Technical Report No. 10

Nest – a decision support system for management of the Baltic Sea

A user manual

August 2013

Fredrik Wulff, Alexander Sokolov and Oleg Savchuk

Baltic Nest Institute

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Contributors

Behind the Nest system are the collective efforts of many people primarily at the Baltic Nest Institute (BNI) now part of the Stockholm University Baltic Sea Centre. Alexander Sokolov has designed and developed all the program interfaces of Nest. Oleg Savchuk, together with Fredrik Wulff, has developed the marine model SANBALTS. Bo Gustafsson, Oleg Savchuk and Bärbel Müller-Karulis are the key developers of the BALTSEM marine model. Carl-Magnus Mörth, together with Christoph Humborg, have initiated and developed the drainage basin model CSIM. Chris Harvey, Olle Hjerne and Sture Hansson (at the department of Ecology, Environment and Plant Sciences, SU) developed the fishery model and Ing-Marie Gren (at the department of Economy, SLU) developed the cost-minimization model.

The marine and riverine nutrient load databases were initiated by Fred Wulff and are maintained by Miguel Rodrigues Medina. The marine databases are now to a great extent a common product of many research organizations around the Baltic, thanks to the remote access to regional databases developed by Alexander Sokolov. He has also developed the remote access to the databases and models of atmospheric deposition of nutrients of EMEP (Jerzy Bartnicki) and DEHM (Kaj Hansen Mantzius). Christoph Humborg initiated the drainage basin database, developed and maintained by Erik Smedberg. But the Nest system is truly a collective effort and many people within and outside BNI have contributed with data and ideas.

The Baltic Sea, an ecosystem under pressure

Input of nutrients like nitrogen (N) and phosphorus (P) to the sea is a prerequisite for life, not an environmental problem. It becomes a problem only when the inputs increase to such an extent that the original properties or functions of the ecosystem change. Then it has become "too much of a good thing". When this happens in a marine area or a lake we refer to it as eutrophication. The natural cycle of accumulation and decomposition are no longer in reasonable balance. The semi-enclosed and brackish-water Baltic Sea is in many respects particularly sensitive to eutrophication, with its slow water exchange and built-in natural barriers.

Measures taken by many countries during the last decades have reduced total loads of both N and P, but loads still remain higher than needed if eutrophication is to be reduced to an acceptable state. Eutrophication continues to be a priority environmental problem of major concern in the Baltic Sea Region. There are several reasons behind this. A large proportion of the total load of waterborne and airborne nutrients to the Sea originates from diffuse sources; such as agriculture, a sector where national legislation is not as efficient as for point sources from municipalities and industries. Still, many measures to counteract eutrophication need to be implemented. There are also considerable time delays between measures taken in a drainage basin and detectable reductions in inputs of nutrients to the Sea. The long residence time of nutrients in the sea basins (many years) means that outputs from one region are likely to affect other regions. The open coastal zones are affected not only by nutrient inputs from land, but also from the open sea and, thus, also by transports from other basins.

The dramatic changes of the ecosystem that we have seen during the last century have multiple causes. Eutrophication and fisheries are intimately linked. Climate changes, the establishment of new species in this young sea and the effect of persistent toxic substances are other factors. In order to develop management strategies for any ecosystem, it is important to understand the relative importance of different factors causing change.

Since the effects of eutrophication are the result of nutrient transports and transformations in a number of interlinked systems, management without understanding the links between the systems is likely to result in more costly mitigation programs than necessary. An ecosystem approach is needed. Although our understanding of the Baltic is considerable, it is highly fragmented and there is a need to utilize and synthesize scientific information pertinent to the relevant problem and management scale. A common language for communication between scientists and managers, and a consensus about scales, problems and causes, needs to be established. Such a holistic approach must take into account not only characteristics of the sea but also of the surrounding drainage basin. An understanding of human behavior and how man influence the sea is also an integral component of an ecosystem approach. The decision support system *Nest* has been developed as a tool to synthesize our current understanding of the Baltic Region and as a tool for better management, particularly in relation to eutrophication and fisheries.

The decision support system Nest

The decision support system Nest was initially developed within the MISTRA-funded MARE research program (http://www.mare.su.se), which was completed in 2007. Nest was then successfully used for the development of the eutrophication segment of the HELCOM Baltic Sea Action Plan (BSAP http://www.helcom.fi/BSAP/ActionPlan/en_GB/ActionPlan/#eutrophication), where nutrient load reductions needed to reach a healthy Baltic Sea were calculated, as were the allocations between countries. Nest is also used in many research programs. The maintenance and further development of Nest has continued within the Baltic Nest Institute (BNI, http://www.balticnest.org/).

The Nest system links the entire Baltic Sea region, from watershed to offshore ecosystems, through data and models. It is available online, free of charge, and can be run in both expert and standard mode. The main target groups of the Nest system are decision-makers and scientists in the Baltic region interacting with the Helsinki Commission (HELCOM), as well as those working on the implementation of the EU Water Framework Directive and Marine Strategy Framework Directive. We also hope that it can be useful for students interested in learning more about the Baltic Sea. The different components describe forcing by nutrient inputs and characteristics of the drainage and sea basins. The marine models describe the physics and biogeochemistry of the Sea, as well as of its food webs (to the levels of man and seals), and are used in scenarios of how fisheries, eutrophication, and climate change affect this unique ecosystem. Finally, the strong interdependence of the countries around the Baltic is illustrated when the costs for reducing nutrient load, with or without cooperation, are calculated.

This manual is by no means the final version: it will be continuously improved and modified, both as a result of user inputs and when components of Nest are modified. The most recent version of Nest, as well as this manual, will always be available from our web site http://nest.su.se and www.balticnest.org.

Nest has been designed as a web distributed system and to use it you need access to the Internet; some components are installed on your (client) computer, others are installed on the servers that you communicate with. Experts continuously update the components of Nest. Each time you start the program, your client software is checked and updated if a new version is available. This procedure ensures that you always use the most recent version of Nest.

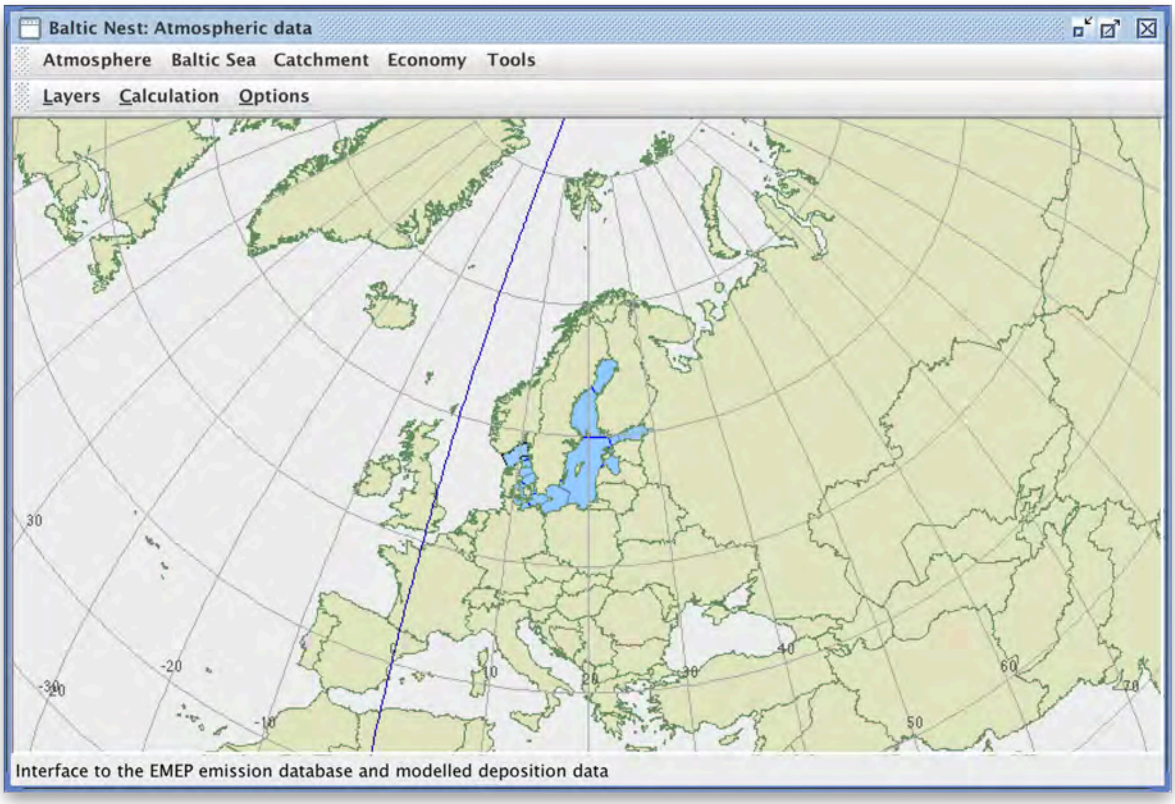
How to get started – launching Nest

The Nest system is accessed through a special web page on the Internet site hosted by the Baltic Nest Institute at Stockholm University. In order to launch and run Nest you need to have Java Virtual Machine (JVM) installed on your computer, and accept that Nest gets access to your computer. In most computer operating systems, Java is already preinstalled.

If you do not have Java Virtual Machine installed you can click Installation in the right hand upper corner of the Nest home page or just manually type in http://java.com and access the Java download page. The Java software can be downloaded free of charge from this site. After installation you will be able to start Nest from the Nest home page: http://apps.nest.su.se/nest

If you have Java installed, click *Start Nest* in the upper right corner of the Nest launch page. The system will now start loading.

Here you can read about recent developments of Nest (*News*) and about program version and data sources (*About*). You must agree on the terms of use (*License*) before you press *Accept* and the initial window of Nest will appear.



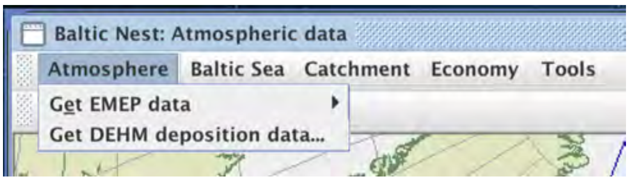
The Nest system contains several modules, which are grouped by environment and can be accessed from the main menu bar (Atmosphere, Baltic Sea, Catchment etc.). The second row of the menu provides tools for each module of Nest and can be different for different modules.

On the bottom of the window there is a signal line that provides some additional explanatory information on the items over which you move the cursor of the mouse.

Most of the modules use GIS maps, which can be manipulated in a common usual ways (mouse scroll to zoom in or out and mouse drag to move a map).

When Nest is open, you will first see the *Atmospheric* module of the system.

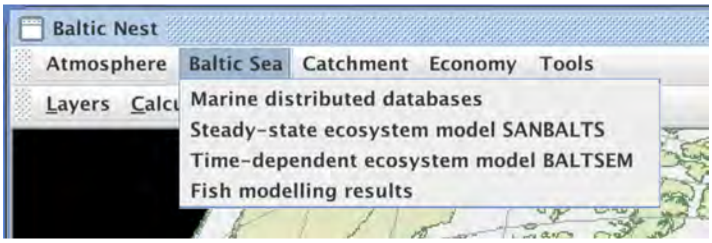
Atmosphere



About 25% of the nitrogen inputs to the Baltic Sea arrives via atmospheric deposition and is thus a very important source. With this interface you can obtain data on atmospheric nitrogen and sulphur emissions from- and depositions onto all countries and seas in Europe, with particular details for the Baltic Region. These data are accessed via the Internet from the UNECE/EMEP databases hosted in Oslo and Vienna and from the DEHM model in Denmark. You can also access 'blame matrices', with which you can calculate how much of the depositions on a specific region originate from a particular source/region or country. The other components are:

Baltic Sea

The *Baltic Sea* menu provides tools to explore a number of databases and models describing different features of the sea:



Marine distributed databases

Here you can extract, view, and analyze the information about hydro-chemical conditions in the sea. Measurements from many large databases located at various (research) institutes around the Baltic are remotely accessed here.

Steady-state ecosystem model SANBALTS

This physical-biogeochemical marine model, called SANBALTS, computes and visualizes effects of how changes in nutrient (nitrogen and phosphorus) loads affect conditions in all the major sub-basins of the Baltic Sea. SANBALTS was used for the calculations of allowable inputs of nutrients for a healthy Baltic Sea of the BSAP (HELCOMs Baltic Sea Action Plan) in 2007.

Time-dependent ecosystem model BALTSEM

Similarly to SANBALTS, this model simulates physics and biogeochemistry of the Baltic Sea, but with a much higher spatial and vertical resolution. You can also study the effects of climate change in scenarios of the future. This model is now used for the revision of the BSAP, to be finalized in 2013.

Fish modeling results

A model of the food web of the Baltic Proper than can be used to evaluate the effects of various fishery management options, as well as effects of eutrophication and seals on cod, herring and sprat.

Catchment

The *Catchment* menu contains tools to explore a number of databases and a model describing characteristics of the Baltic Sea drainage basin:

Riverine database

Includes tools that can be used to estimate riverine loads of nutrients to the Baltic Sea basins from different drainage basins.

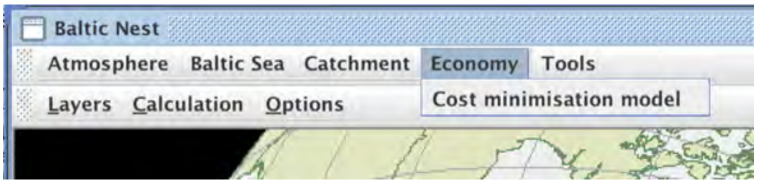
Catchment data

Here, we have compiled a large number of data, describing the distribution of human activities generating most of the nutrient inputs that is within agriculture and sewage treatment from the Baltic Sea catchments. These inputs to the drainage basins are then used in the watershed model (see below). Most of these data originate from EU sources.

Watershed model CSIM

The CSIM (Catchment Simulation) model describes how nutrient runoff from the Baltic watershed to the Sea depend on drainage basins characteristics such as land cover, agriculture, populations, etc. You can change these sources and explore the resulting effects on loads.

Economy



Cost minimization model

The model that is currently available here can be used to calculate minimum-cost solutions (for measures within major sectors of society) needed to achieve a specific improvement in water quality in any of the seven major Baltic Sea sub-basins. The data behind the model are not up to date, but the model still shows, qualitatively, the principles regarding how we can reach a cost-minimization solution for the Baltic.

Tools

The *Expert mode* allows you to display results with higher details compared to the default mode. *Documentation* will lead you to web pages with further information about the models and Nest.

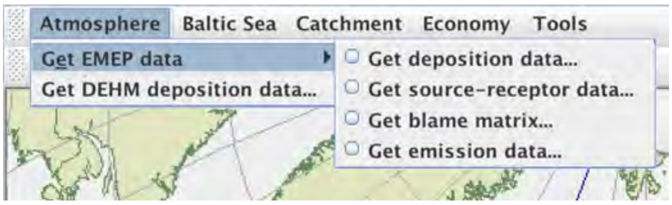
The rest of this manual is devoted to a detailed description and user manual of all the components of Nest. Each section includes a list of references to studies where these components have been used.

Atmosphere

This is an interface to emissions and modeled deposition fields of nitrogen and some other substances for Europe. The data are accessed from EMEP (European Monitoring and Evaluation Programme) and the Danish Eulerian Hemispheric Model (DEHM), with a resolution of 50 km x 50 km. You select the data source by clicking on *Atmosphere*.

