha tested with a test case, and the test case is described.

2 Supported marine spatial planning workflow

The supported workflow is shown in figure 1.

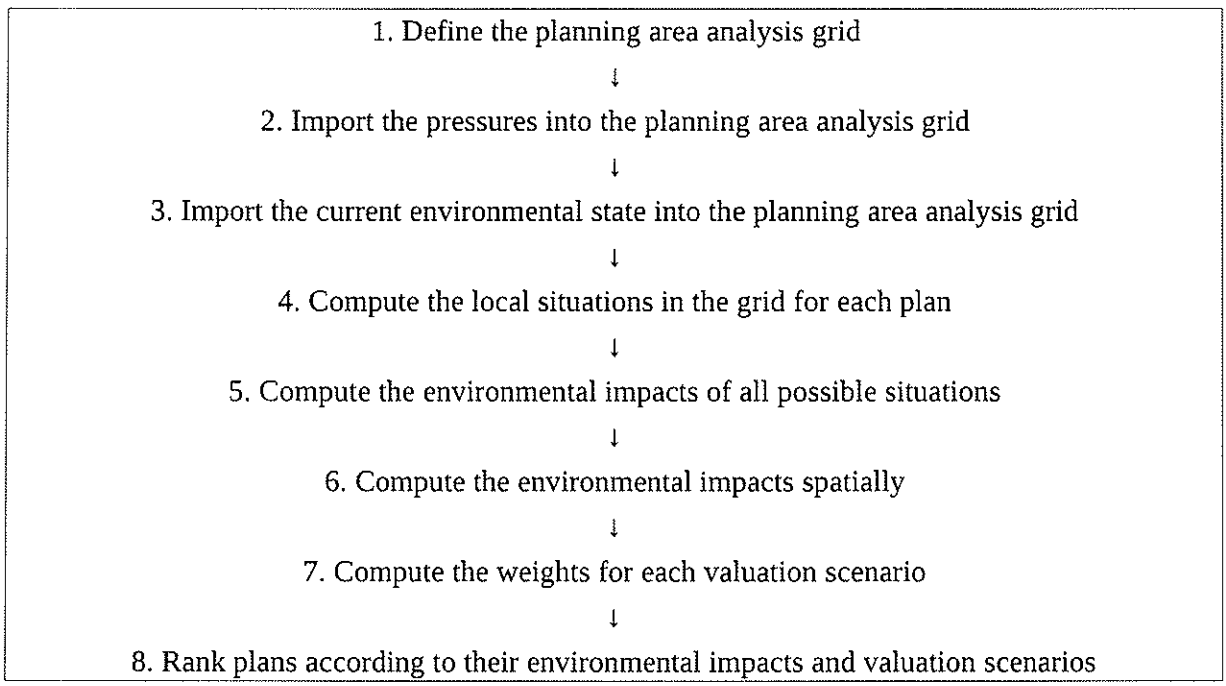

Figure 1. The marine spatial planning workflow that is supported by the prototype tool. The steps are described in the text.

In step 1. the planning area is delineated and a divided into equal sized grid cells. In step 2. the magintudes of the pressures are computed in each grid cell. In step 3. the current environmental state and values are computed at each grid cell. In step 4. the pressures are discretized similarly as in impact model and stored as cases. In step 5. the environmental impact model (Bayesian network) is run for all combinations of pressure values. In step 6. the impact model is applied in each grid cell by using the results from steps 4. and 5. In step 7. the valuation model (Bayesian network) is run to obtain weights for all valuation scenarios. In step 8. the plans are ranked by the sum of

ecological impacts.

3 TOPCONS tool

3.1 Software platform

The tool is implemented on a software platform that consists of the following components.

Hugin environment for Bayesian networks

> Hugin is proprietary software that is developed and sold by a Danish company Hugin Expert A/S. Hugin has two parts, the Hugin Decision Engine and the Hugin graphical program for developing and using Bayesian networks. The graphical program is not needed for the workflow. The decision engine is used by some programs of the TOPCONS tool.

Hugin Decision Engine interface for Perl

> The Perl interface for Hugin Decision Engine is independently developed by Ari Jolma. It is free software and available from http://ajolma.net (under Subversion repositories).

Geoinformatica

> Geoinformatica is a Perl extension for geospatial data developed by Ari Jolma. It is free software and available from https://github.com/ajolma/geoinformatica.