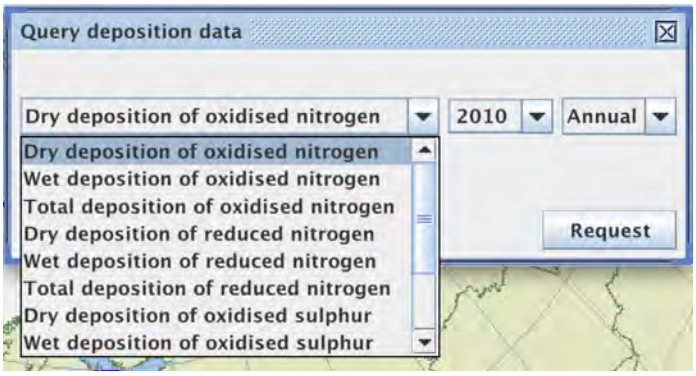
EMEP data

Atmospheric nitrogen depositions/emissions to the Baltic Sea used in the EMEP module originate from the UNECE/EMEP emission database. For information about the modeled data, please go to the EMEP web site. The data aggregations and averaging for 2000-2006 were compiled by EMEP to be used by BNI for the calculations of the HELCOM Baltic Sea Action Plan. With EMEP data you have several options:

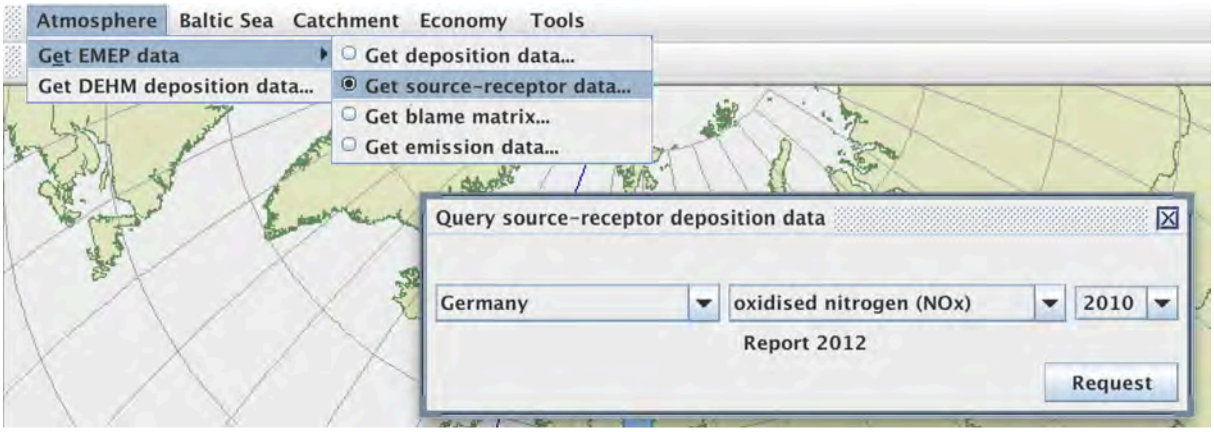


Deposition data

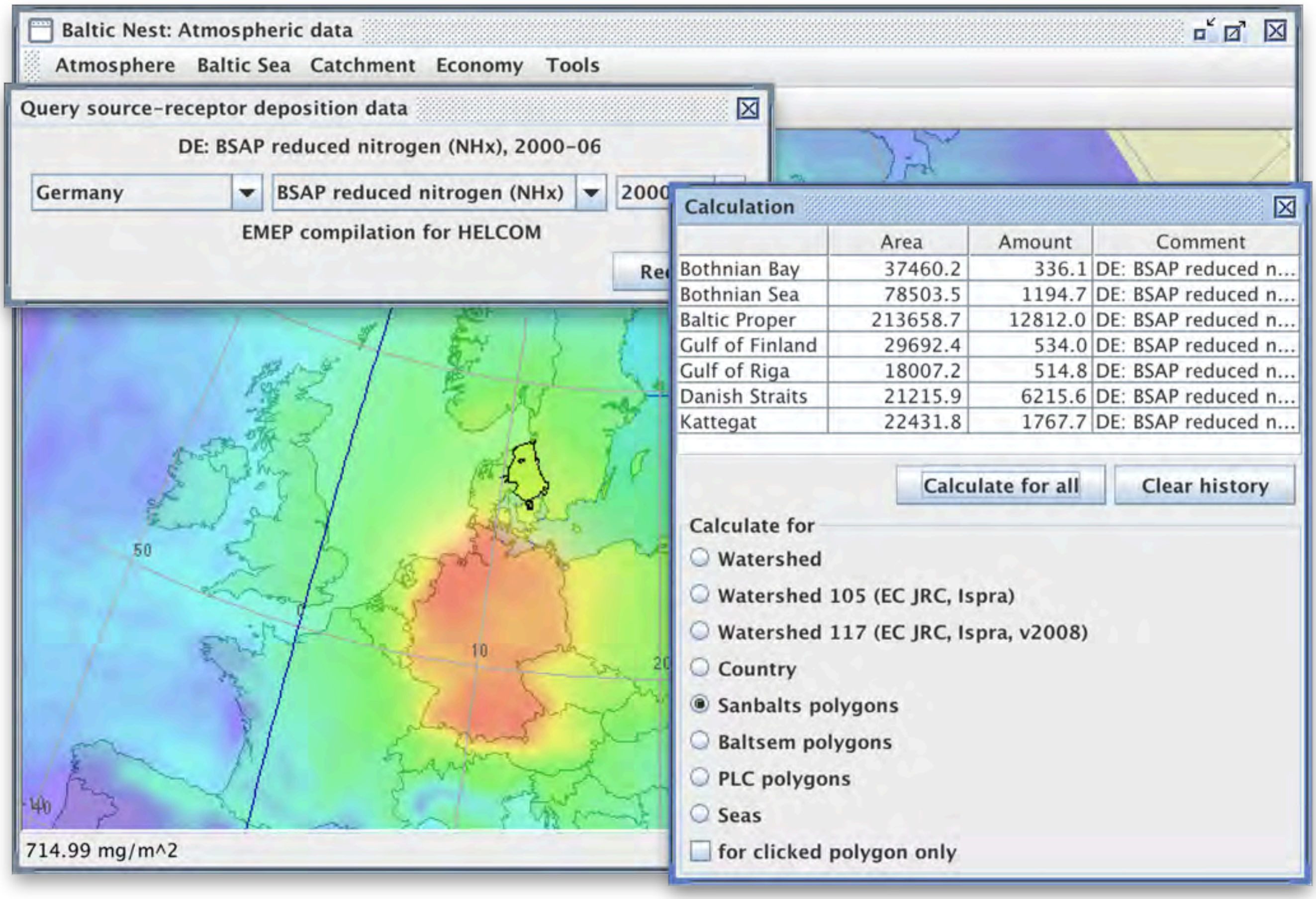
If you choose *Get deposition data* from the EMEP databases, you can then select time periods and various forms of nitrogen (oxidized or reduced, wet and dry, and total amounts), as well as depositions of sulphur.



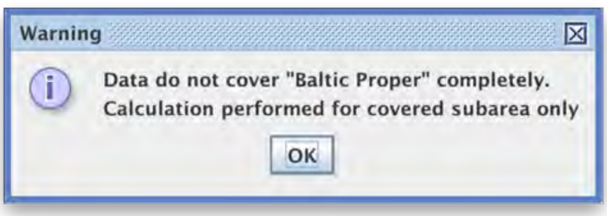
Source-receptor data



The source-receptor calculations show depositions of nitrogen and sulphur from a particular country on the EMEP grid. A description of these data and the calculations are found at http://www.emep.int/SR_data/sr_grid.html.



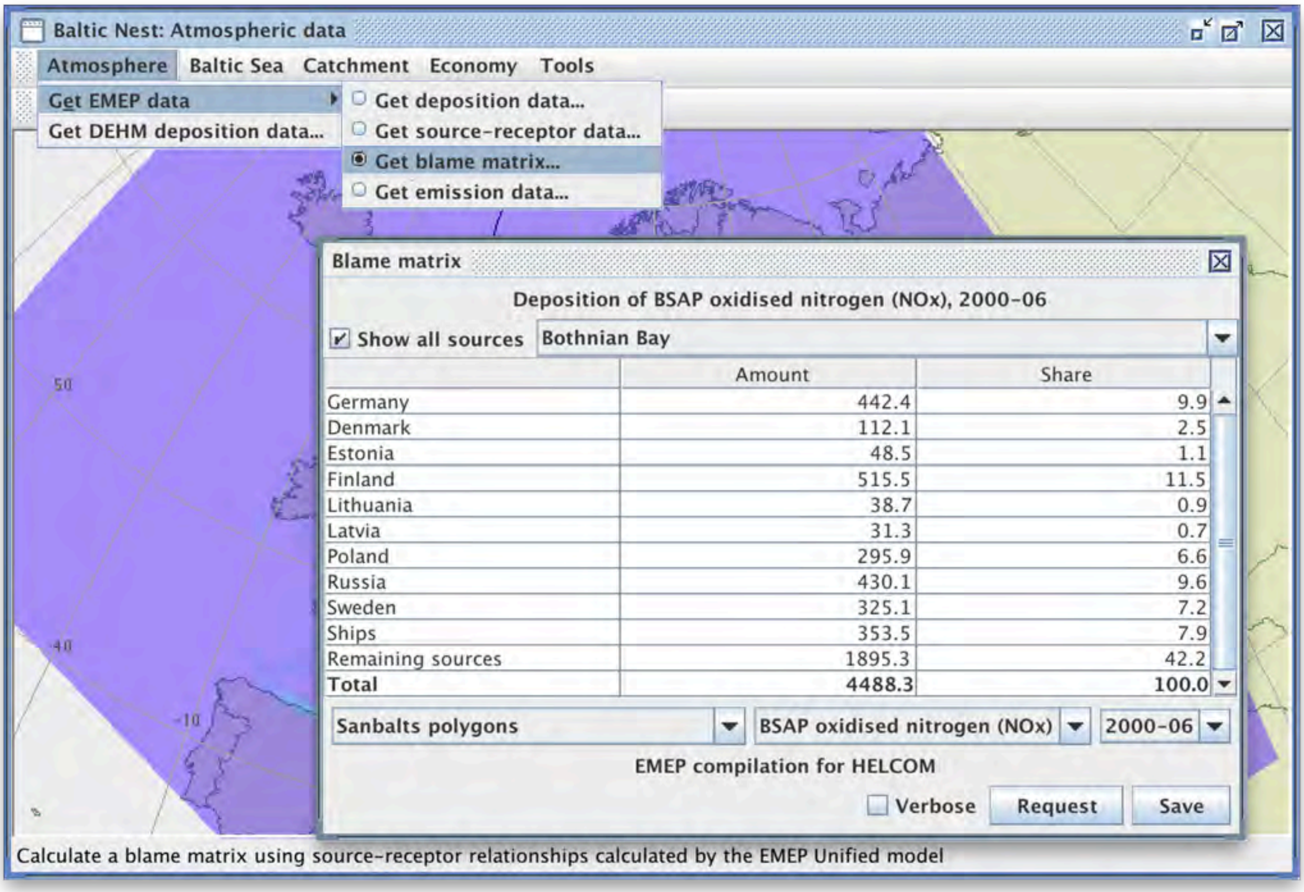
In addition to total amounts, source-receptor deposition data for combustions, transports and agriculture can be selected. In some cases you will receive a warning, such as this:



This means that the modeled deposition fields may contain questionable data for some points, especially at very low levels of the chosen variable. These data are then omitted from the calculations of the total depositions over the requested areas, and only the areas that contain valid data are calculated. When this warning is shown, some parts of the Sea, country or drainage basin are thus not included. You can decide how large this omission is by comparing the calculated areas, using another deposition variable that does not give this warning.

Blame matrix

From the EMEP model, you can get estimates of how much of the deposition that reach a particular sub-basin originates from a specific country around the Baltic Sea. In addition, estimates are given for depositions from ships on the Baltic, as well as from sources outside the region. These estimates can be calculated for each of the different marine regions and watersheds, with the spatial resolutions described earlier. If you click the option *Show all sources*, you will get the deposition from all countries and other sources outside the Baltic region, on the polygon you select. These calculations are available for all years since 1997, as well as averages for the periods 2000-2006 and 1997-2003. This example shows the origin of BSAP oxidized nitrogen depositions over the Bothnian Bay, averaged for 2000-2006.

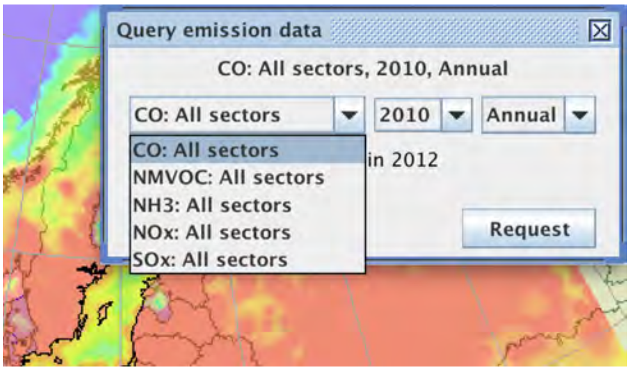


The check box *Verbose* tells the system to notify the user about any warnings, which can occur during the calculation. Note that it can produce hundreds of notifications when data are not covering the areas completely.

If you click the *Save* button, all blame matrices can be stored in a CSV-file that can later be read and used by other programs, such as Excel. You can also right-click with the mouse on the table to save only the selected content of the table.

Emission data

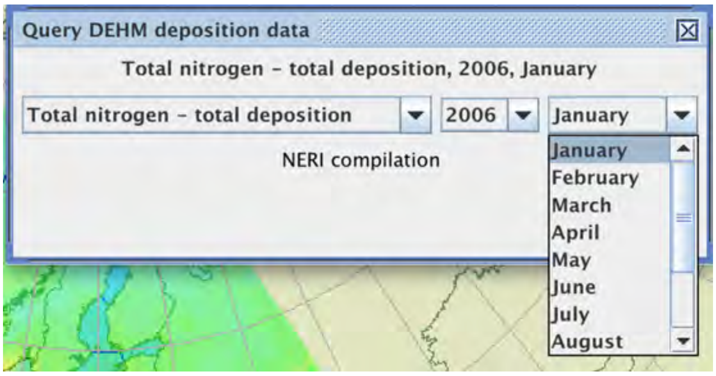
This is the interface to the gridded data from the emissions database of EMEP with the official, reported emissions from the countries for a particular year. Gaps in coverage are filled by EMEP.



NMVOC is the abbreviation for non-methane volatile organic compounds. NMVOC is also used as a sum parameter for emissions, where all NMVOC emissions are summed up per weight into one figure. In absence of more detailed data, this can be a very coarse parameter for pollution, e.g. for summer smog or indoor air pollution.

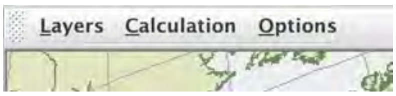
DEHM deposition data

The Danish Eulerian Hemispheric Model (DEHM), is a atmospheric chemistry transport model that covers the Northern Hemisphere with a resolution of 150 km x 150 km. It uses a two-way nested grid for the European area with the resolution 50 x 50 km developed at the University of Aarhus in Denmark (http://envs.au.dk/en/). These data have a higher temporal resolution (monthly) than the currently available EMEP sets (annual or longer). A high temporal resolution could be useful, e.g. for detailed budget calculation where the relative contributions of various nitrogen sources on a monthly resolution are needed.

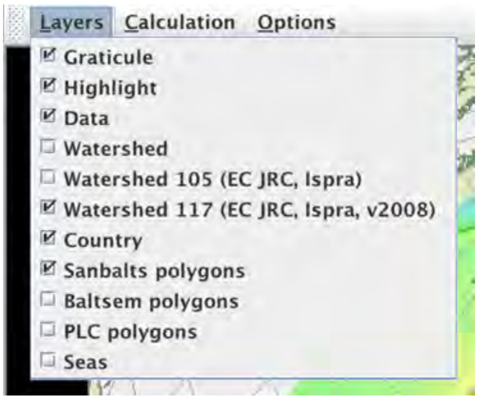


Analysis of data

The user can control visualization and data analysis using the sub-menu:



Layers



Here you can select the layers that you want to see and use on the map:

☐ *Graticule* draws latitudes and longitudes, 10° apart on the map with the default scale (step can vary with a map scale).

☐ *Highlight*. With this option the region you have chosen is brightly colored when you click on the map.

☐ *Data* layer shows requested gridded data for the selected variable and time on the map.

Other options determine which areas can be used for integration of the requested data

☐ *Country* shows boundaries for all countries in Europe.

☐ *Sanbalts polygons* are the sea boundaries used by the SANBALTS model, which are also available in Nest.

☐ *Baltsem polygons* are the sea boundaries used by the BALTSEM marine model, also available in Nest.

☐ *PLC polygons* are the set of sea boundaries used in PLC (HELCOM Pollution Load Compilation).

☐ *Seas.* With this option, other seas in Europe (within the modeled domain) are available for calculations.

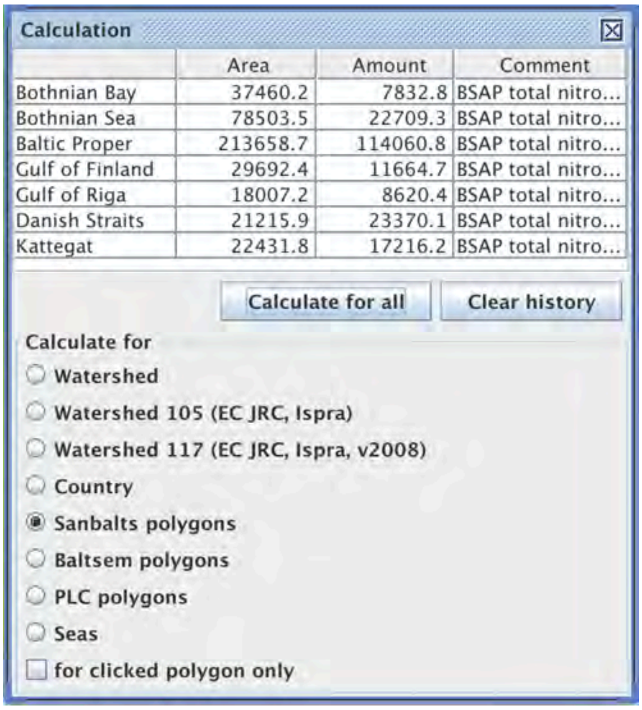
☐ *Watersheds*. By default a total of 81 sub-drainage basin boundaries developed by Grid-Arendal (http://www.grida.no/baltic/) are used. Note that you must deselect country boundaries if you want to see watershed boundaries.