PostgreSQL

> PostgreSQL is a relational database management system. PostGIS adds support for geospatial data and methods to PostgreSQL. PostgreSQL is free software.

QGIS

> QGIS is a geographic information system. QGIS is free software.

The tool development was done on a Linux based system which supports Perl and other tools that are needed by the above mentioned components of the TOPCONS tool. However, there is nothing that inherently prevents one from using the TOPCONS tool in other operating systems.

3.2 TOPCONS software

TOPCONS software consists of a QGIS plugin and five small Perl programs.

The TOPCONS QGIS plugin

> The plugin consists of five files: icon.png, __init__.py, mainPlugin.py, metadata.txt, and topcons.ui. icon.png is an image that is added to the QGIS toolbar for opening the plugin dialog box. __init__.py is a very small piece of Python code required by QGIS. mainPlugin.py is the main Python code that implements the plugin functionality. metadata.txt is required by QGIS and contains information about the plugin. topcons.ui is a Qt Designer user interface file. The two Perl programs are examples of how Perl code can be executed within a QGIS plugin.

grid.pl

grid.pl is a simple program which creates a 100 m x 100 m grid for a specified area in a specified map projection. The program creates both a GeoTIFF raster and inserts square polygons into a PostgreSQL table. The polygons are only inserted if they intersect with a polygon in the table alue_iso.

oilrisk2ruudut.pl

oilrisk2ruudut.pl is a simple program which can be used to add attribute values for the TOPCONS grid cells from a raster.

cases-for-each-plan.pl

cases-for-each-plan.pl is a program which computes the pressures at each TOPCONS grid cell in each plan and stores them as "cases". A case is a vector of node state indices of a Bayesian network (impact model).

BN-cases.pl

BN-cases.pl is a program, which computes the environmental impacts of all possible local pressure combinations. The program prints out SQL that stores them into a table.

4 The alpha test

The prototype was tested with a set of five plans that each consisted of a fairway system, and a selection of windmill parks (or no windmills at all). For the plans two fairway systems and three windmill parks were designed. Oil spill probability was an additional pressure. Two types of ecological impacts were considered: impacts to bird nesting and impacts fish nursery areas. The bird species that were considered were *Arenaria interpres, Charadrius hiaticula, Larus fuscus,* and *Melanitta fusca*. The only fish species that was considered was *Sander lucioperca*. The impact model linked the three pressures (disturbances from fairways and windmills and oil spill probability) to ecological losses. The valuation model linked ten different valuations to weights of ecological values.

The data for the alpha test was obtained as follows. The test area was selected as the sea area of Finnish municipalities Pyhtää, Kotka, Hamina and Virolahti. A buffer of 1 km was added to the area. The bounding box of the area was obtained with the SQL command

```
SELECT ST_AsText(ST_Envelope(geom)) from alue_iso
```

and the grid was created with grid.pl. The resulting grid had 229 578 grid cells. The fairways and the windmill parks were designed with QGIS into the PostgreSQL database based on existing fairways and assumed possible sites for windmill parks. The spatial oil spill probability data was computed with the SAFGOF tool (Jolma et al. 2014) and stored as a GeoTIFF. The bird nesting areas were extracted from the OILRISK database and the pikeperch nursery area data (predictions) was obtained as a raster from Finnish Game and Fisheries Research Institute. The current ecological state at each grid cell were computed with oilrisk2ruudut.pl (*Sander lucioperca*) and with SQL commands of the following kind for birds areas.

```
update topcons
set    birds[i]=st_intersects(topcons.geom, bird_areas.geom)
from   bird_areas where species='x'
```

The spatial variables of the impact model were "Distance to fairway", "P of becoming oiled", and "Distance to windmill". "Distance to fairway" had nine states, "P of becoming oiled" had five states, and "Distance to windmill" had nine states.

The pressures at each grid cell were computed with cases-for-each-plan.pl, which stored them into the table topcons_cases. The impacts for all possible pressure combinations were computed with BN-cases.pl and stored into table bn_cases. The ecological losses were computed with SQL commands of the following kind for all birds species.

```
update topcons_cases
set    bird_loss[1] = topcons.birds[1]::int*bn_cases.e/100
from   topcons,bn_cases
where  topcons.id = topcons_cases.cell
       AND topcons_cases."case" = bn_cases."case"
       AND bn_cases.var ~ 'Arenaria'
```

The tables in the database at this point are shown in figure 2. The cases table is added for illustration.