☐ *Watershed 105 (EC, JRC, Ispra).* Boundaries defined by the Joint Research Centre of the European Commission at Ispra, Italy (see http://ccm.jrc.ec.europa.eu/php/index.php?action=view&id=23) These 105 boundaries are currently used in the Watershed model CSIM in Nest.

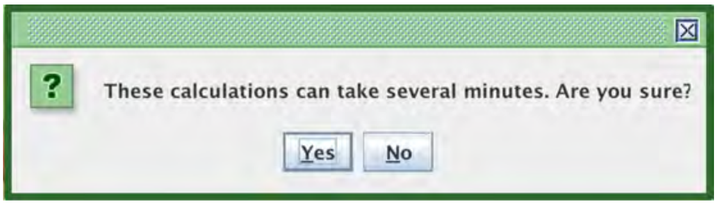
☐ *Watershed 117 (EC, JRC, Ispra, v2008).*

Calculation

When you select the *Calculation* check-box, a panel appears over the map and you can then select to calculate integrated depositions/emissions for various types of regions shown on the map. It is important to make sure that the selected layer in the Calculation panel is also selected in the Layers menu to ensure that the required polygons are drawn on the map. The *Sanbalts* and *Baltsem polygons* correspond to the spatial resolutions of the Baltic in the two marine models available in Nest. Below you see the panel of total annual nitrogen depositions on each Baltic Sea major basin, averaged for the period 2000-2006, as calculated by EMEP for HELCOM. The calculations are performed using only the gridded data that you have already requested using the *Request* panel.

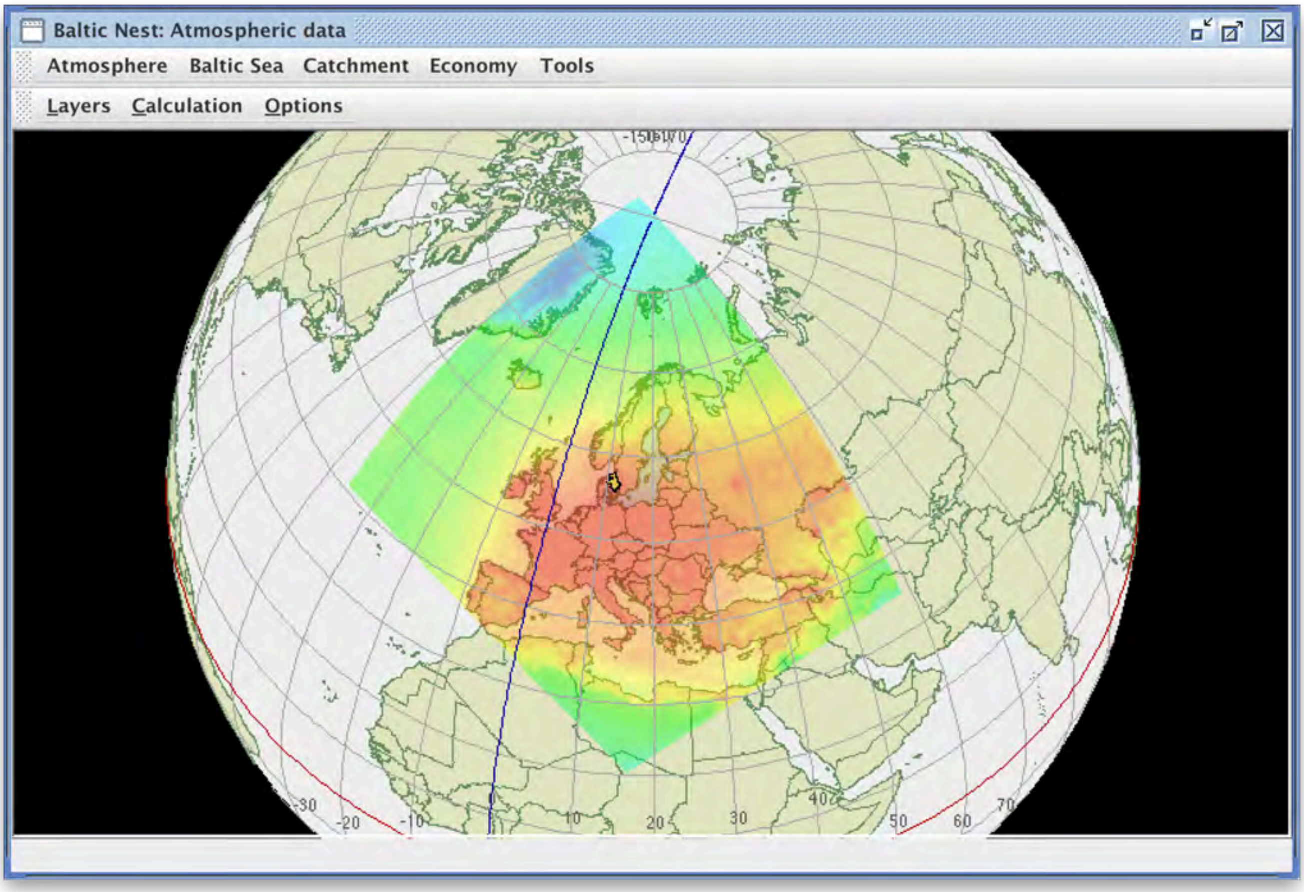


You could get these results if you click *Calculate for all*. Alternatively, you can click on each region (polygon) on the map. You can change the size of the calculate window by clicking on it and drag any corner with the mouse. You can also keep the data and select another data set in the Request panel. If you press *Calculate for all* again, these results are shown below the first compilations. If you don't want this, click the *Clear history* button. Some of the computations are quite time consuming and you will see a warning window before you continue with the calculations.



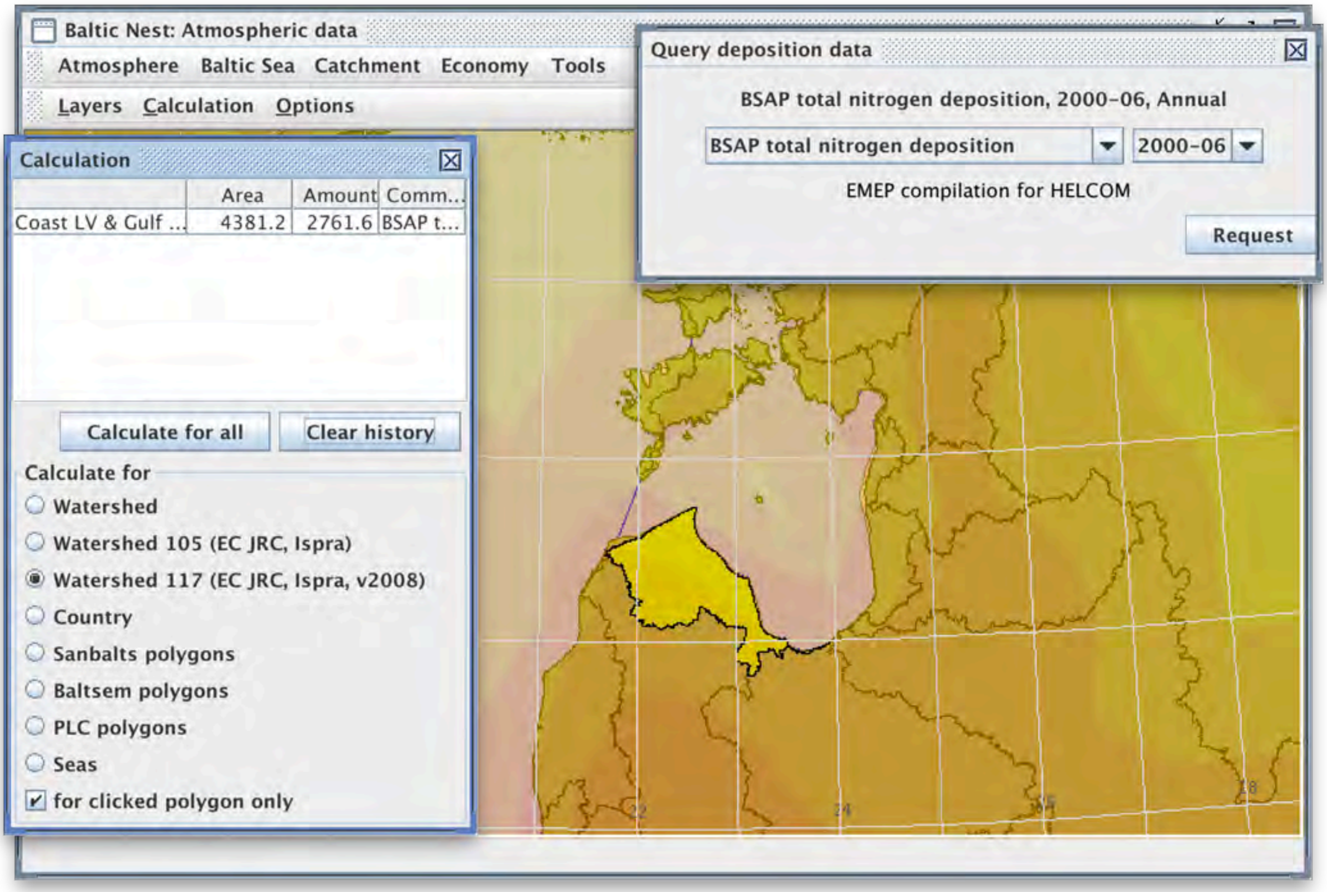
The units for the numbers shown in the *Calculation* window are shown in the lower left corner of the Nest main window.

Important! Do **not** use the *Calculate for all* option for *Country*. There are several reasons for this, asides from taking a very long time; the deposition databases do not cover the entire territory for many countries. For the Baltic region only the Western part of Russia is covered. You can find data outside the Baltic regions for many European countries, and for e.g. Spain, outlying regions, like the Canary Islands, are not covered. As you can see from the coverage below, you can get complete data for many countries outside the Baltic Region. The EMEP coverage (shown here) is however larger than the DEHM deposition fields.

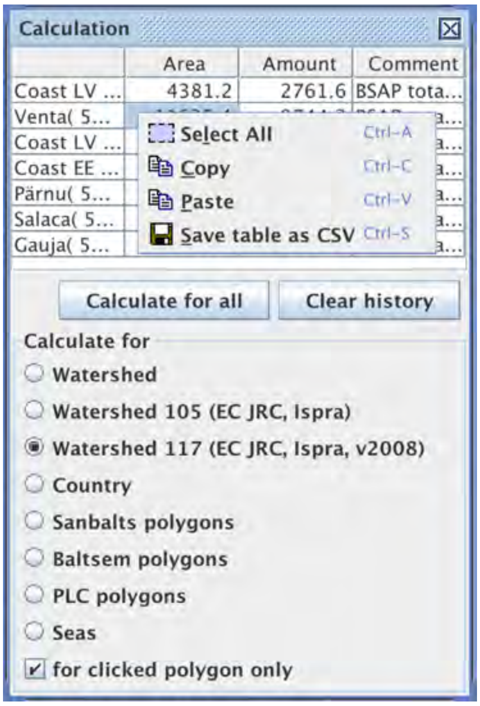


For countries, the best approach is to click on each country/polygon in turn and the results are then shown in the Calculation window. You can thus get a measure for the Spanish mainland, but excluding e.g. the Canary Islands.

You can also select an area with the mouse, surrounded by a *clicked polygon only* (usually an island or a smaller watershed), within a greater region. In this example, we show a watershed adjacent to the Gulf of Riga, with the resolution of the ISPRA watersheds from 2008 and total nitrogen depositions from EMEP, averaged for 2000-2006.

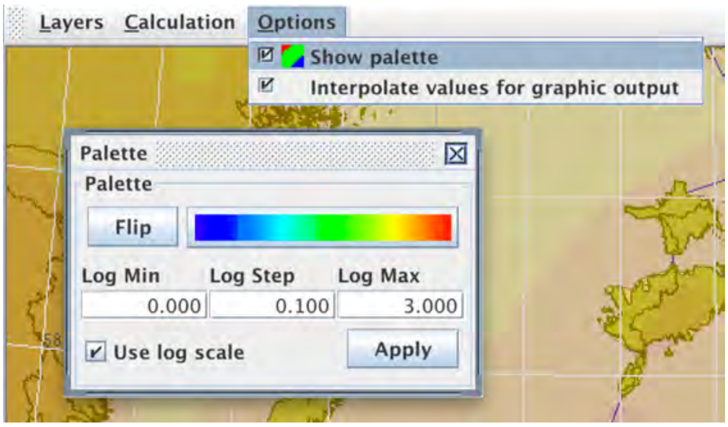


All the data within the tables can be 'copied and pasted' into other applications (right-click on the table), as well as saved as a CSV file.



Options

A palette is shown in a window on the map that can be used to change the color scheme of the deposition/emission fields. Gridded values are interpolated for smoother graphical presentations by default. You can deselect this in order to show gridded data in their original resolution.



Literature

Bartnicki, J., & S. Valiyaveetil. 2008. Estimation of atmospheric nitrogen deposition to the Baltic Sea in the periods 1997–2003 and 2000–2006. EMEP MSC-W, Summary Report for HELCOM.

Bartnicki, J., A. Gusev, W. Aas, H. Fagerli and S. Valiyaveetil. 2008. Atmospheric supply of nitrogen, lead, cadmium, mercury and dioxines/furanes to the Baltic Sea in 2006. EMEP Centers Joint Report for HELCOM, Technical Report MSC-W 3/2008, Oslo, Norway.

Bartnicki, J., V.S. Semeena and H. Fagerli. 2011. Atmospheric deposition of nitrogen to the Baltic Sea in the period 1995–2006. Atmospheric Chemistry and Physics Discussion 11: 1803–1934. doi: 10.5194/acpd-11-1803-2011.

EMEP – European Monitoring and Evaluation Programme - a scientifically based and policy driven programme under the UN Convention on Long-range Transboundary Air Pollution (CLRTAP) for international co-operation to solve transboundary air pollution problems.

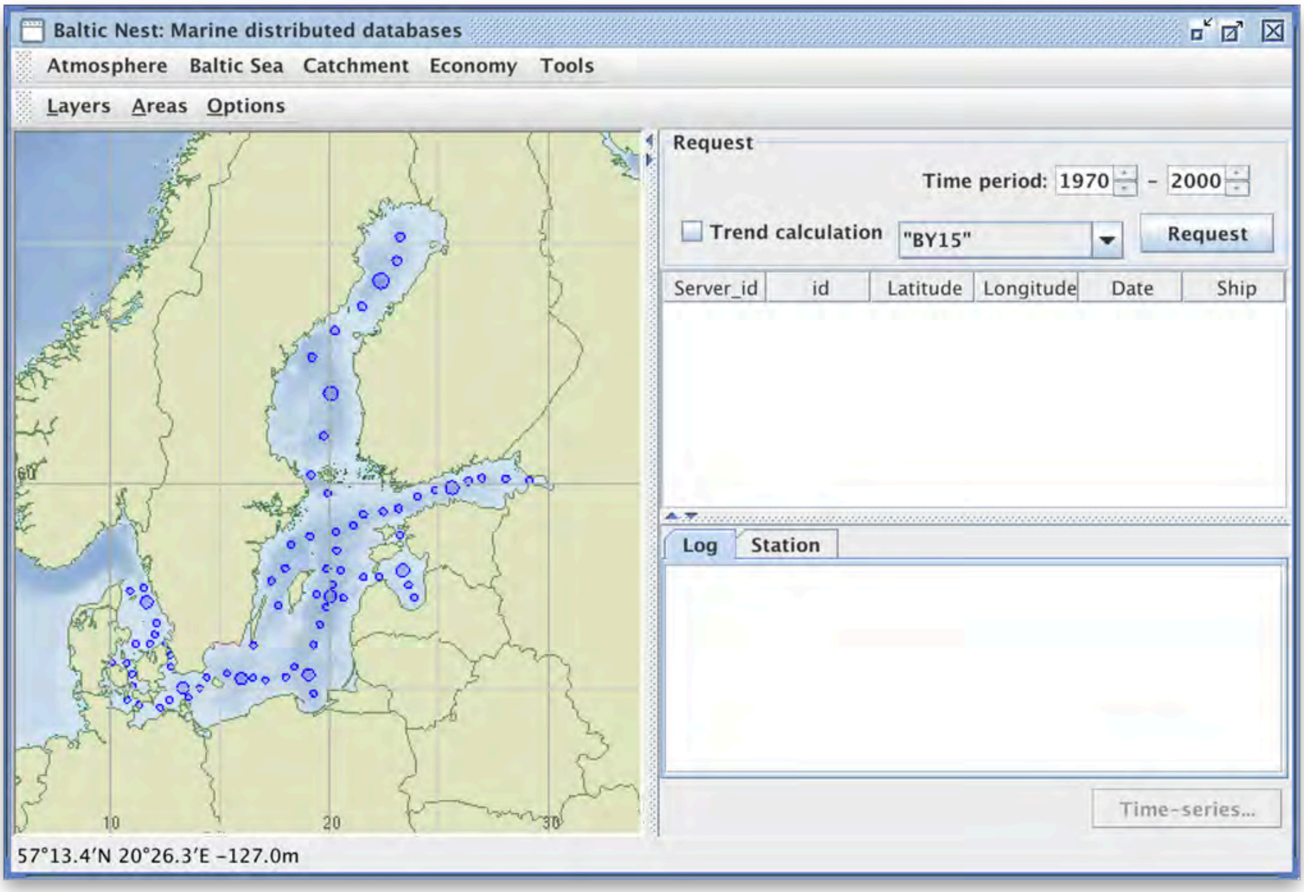
Ruoho-Airola, T., K. Eilola, O. P. Savchuk, M. Parviainen and V. Tarvainen. 2012. Atmospheric Nutrient Input to the Baltic Sea from 1850 to 2006: A Reconstruction from Modeling Results and Historical Data. *Ambio*, *41* (6), 549-557.

Baltic Sea

Marine distributed databases

With this module you can explore the hydrographic and geochemical conditions in the Sea. It is also intended as a convenient tool for evaluating some of the data needed to develop and validate the various marine models used in Nest.

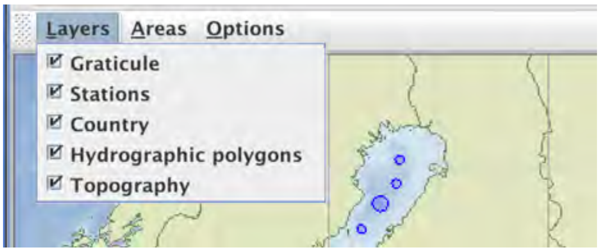
The large databases, located at BNI as well as in several countries around the Baltic Sea, are regularly updated as new data compilations become available on hydrochemical marine observations. These data are presented in great detail. The purpose for doing so is to permit a free and open evaluation.



The left panel shows a map of the Baltic Sea. In the menu bar above the map you can chose between:

Layers

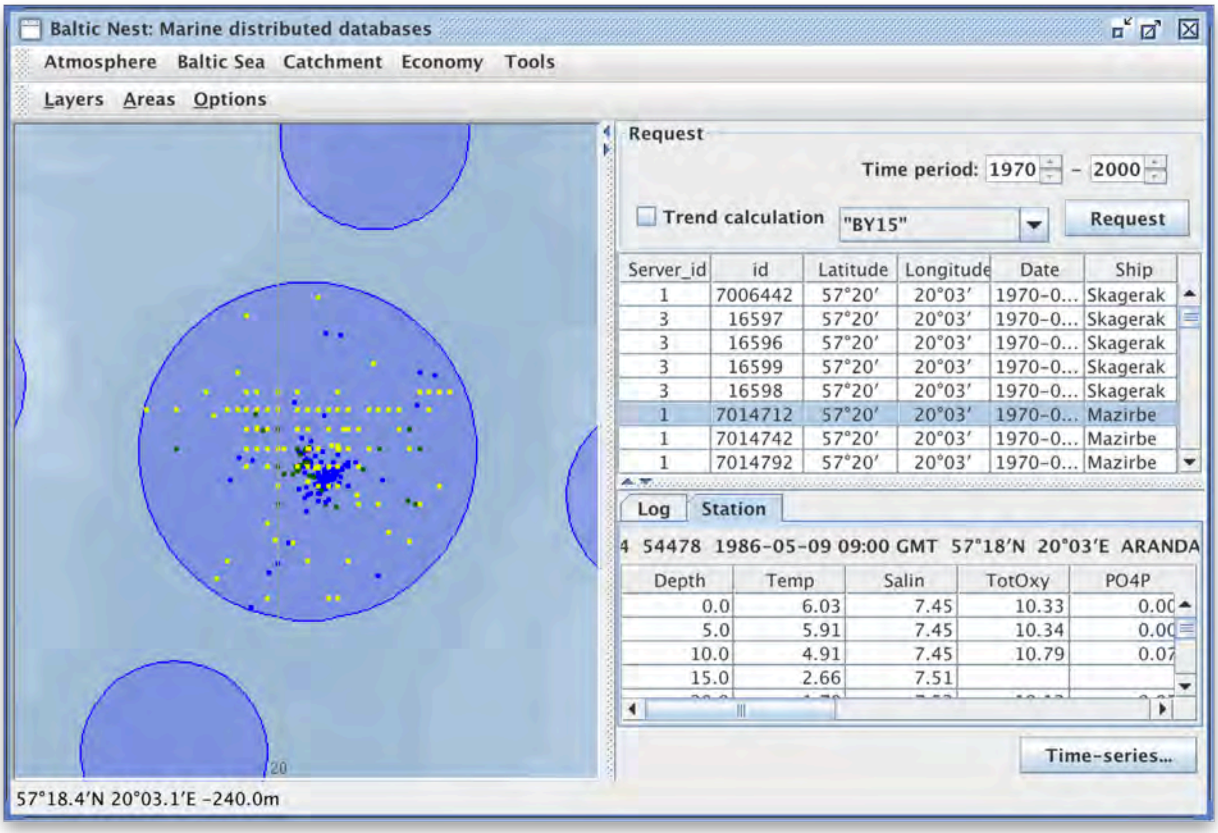
Here you select visualizing layers on the map. These are shown on the map and can also be used to select data when you click within the boundaries. The different features are:



Graticule
Places a 10-degree latitude-longitude grid over the map.

Stations
Shows the position of all hydrographic observations, requested and received from the databases.

Hydrographic polygons
The layer *Hydrographic polygons* is used to select an area for data request. You can request data for two types of areas: a circle and a polygon. By default, there are a large number of circles bordering the major monitoring stations in the Baltic. The user can click on any of these and the corresponding name appears on the Request panel (in the upper right corner). In this panel it also possible to select a *Time period* and request the data from a set of distributed databases by clicking the *Request* button. This is the preferred method to select data from often visited monitoring stations, since the ships cannot always make measurements at very exact, predefined coordinates each time. Here is an example from BY15 in the Eastern Gotland basin. All the stations, within the circle and within the time interval prescribed in the right panel, are shown on the map (enlarged here) as dots. The actual measurements at a specific position are shown in the lower right panel if you click on a specific dot on the map.



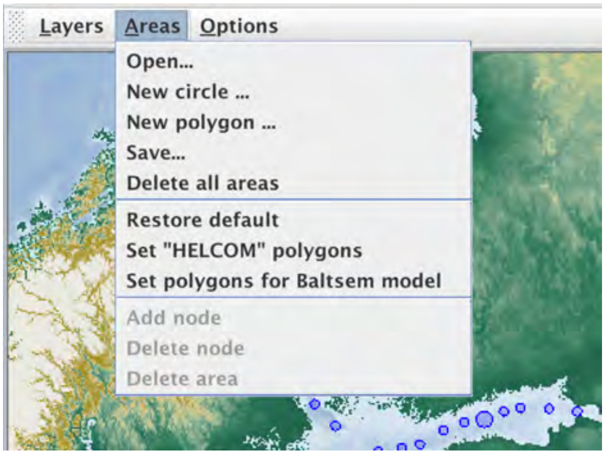
Country

A map layer showing country borders, even those outside the Baltic region.

Topography

A topographic map is shown covering both land and sea. This map is hidden when the Country layer is also selected. Water depths or land elevations at the point of the cursor are shown in the lower left corner.

Areas

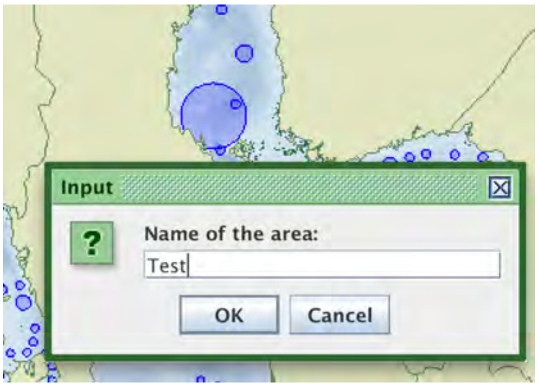


Open

Gives you the option of using a previously defined and stored circle or polygon on your computer.

New circle

You can define your own circle to retrieve all stations encompassed by the circle. Use the mouse to place and define the size of the circle. You can then give it a name when you click on the map anywhere outside the circle. When you have saved the circle, you can then click on it and retrieve data within its borders.



New polygon

You can define a user-defined region by creating a *New polygon* from the drop-down menu. Draw the polygon by clicking with the cursor around the boundaries. Double-click on the last node when you have finished and then click outside the polygon to name it in the window that now appears on the map.

Save

Save allows you to save current areas (circles and/or polygons) on the local computer for later use (see *Open* menu item).

Delete all areas

This menu item allows you to take away all areas from the map, predefined as well as those created by the user.

Restore default

This option will place the predefined circles surrounding major monitoring stations on the map.

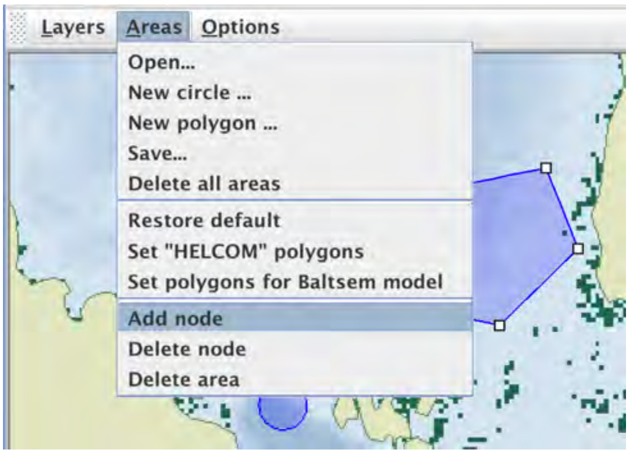
Set 'HELCOM' polygons.

This option divides the Baltic Sea into the sub-regions officially defined by HELCOM and used in the marine model SANBALTS.

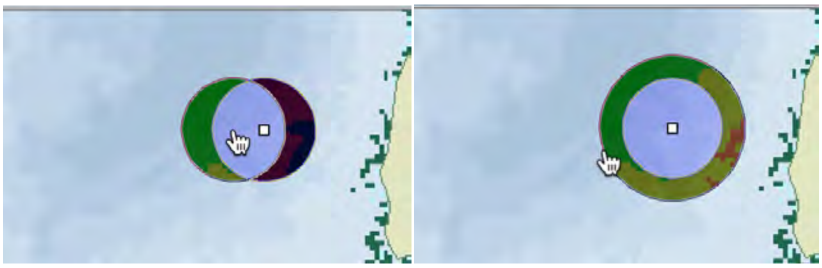
Set polygons for the Baltsem model

You will then choose the sub-regions used by the BALTSEM marine model (for further details, see this module below)

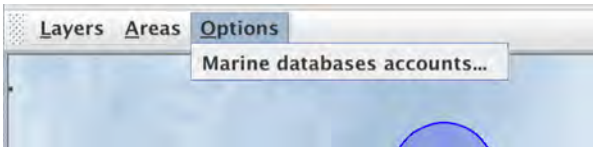
The three last items in the Areas menu (*Add (clone) node*, *Delete node* and *Delete area*) can be used to change the shape of any polygon on the map or delete the selected area. Usually these items are disabled (greyed out) and become active only when an area is selected for editing by a right button mouse click. The selected area can also be moved with the mouse in editing mode.



If the editing area is a circle the user can drag it by the center and/or resize it by dragging the outer boundary.

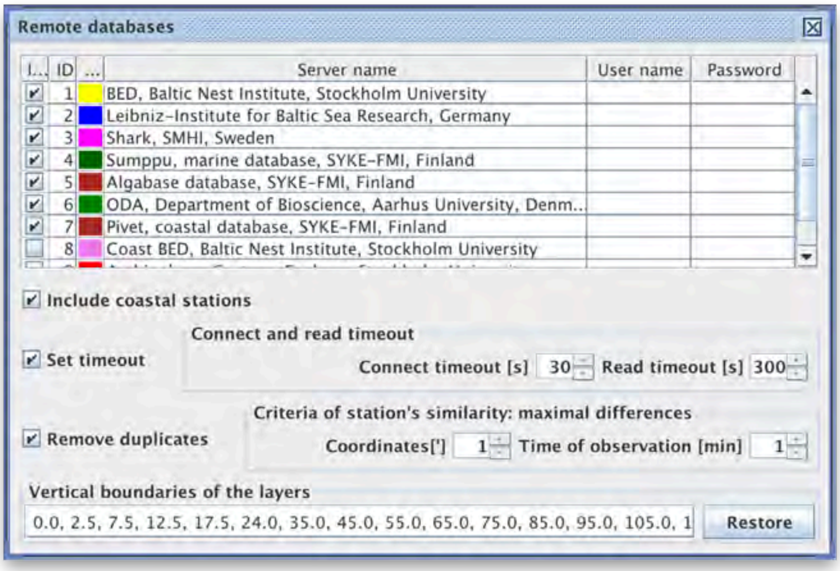


Options



Marine databases accounts

Here you will have the possibility to include/exclude various hydrochemical databases. We have managed to establish a number of agreements with institutions around the Baltic that collect marine observations and maintain these databases. They can now be remotely accessed through Nest. Click on this menu item and you will see them:



By default, the first seven databases are publicly available.

BED *(Baltic Environmental Database*) is maintained and updated by BNI. We have here collected data from various data providers over many years. BED contains data since 1877. According to the terms of some data providers, access to some data still requires permission and a password, which can be acquired through the data manager of BED.

The *Leibniz-Institute for Baltic Sea Research (IOW)*, situated in Warnemünde, Germany, is responsible for German monitoring in the Baltic, see http://www.io-warnemuende.de/. Data from the last three years require permission and password.

The *Shark* database is maintained by the Swedish Meteorological and Hydrological Institute (SMHI). It contains their own measurements but also many coastal observations collected by local and regional Swedish organizations. Further information (in Swedish) is found at http://www.smhi.se/klimatdata/oceanografi/Havsmiljodata

Sumppu is the marine database maintained by SYKE, the Finnish Environmental Institute. It contains most marine monitoring data collected by Finnish institutes.

The *Algabase* database is also maintained by SYKE and contains data collected by Algaline.

ODA, is maintained by the Department of Bioscience and the Department of Environmental Science at Aarhus University in Denmark.

Pivet is a marine database maintained by SYKE and contains data from coastal stations.

Set timeout

If you are using a slow Internet connection or expecting a very large amount of data (for big area and/or long time interval), you may want to increase the default values here.

Criteria of station's similarity: maximal differences

It may happen that the same observation is available in several databases. You can avoid including the same data more than once by setting space and time criteria. By default, measurements that were collected within the same minute, both in terms of coordinates (latitude, longitude) and time, are treated as identical and duplicates are thus ignored.

Include coastal stations

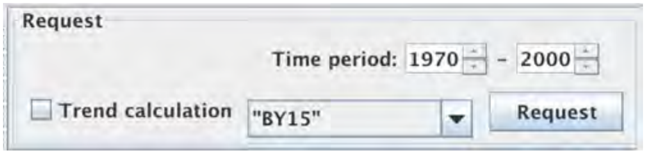
Accessing data from the large HELCOM and BALTSEM sub basins (polygons) and depending on the purpose of your query, you may or may not want to exclude coastal stations. In the graphical presentation of the results, all observations within a specified depth interval are averaged. This means for instance that coastal stations may bias the descriptions of concentrations for a particular sub-area. Note that this option is applied only to data from the BED database where all stations have a flag for coastal/offshore.

Vertical boundaries of the layers

For the graphical and statistical outputs, all observations within each depth interval are averaged. You may change boundaries for these intervals here.

The Request panel

This panel is used to set parameters when you request data from the databases. A user can set the area either from the drop-down list of areas or from the map using the mouse, and also set the *Time* *period* for the query. The *Averaging interval (days)*, from which measurements are pooled and averaged, cannot be set longer than 90 days.