The weights for ecological values were computed and added to the database as a table stakeholder_weights with the program stakeholder-scenario-weights.pl. The plans could then be ranked according to their ecological impacts for each weighting scenario with an SQL command

```
select plan,
       f.scenario as scenario,
       sum(fish_loss_max*f.value+bird_loss_max*b.value) as
       loss_valued
from   topcons_cases, stakeholder_weights f, stakeholder_weights b
where  f.valuation='Valuation NA' and
       b.valuation='Valuation BA' and
       f.scenario=b.scenario
group by plan,f.scenario
order by f.scenario,loss_valued
```

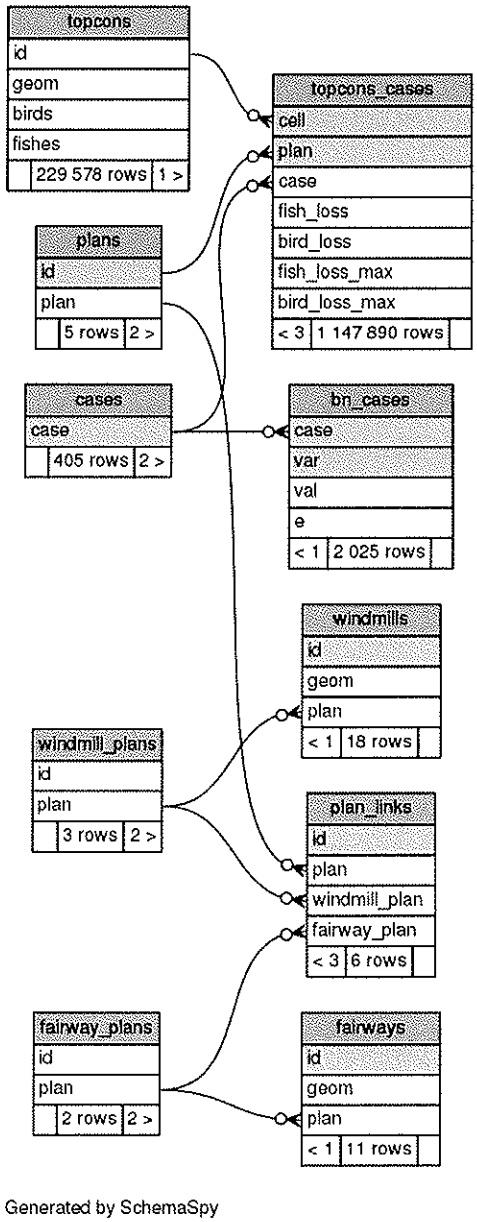

Figure 2. The schema of the TOPCONS database with the grid (topcons), plans, and data from impact model.

5 Further work

The TOPCONS tool is a prototype, which is planned to provide support for a specific workflow. It is probably not possible to develop a fully flexible tool that would automatically run the whole workflow automatically. This is because the variations that the case at hand, data, workflow itself, or something else allows and/or necessitates prohibits it. Also, at its current state of development the tool is not ready for production use. Two areas of immediate further development can be identified.

Currently many of the Perl programs have case specific data hard coded into them. This is not fatal as they can be easily changed but ideally they should be obtained from Bayesian networks of the

case or from the database.

Currently the code of the TOPCONS plugin does very little that actually supports the workflow. The user interface is mostly a proof-of-a-concept and should be developed further.

There are also some deeper issues concerning the workflow and the technical approach that warrant more thought. For example it might be more efficient to use rasters for the analysis instead of a vector grid since the vector grid, while it has some benefits, is relatively slow to update, visualize, etc.

6 References

A Jolma, A Lehikoinen, I Helle, R Venesjärvi. 2014. A software system for assessing the spatially distributed ecological risk posed by oil shipping. Environmental Modelling & Software 61, 1–11.

7 Attached files

The attached files are in a package TOPCONS too files.zip.

topcons/*

: The plugin

*.pl

: The Perl programs for various tasks

app.qgs

: QGIS project file for the alpha test

database_schema.sql

: PostgreSQL database schema for the alpha test

*.oobn

: TOPCONS models used in the alpha test

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