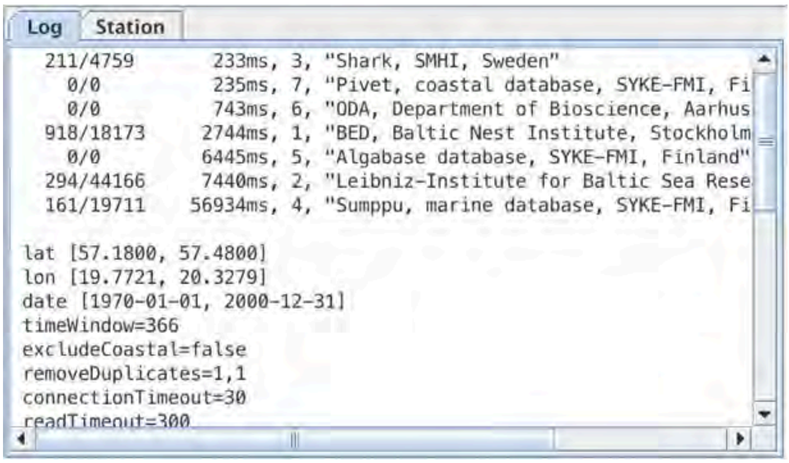


In the figure above, we have chosen station BY15 (by clicking of the station on the map) and the time period 1970-2000, with an *averaging interval* of 30 days. This means that monthly averages are used in the graphical presentation (see below).

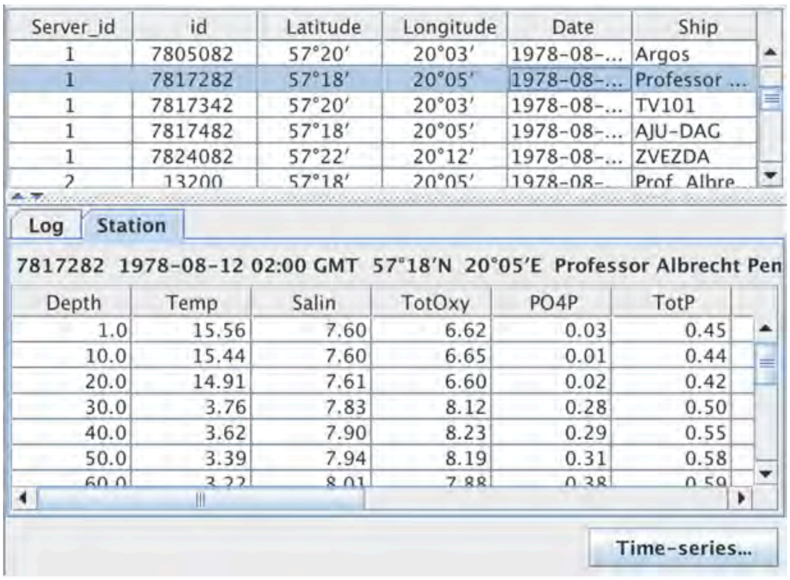
The middle panel shows a list of all stations extracted from the databases for the selected area. The *Server_id* relates to the particular databases you selected to be included in the *Options/Marine databases accounts*, described above. Each measurement is stored in the database with a unique *id*, useful if you find e.g. dubious data that you want to discuss with the database provider. In addition, information about position, date and name of the ship for the measurements are shown.

Server_id	id	Latitude	Longitude	Date	Ship
1	7006442	57°20′	20°03′	1970-0...	Skagerak
3	16597	57°20′	20°03′	1970-0...	Skagerak
3	16596	57°20′	20°03′	1970-0...	Skagerak
3	16599	57°20′	20°03′	1970-0...	Skagerak
3	16598	57°20′	20°03′	1970-0...	Skagerak
1	7014712	57°20′	20°03′	1970-0...	Mazirbe
1	7014742	57°20′	20°03′	1970-0...	Mazirbe
1	7014792	57°20′	20°03′	1970-0...	Mazirbe

The *Log* panel in the bottom panel, below, shows how many stations/and individual measurements that were extracted from each database, and how long time it took to extract these. The coordinates of the rectangle for the area from where measurements have been requested are shown, as is whether costal stations are included. You can also see how many duplicate stations were removed using the criteria that were set in the panel for the marine database accounts.

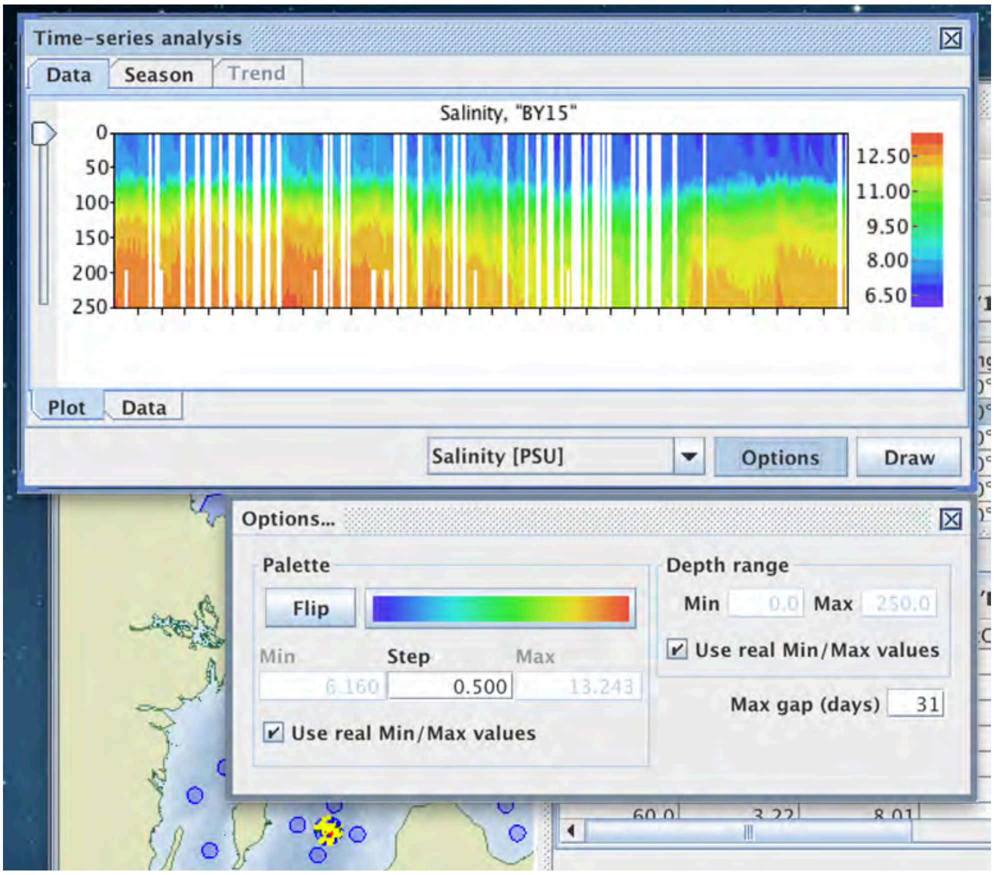


The *Station* panel shows measurements at a selected hydrographic station. It is initially empty, but if you select a station from the list above or from the map by clicking on the station's position, the actual measurements are shown. This particular station is now shown in red on the map.



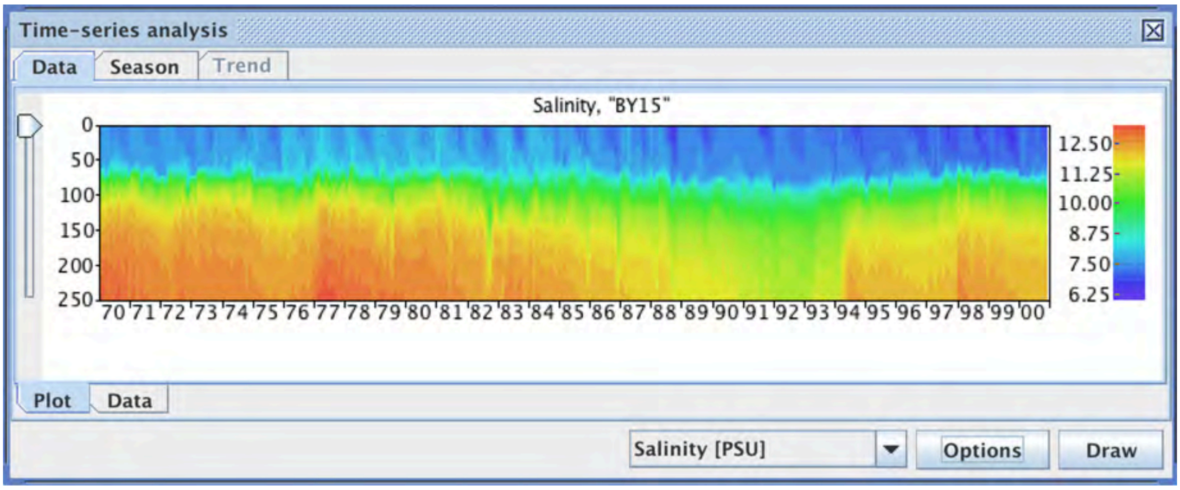
Time series

When you click on the *Time series* button, a new window is opened on the screen. Here you can select which variable you want to display. With the *Option* button you can change the color scale and other parameters of the graphical output.

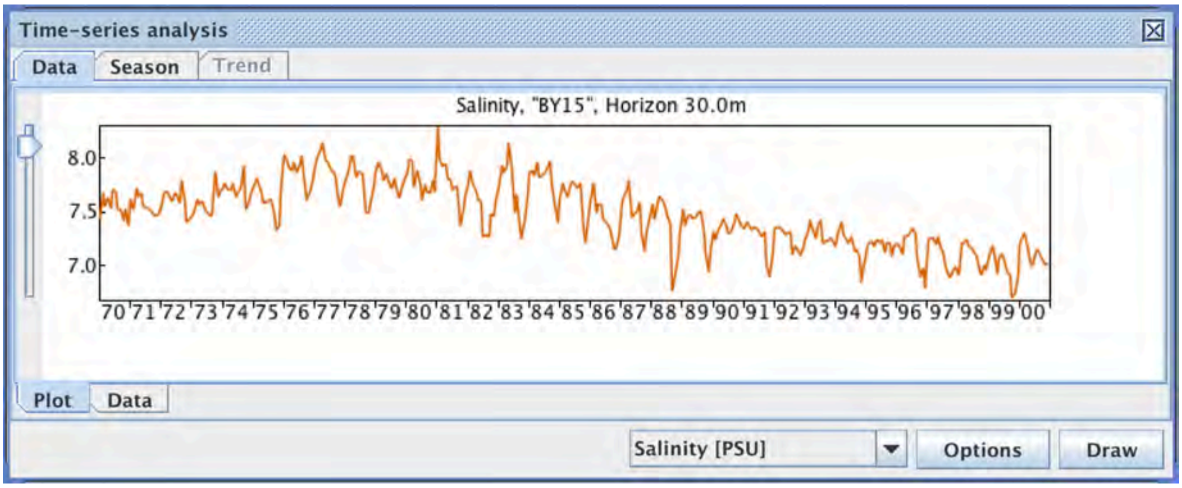


White gaps are shown when the sampling interval is greater than the *Max gap (days)* value (by default, one day longer than *Averaging interval* applied in the *Request*). You can change this value in order to cover the gaps with linear interpolation for a smoother time-depth contour plots.

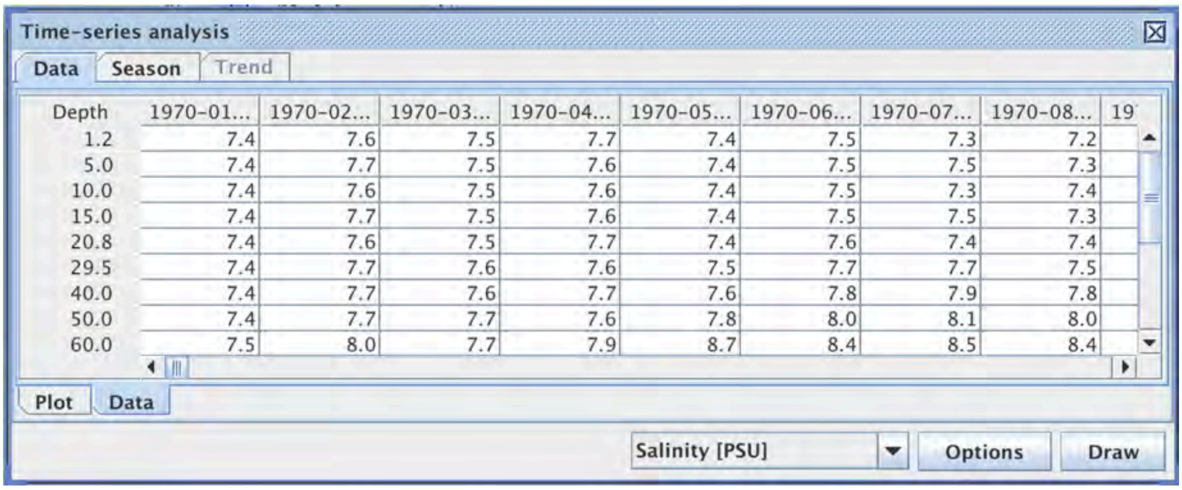
By resizing the window you can change the visual resolution of the time-depth image and get additional information on the axes.



With the vertical slider to the left of the depth axis, you can select a specific depth and plot the temporal variations at that depth.



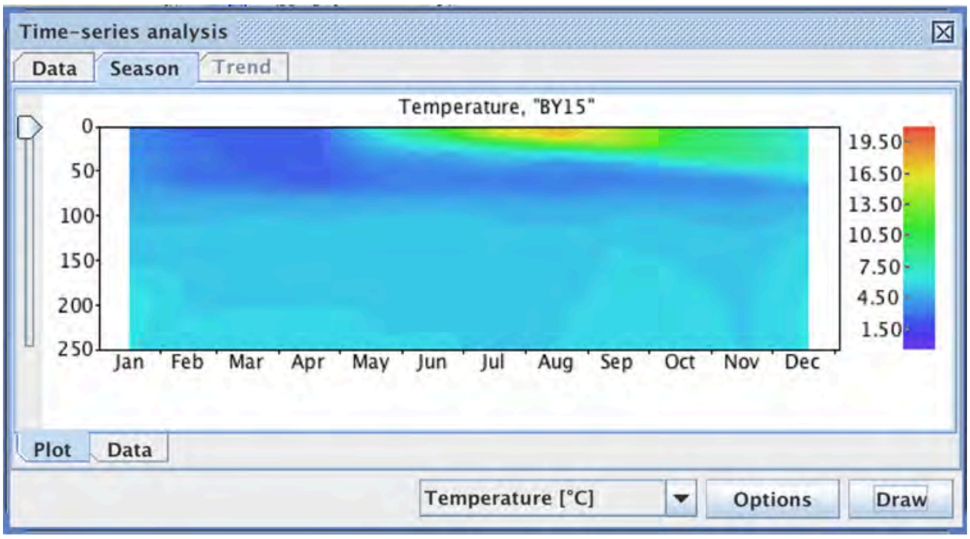
If you click on *Data* in this panel, the data behind the graph are shown.



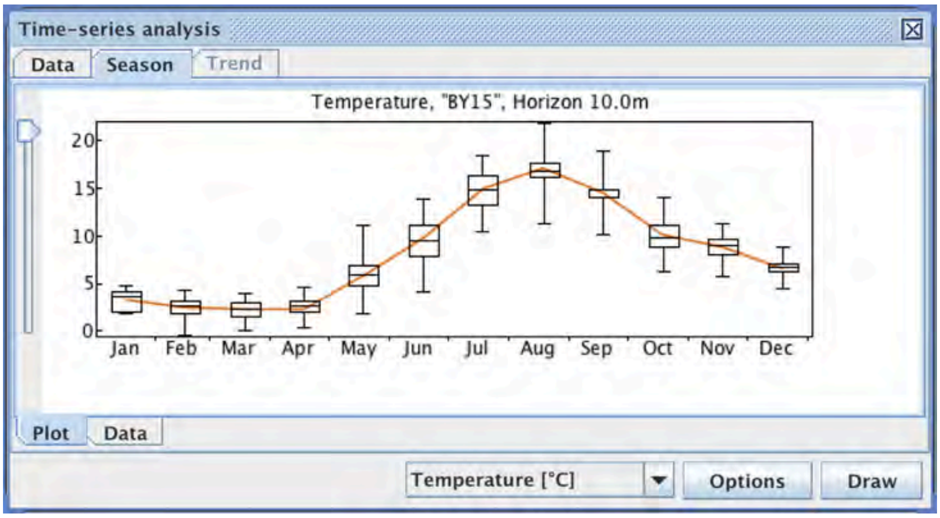
Depth	1970-01...	1970-02...	1970-03...	1970-04...	1970-05...	1970-06...	1970-07...	1970-08...	19
1.2	7.4	7.6	7.5	7.7	7.4	7.5	7.3	7.2	
5.0	7.4	7.7	7.5	7.6	7.4	7.5	7.5	7.3	
10.0	7.4	7.6	7.5	7.6	7.4	7.5	7.3	7.4	
15.0	7.4	7.7	7.5	7.6	7.4	7.5	7.5	7.3	
20.8	7.4	7.6	7.5	7.7	7.4	7.6	7.4	7.4	
29.5	7.4	7.7	7.6	7.6	7.5	7.7	7.7	7.5	
40.0	7.4	7.7	7.6	7.7	7.6	7.8	7.9	7.8	
50.0	7.4	7.7	7.7	7.6	7.8	8.0	8.1	8.0	
60.0	7.5	8.0	7.7	7.9	8.7	8.4	8.5	8.4	

You can right-click on these data to extract these into, e.g. an Excel file.

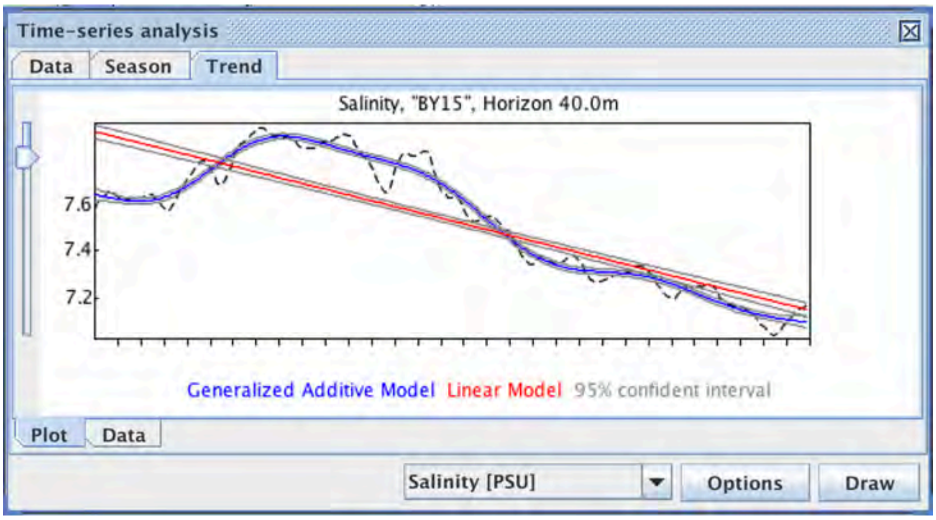
If you select *Season* you will get a graphical output (and table) showing the long-term monthly averages for each depth interval



If you use the vertical slider on this graph, you will get a line showing average values of the selected parameter. In addition, box and whisker plots are shown (sample minimum and maximum, the lower and upper quartiles and median). On any graph you can see the actual value of the selected parameter corresponding to the current cursor position in the lower left corner of the Nest window.



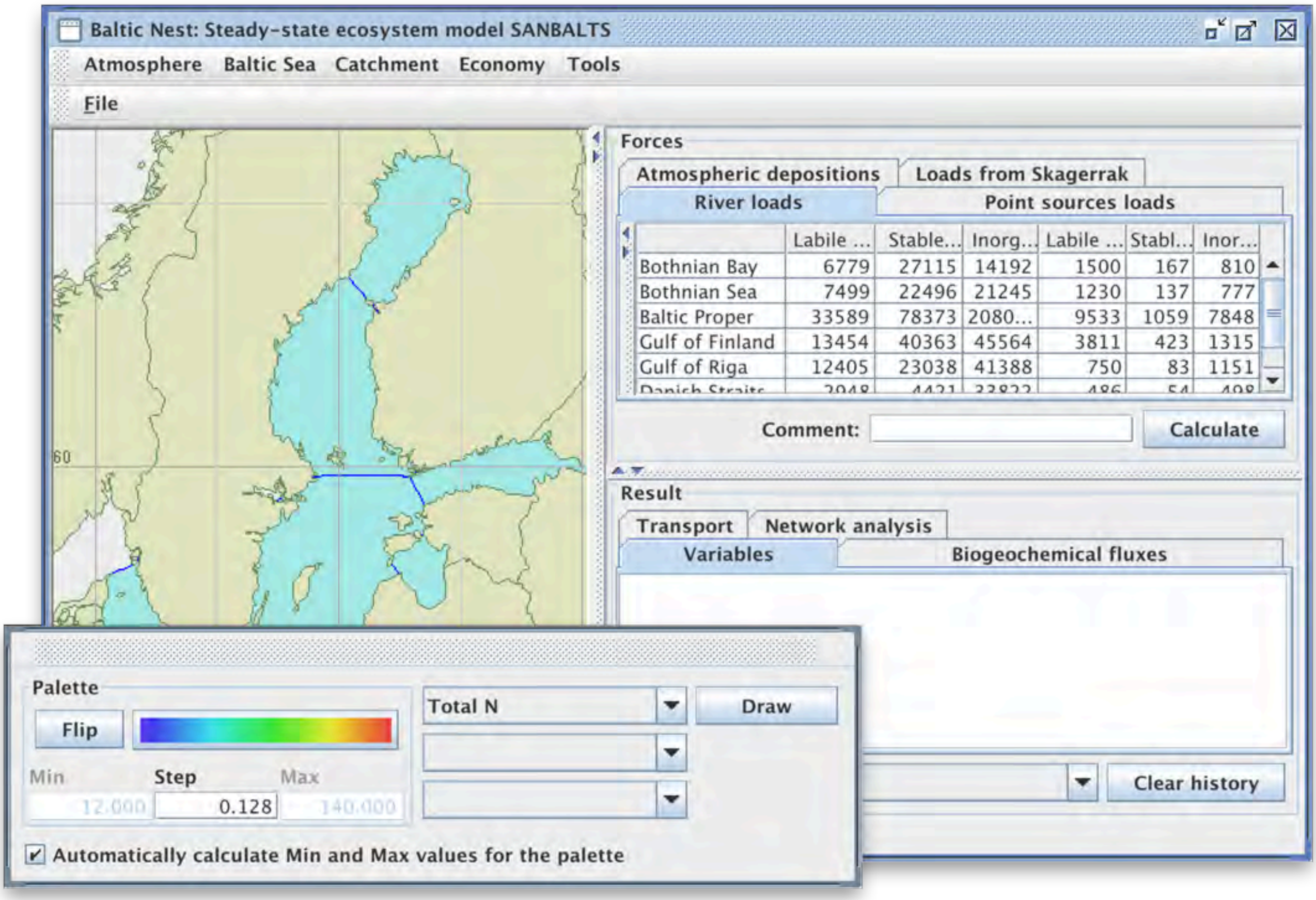
If you had previously checked *Trend calculations* in the *Request* panel, you will get graphical outputs showing results of a seasonal decomposition of the time series by LOESS, using the statistical software R. For further details see http://stat.ethz.ch/R-manual/R-devel/library/stats/html/stl.html



Steady-state ecosystem model SANBALTS

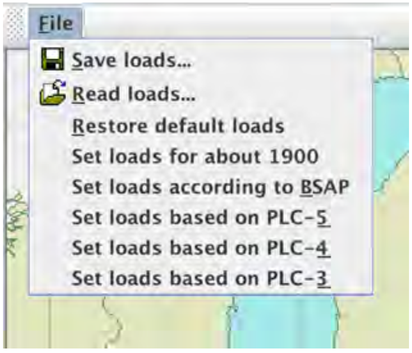
This coupled physical-biogeochemical model, called SANBALTS (Simple as Necessary Baltic Sea), describes the effects of changing nutrient loads on environmental state in the seven major marine basins. In Nest, the SANBALTS model is implemented in a steady-state mode that shows which trophic state will eventually be established from changes in nutrient inputs. SANBALTS has been used in the development of the eutrophication segment of the Baltic Sea Action Plan (http://www.helcom.fi/BSAP/en_GB/intro/), where it was used for the computation of the maximum allowable inputs of nitrogen and phosphorus that would secure marine environments "unaffected by eutrophication" in the entire Baltic Sea. For further details, see the reference list at the end of this section.

When you open SANBALTS the following window is shown:



To the left is a map of the modeling region with boundaries (blue lines) drawn between the basins. To the right you will find two panels: the panel *Forces* show nutrient loads, and the panel *Results* show the results from the model runs. A separate "floating" window appears on top of the main window, in which you can select variables to be displayed on the map. This window can be placed anywhere on the screen, depending on what the user finds convenient. Explanations for the displayed parameters are usually shown in the lower left corner, below the map, when you move the cursor over an object. You can analyze the model result in standard or expert mode by selecting this option in the upper right corner of the Nest window and then obtain more details of model outputs.

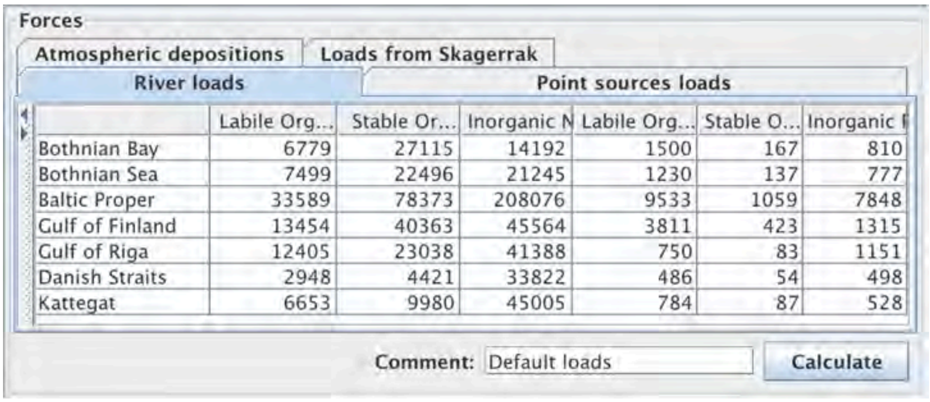
File



You can choose pre-compiled nutrient load data sets that are then used to drive the marine model from the *File* menu, above the map. You can also compile (in the right top panel) and then *Save* your own set for later use with the *Read loads* option. The *PLC-3, PLC-4, and PLC-5* data sets are based on data collected by HELCOM and EMEP for the *P*ollution *L*oad *C*ompilations corresponding to the specific years 1995, 2000, 2006 or averaged over 2003-2007 (for details see HELCOM, 1998, 2004, 2011; Savchuk et al., 2012). *Set loads according to BSAP* are the allowable inputs of nitrogen and phosphorus to each basin, evaluated with this model and used in the original 2007 Baltic Sea Action Plan (see Anon, 2007). The *Default loads* are also based on HELCOM compilations of land loads, averaged for 1997-2003, EMEP compilations of atmospheric depositions provided to HELCOM, and Skagerrak concentrations of nutrients, averaged for 1997-02. *Set loads for about 1900* sets inputs for a more oligotrophic Baltic, before the expansion of human inputs from sewage, industry and agriculture, described by Savchuk et al. (2008).

Forces

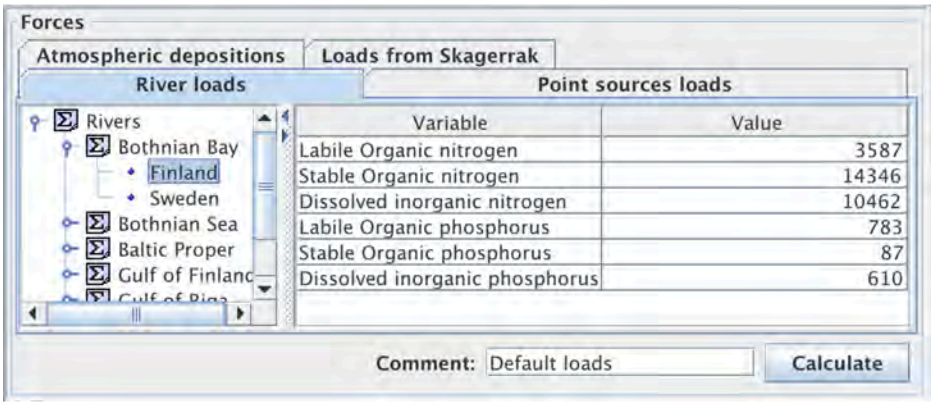
This panel shows the different sources of nitrogen and phosphorus: separated into *River loads, Point sources load, Atmospheric depositions* and *Loads from Skagerrak*. A detailed description on how these were derived can be found in (Savchuk & Wulff, 2007).



	Labile Org...	Stable Or...	Inorganic N	Labile Org...	Stable O...	Inorganic
Bothnian Bay	6779	27115	14192	1500	167	810
Bothnian Sea	7499	22496	21245	1230	137	777
Baltic Proper	33589	78373	208076	9533	1059	7848
Gulf of Finland	13454	40363	45564	3811	423	1315
Gulf of Riga	12405	23038	41388	750	83	1151
Danish Straits	2948	4421	33822	486	54	498
Kattegat	6653	9980	45005	784	87	528

You can also make a detailed examination of these values by clicking on the little arrow to the left of the table (>). You can then see the contributions from each country when you have selected these by clicking on the label with the mouse. Return to the summary table by clicking on the other arrow (<) to the left of the table.

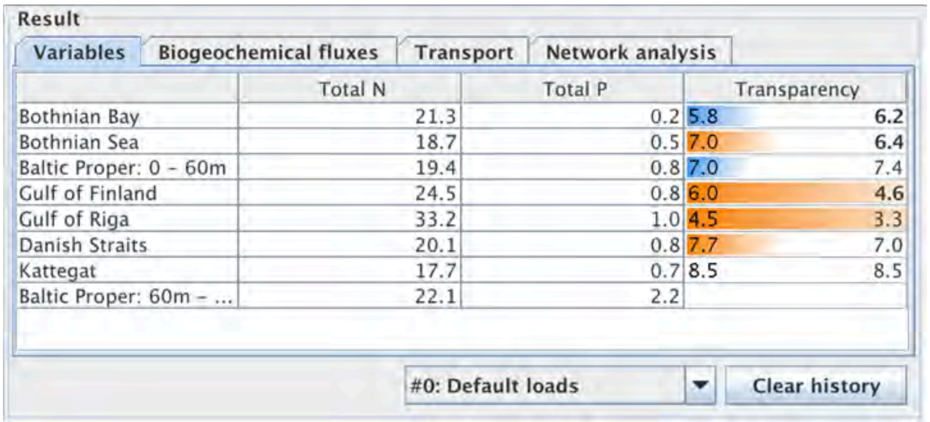
The important interactive feature of this module is that you can set your own values for any nutrient inputs at all levels of details, from particular country to the entire basin. This is done by double-clicking in the corresponding cell, replacing its content with your number, and confirming the replacement by pressing *Enter*.



Results

After setting a specific set of nutrient inputs, either pre-compiled or using your own values, you can provide some description of the loads in the *Comment* below the tables, which will be used as a description of this model run. Press *Calculate* and wait until the corresponding steady state is computed. The results can be seen graphically on the map as well as in several tables. In the default, standard mode you can see only some general parameters. In *Expert* mode you can see all variables, biogeochemical fluxes, and transport flows computed by the model, including concentrations in sediments and fluxes between water and sediment. Note that you have to enlarge the Nest window to see all columns simultaneously.

Variables



Here the results in terms on nitrogen (N) and phosphorus (P) concentrations for the seven basins are shown (Baltic Proper consists of two boxes; above and below the halocline). The inorganic and organic fractions of nitrogen and phosphorus are summarized. Water transparency (Secchi depth, in meters) is calculated from empirical relationships with nutrient concentrations, either N (in bold) or P. The left column shows water transparencies, estimated by the HELCOM EUTRO PRO project as representing target levels in the Baltic Sea with acceptable environmental conditions. For further details, see Anon (2007). In *Expert* mode you can see all fractions used in the model, including concentrations in sediments.

Result

Variables | Biogeochemical fluxes | Transport | Network analysis

	Total N	Total P	Transpar...		Labile org..	Stable orga...	Inorganic N	Labile or...	Stable org...	Inorganic P	Bentic N	Bentic P
Bothnian B...	21.3	0.2	5.8	6.2	1.69	12.58	7.04	0.11	0.03	0.05	558	260
Bothnian S...	18.7	0.5	7.0	6.4	3.44	12.02	3.23	0.22	0.03	0.25	1203	430
Baltic Pro...	19.4	0.8	7.0	7.4	4.06	12.91	2.47	0.26	0.04	0.50	1339	314
Gulf of Fin...	24.5	0.8	6.0	4.6	3.70	15.23	5.59	0.24	0.05	0.52	1196	224
Gulf of Riga	33.2	1.0	4.5	3.3	7.55	18.73	6.96	0.48	0.04	0.49	833	53
Danish Str...	20.1	0.8	7.7	7.0	5.39	11.56	3.11	0.35	0.04	0.40	1581	168
Kattegat	17.7	0.7	8.5	8.5	4.55	8.57	4.59	0.28	0.03	0.37	1255	110
Baltic Pro...	22.1	2.2			2.51	12.23	7.38	0.19	0.04	1.95	811	89

#0: Default loads | Clear history

Biogeochemical fluxes

Here you can explore most fluxes calculated by the model. The major internal source and sink terms in the model are shown here. Units are, as usual in Nest, shown in the lower left corner. Nitrogen fixation is a major internal source of nitrogen in some basins, and the fluxes seen here can also be seen as a measure of the intensity of cyanobacterial blooms.

Result

Variables | Biogeochemical fluxes | Transport | Network analysis

	Primary prod...	Half life	N-fixation	Denitrification
Bothnian Bay	24.8	0.0	0.0	17.0
Bothnian Sea	124.0	0.0	17.6	88.1
Baltic proper	187.8	0.0	366.5	858.6
Gulf of Finland	141.0	0.0	18.1	64.4
Gulf of Riga	259.5	0.0	1.3	45.7
Danish Straits	215.9	0.0	6.1	42.3
Kattegat	222.9	0.0	3.0	88.1

#0: Default loads | Clear history

Half life, is defined as the time it takes for the basin's annual primary production to develop half of the eventual final, steady state response to altered loads, namely to achieve basin-wise values: $\mathbf{PP_{0.5} = PP_{default} + (PP_{altered} - PP_{default})/2 = (PP_{default} + PP_{altered})/2}$. These $\mathbf{PP_{0.5}}$ values are zero for default loads since the default initial conditions of the model are set to those found at steady state. More interesting are the half-life values calculated when the model has been perturbed by altering the loads, for example to the maximum allowable loads corresponding to BSAP. In this case, half-life's for the different basins vary greatly, from 5 years for Kattegat to more than 100 years for the Bothnian Bay.

Result

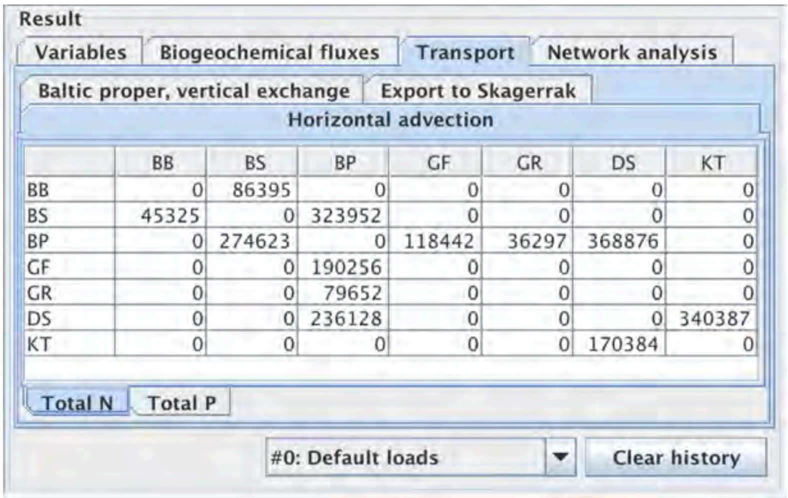
Variables | Biogeochemical fluxes | Transport | Network analysis

	Primary prod...	Half life	N-fixation	Denitrification
Bothnian Bay	21.3	105.0	0.0	14.5
Bothnian Sea	71.6	83.0	0.0	51.6
Baltic proper	130.3	24.0	113.4	575.7
Gulf of Finland	81.4	32.0	0.0	38.1
Gulf of Riga	133.1	27.0	0.0	24.0
Danish Straits	165.3	9.0	1.4	32.5
Kattegat	193.1	5.0	1.1	76.9

#1: BSAP loads | Clear history

Transport

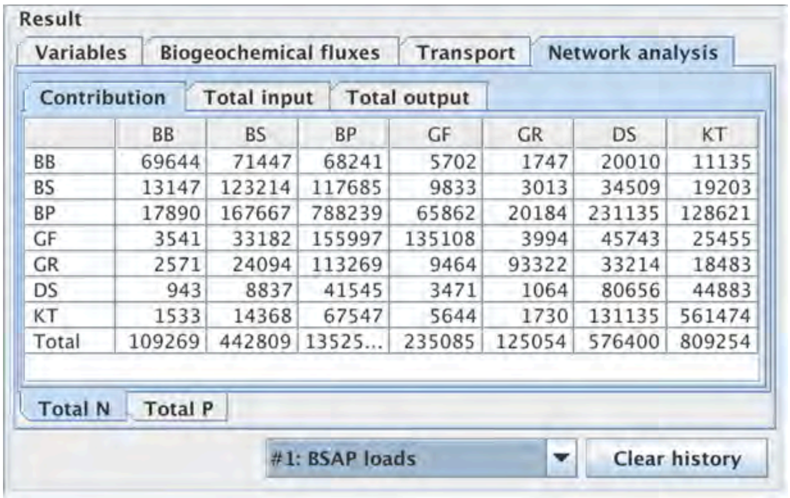
These tables give you a detailed account of flows for both N and P between basins (*Horizontal advection*), between the surface and the deep layer of the Baltic Proper, as well as the export to Skagerrak. The advective flows are directed from "row" basin to "column" basin. You can use these numbers, together with inputs (*Forces*) and finally, the internal source and sink terms (*Biogeochemical fluxes*), to create detailed mass balance budgets of the Baltic and its major sub-basins. In *Expert mode* you are able to obtain the transport data for inorganic, as well as for labile and stable organic, fractions. Explanation for each value is, as always, available in the lower left corner of the Nest window.



	BB	BS	BP	GF	GR	DS	KT
BB	0	86395	0	0	0	0	0
BS	45325	0	323952	0	0	0	0
BP	0	274623	0	118442	36297	368876	0
GF	0	0	190256	0	0	0	0
GR	0	0	79652	0	0	0	0
DS	0	0	236128	0	0	0	340387
KT	0	0	0	0	0	170384	0

Network analysis

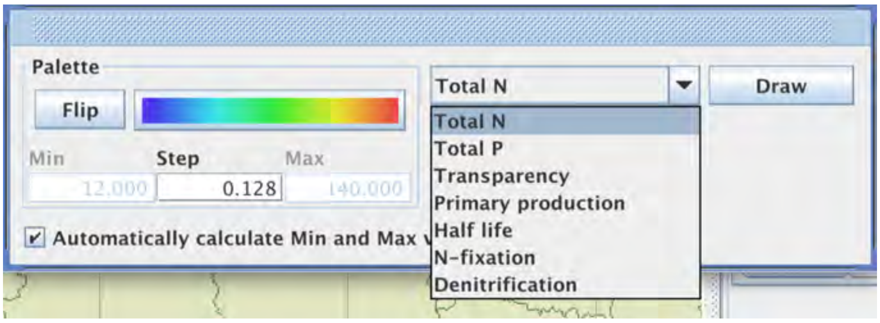
Here you have three additional panels for both nitrogen and phosphorus. In *Contributions* you can see how much of the inputs to one basin reach a particular basin. The *Total Input* panel gives a detailed account of the sources to each basin. The *Total output* panel gives an account of the exports from each basin, by advection or by internal processes.



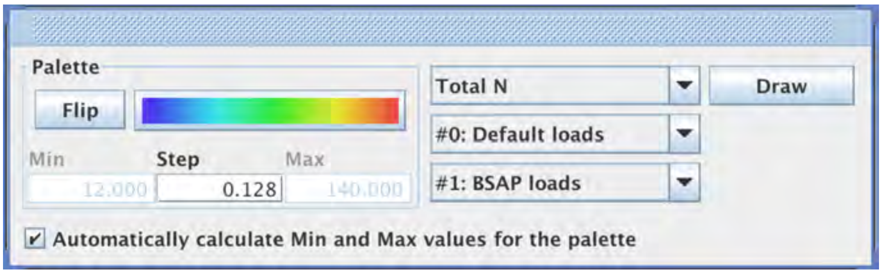
	BB	BS	BP	GF	GR	DS	KT
BB	69644	71447	68241	5702	1747	20010	11135
BS	13147	123214	117685	9833	3013	34509	19203
BP	17890	167667	788239	65862	20184	231135	128621
GF	3541	33182	155997	135108	3994	45743	25455
GR	2571	24094	113269	9464	93322	33214	18483
DS	943	8837	41545	3471	1064	80656	44883
KT	1533	14368	67547	5644	1730	131135	561474
Total	109269	442809	13525...	235085	125054	576400	809254

Visualizing the results

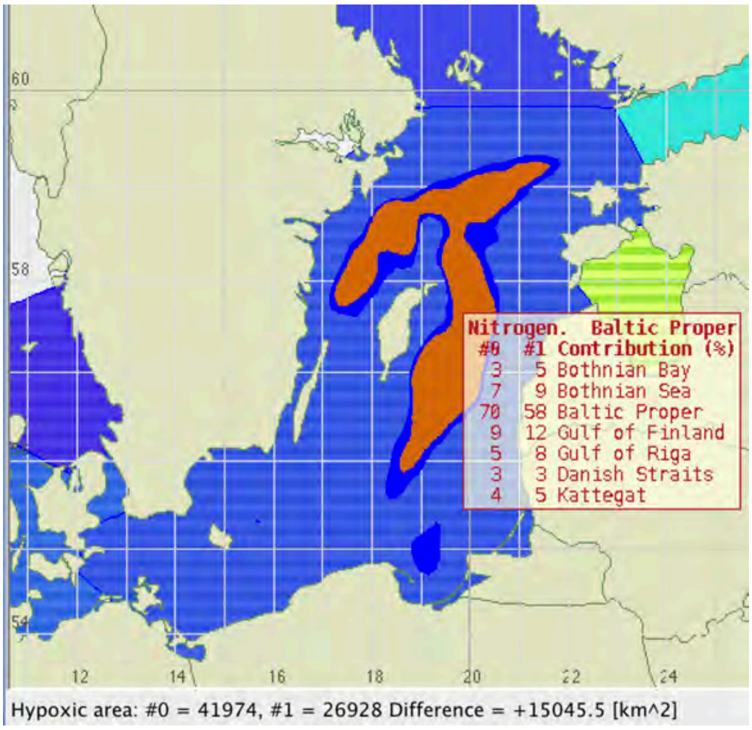
Visualization of the modeled results on the map in the left panel can be managed using the separate window.



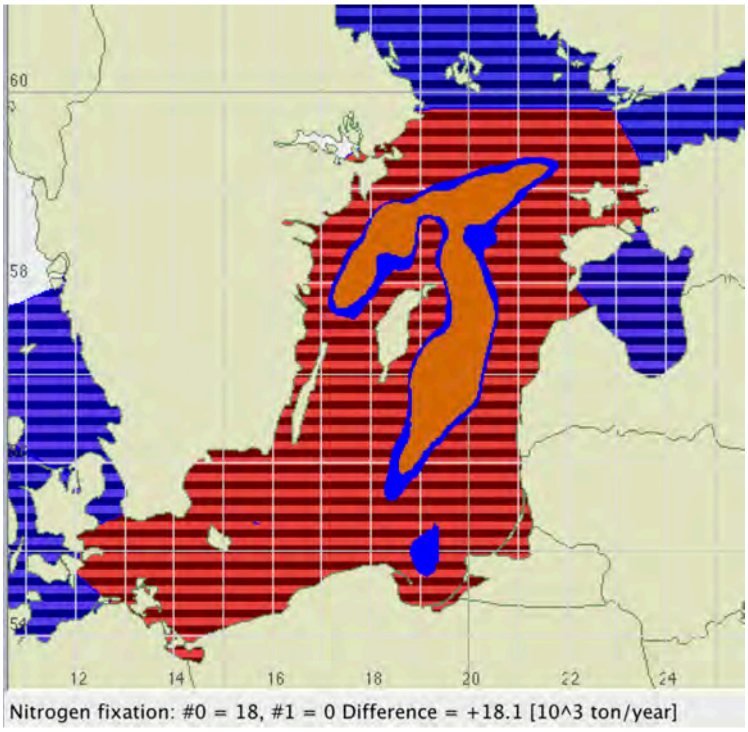
Here, you can select any of the model variables, fluxes, and derived characteristics from the drop-down box. Click on the color scale to change it and set different minimum and maximum values for the palette. Move the cursor over the different basins and see the actual values of the particular model variable in the lower left corner. When you have run another simulation you can compare the results in the map panel.



In the lower left corner you can see a comparison between the model runs. If you move the cursor over the center of the Baltic Proper, you will get information on area extension of the hypoxic bottoms and, with a click, the depth to hypoxic interface in the water column. You will also see the contributions (in per cent) of nutrients (in this case nitrogen) originating as loads to the different sub-basins for the two model runs (#0 and #1) by clicking on any of the basins. In this case, N loads to the Baltic Proper contribute with 70 % and decrease to 58 % when the BSAP plan is implemented. Also, the hypoxic area decreases by 15,046 km^2 from 41,974 km^2.



Other modeled characteristics (selected in the *Draw* window) give more information. In the picture below, nitrogen fixation is shown, and by clicking on the Gulf of Finland you can see that the annual nitrogen fixation is eliminated here (decreasing from 18 100 tons per year to 0). The colors on the basins show levels of the chosen variable. You can change these with the palette option in the *Draw* window. All these results are also available in the tables in the *Result* window.



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Savchuk, O. P. & Wulff, F. 2009. Long-term modeling of large-scale nutrient cycles in the entire Baltic Sea. *Hydrobiologia* **629**, 209-224, doi:10.1007/s10750-009-9775-z .

Savchuk, O. P., Wulff, F., Hille, S., Humborg, C. and F. Pollehne. 2008. The Baltic Sea a century ago - a reconstruction from model simulations, verified by observations. *Journal of Marine Systems* **74**, 485-494, doi:10.1016/j.jmarsys.2008.03.008 .

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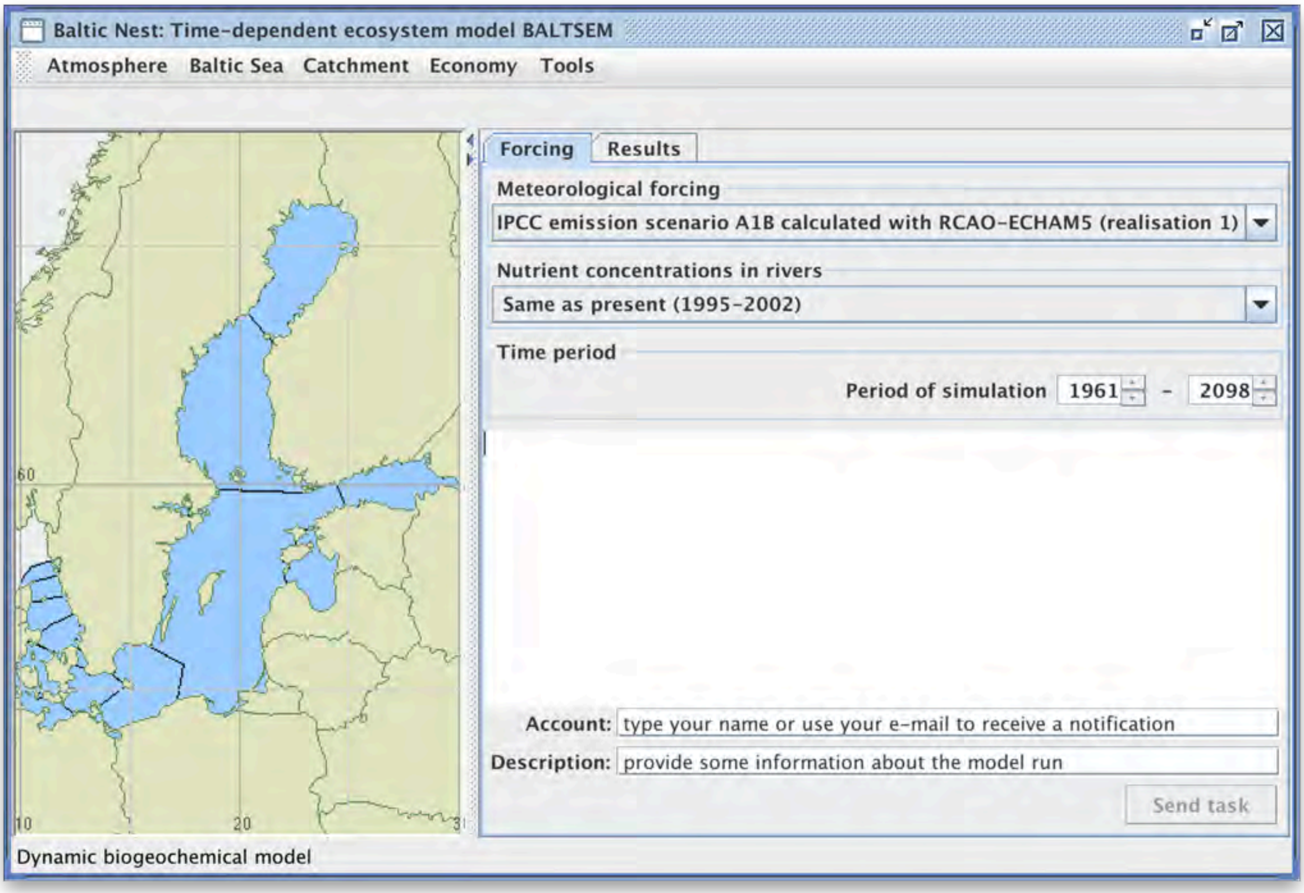
Savchuk, O.P., Gustafsson, B.G., Rodríguez Medina, M., Sokolov, A.V., Wulff, F.V. 2012. External nutrient loads to the Baltic Sea, 1970-2006. *BNI Technical Report* No 5, 22 pp.

Wulff, F., Savchuk, O. P., Sokolov, A., Humborg, C. and C. M. Mörth. 2007. Management options and effects on a marine ecosystem: Assessing the future of the Baltic. *Ambio* **36**, 243-249.

Time-dependent ecosystem model BALTSEM

In the original calculations of allowable nutrient inputs for the BSAP agreement in 2007 the SANBALTS model *(Simply As Necessary BALtic Sea*), available in the Nest system, was used. SANBALTS computes steady-state results with a coarse horizontal and vertical resolution. These model outputs are not easily verified against observations since measurements have to be aggregated to the same resolution (basin-wide annual averages). Therefore, there is a need for a model that is both reliable and convenient enough to be used for the revision of BSAP and implementation of the EU Marine Strategy Framework Directive (MSFD), as well as for other managerial tasks included in an ecosystem management approach for the Baltic Sea. To serve these needs, the model should be computationally fast in order to allow multiple numerical runs necessary for finding and testing suitable distributions of the water-protection measures. Furthermore, for building up credibility, necessary in the national deliberations and international negotiations, it should also be publicly accessible through the decision support system Nest. Such a model would allow any interested party to run and explore the hindcast and scenario experiments, as well as visualize results. For these purposes, we have developed the *Baltic Sea Long-Term large Scale Eutrophication Model* (BALTSEM), which captures the main features of the Baltic Sea eutrophication, and now serves as the next generation marine model in the Nest system.

You will see a map to the left and options for selecting forcing and display result in the right panels, when you open this interface. The Baltic is divided into 13 sub-basins, as seen on the map.

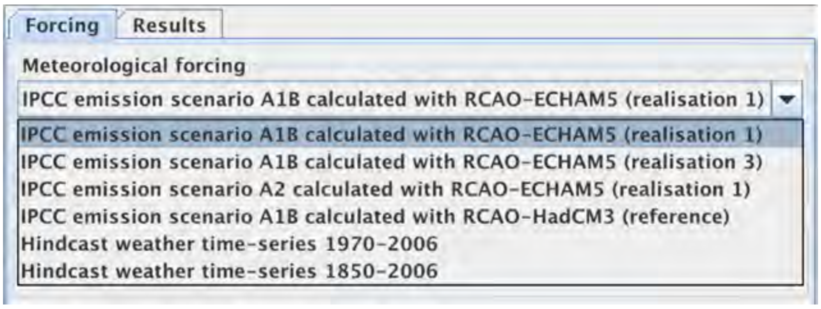


In the right-hand panel, you can specify *Meteorological forcing* and *Nutrient concentration in rivers*.

Meteorological Forcing

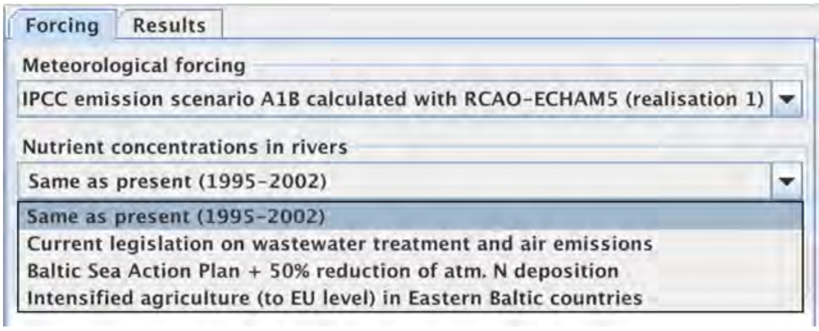
Here you set the meteorological forcing for the model run. You can choose between the ERA40 reanalysis of present climate (*Hindcast*) and four climate model simulations generated within the

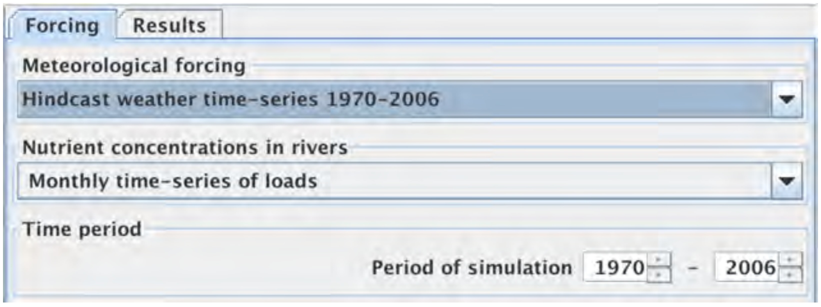
ECOSUPPORT project which address responses to the IPCC A1B and A2 greenhouse gas emission scenarios. A detailed description of these scenarios can be found in Meier et al., (2011a, b). Meteorological forcing covers 1970 – 2006, 1850 - 2006 (*Hindcast*) and 1961 – 2098 (*Climate scenarios*). Please note that global climate models cannot simulate the observed meteorological conditions. Therefore the years 1961 – 1998 in the climate scenarios represent the statistical characteristics of current climate, but not the sequence of actual weather events.



Nutrient concentrations in rivers

In combination with each set of meteorological forcing, you can choose between four load scenarios and a hindcast, for details see Gustafsson et al. (2011) and Meier et al. (2011).

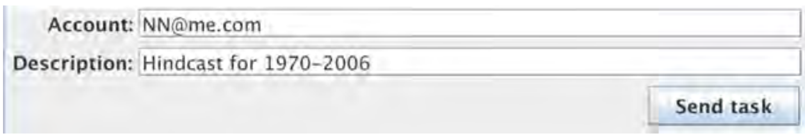




Period of simulation

You can select the entire period for a particular scenario or a shorter period within this interval.

Send task



Since the model run will take from several minutes to one hour on the host computer, it is useful to supply an e-mail address, to which you will be notified when the simulation is ready. Actually you can use whatever name you want as an account, but the notification will only be sent if the account looks like a legitimate e-mail address. Below is an example of an e-mail received when a simulation is ready.

baltsem@nest.su.se
To: Wulff Fredrik
9c835b73-8b5f-42d2-b18d-fe419217e27a

fredwulff11@me.com,

Your task

Hindcast

is ready.

id	9c835b73-8b5f-42d2-b18d-fe419217e27a
start	2012-11-01 09:54:57.352 GMT
end	2012-11-01 10:12:38.379 GMT

baltsem

The id (uuid) is the unique identifier of the model run, which you can paste into the *Results* box if you want to analyze this model run or download all the data to your computer. Also shown is the time it took to run the simulation, in this case 17 minutes and 41 seconds.

You may run several simulations, and each will have a unique id (uuid), but it is very useful to have meaningful description as well in order to distinguish between the different runs.

You have to provide an account (e-mail address) to access all your modeling results. You can switch to the *Results* panel when you have received the e-mail notification about available results.

Results

When the user provides his/her *Account* information (e-mail), the list of model runs appears in the *Result* panel. Start by selecting one of the model runs. Clicking the right-hand mouse button opens a window describing this run.

9c835b73-8b5f-42d2-b18d-fe419217e27a

Hindcast

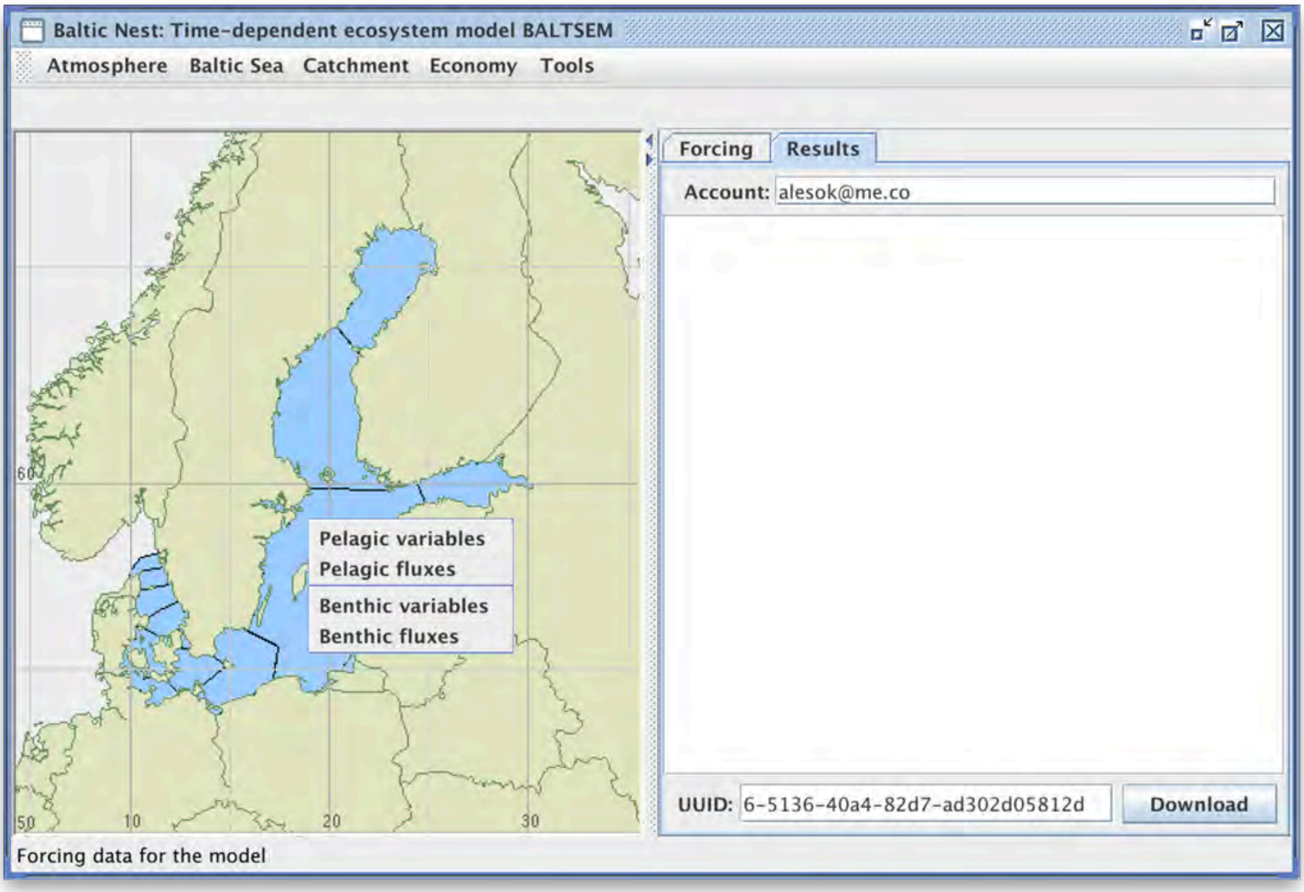
username	fredwulff11@me.com
start	2012-11-01 09:54:57.352 CET
end	2012-11-01 10:12:38.379 CET

&control
startdate(1)=1961
enddate(1)=2006

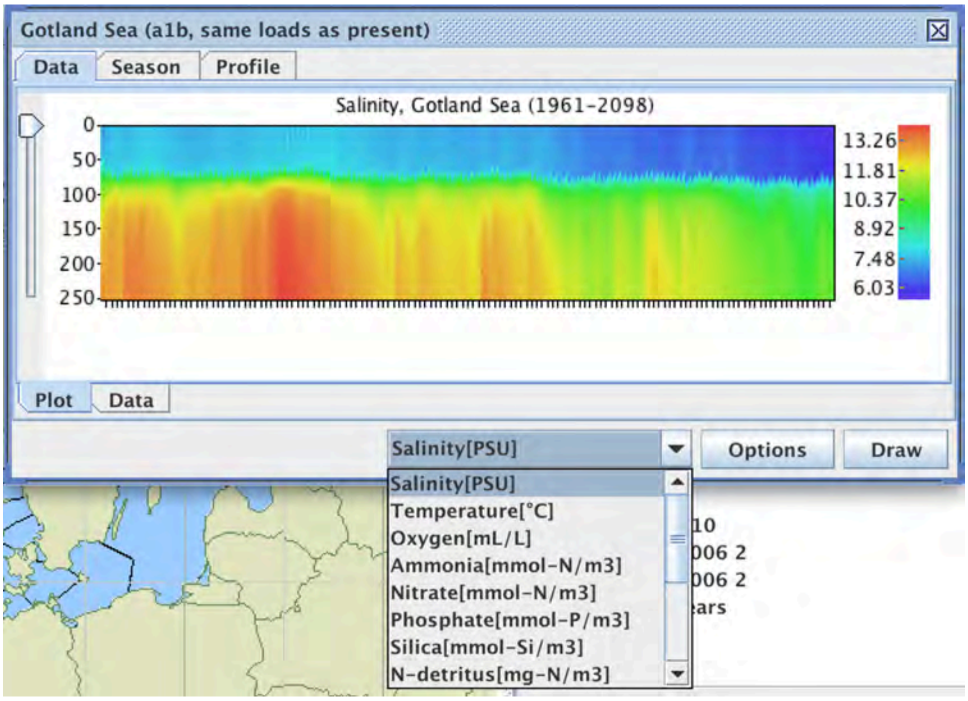
&end

You can download a compressed (zip) folder to your computer and analyze the results locally, using your own software, by providing your *uuid*. You can also share access to your results with someone else who is also using Nest if you provide this information. It is important to note, that this feature is for advanced users since there are many files in the zipped archive with very detailed, not very intuitive information.

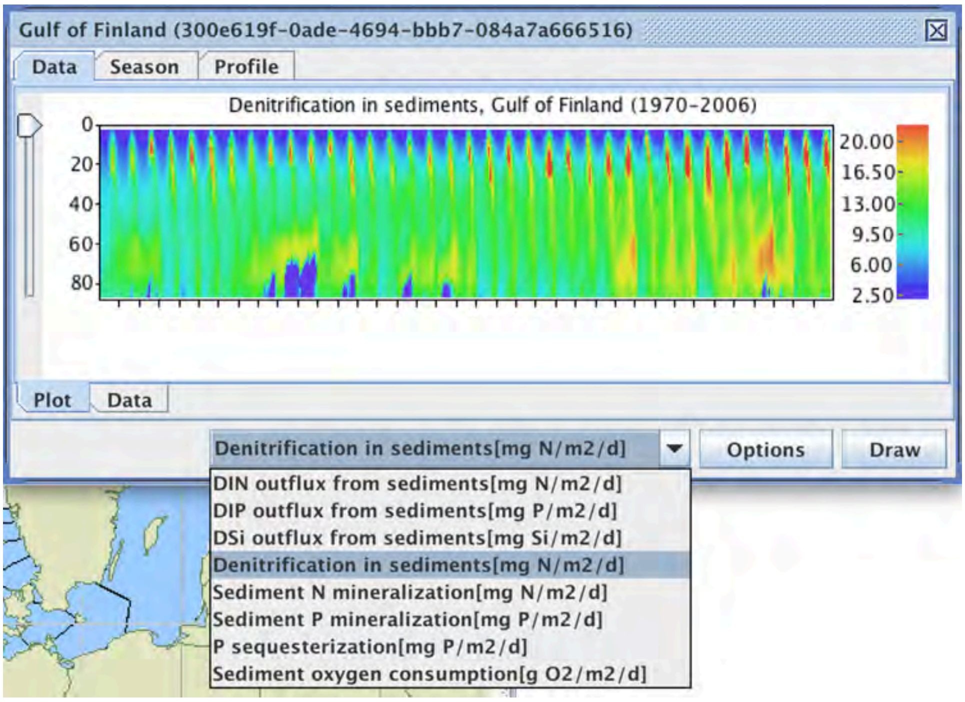
You can also visualize some of the results within Nest by clicking on the map (over one of the sub-basins) and then select *Pelagic* or *Benthic* variables or fluxes for visualization.



In this case, the user has selected *Pelagic variables* for the Baltic Proper. A new floating window appears on the screen and all associated variables will be downloaded to the local computer. The drop-down list allows you to select the variable you want to display.



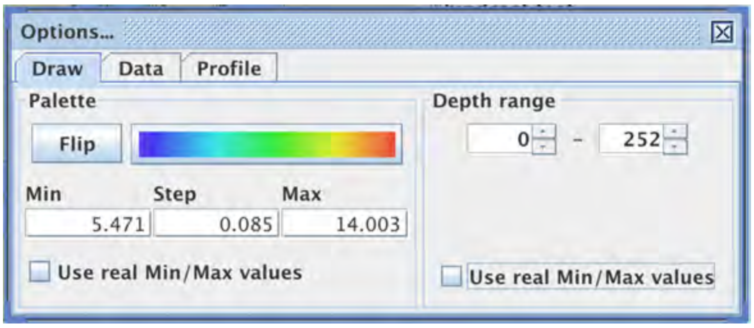
Note, you can open several windows for the same and/or different basin(s) from the same and/or different numerical experiments, resize them, and move them around the entire computer screen. In the example below, the user has selected *Benthic fluxes* in the Gulf of Finland from hindcast simulation for 1970-2006



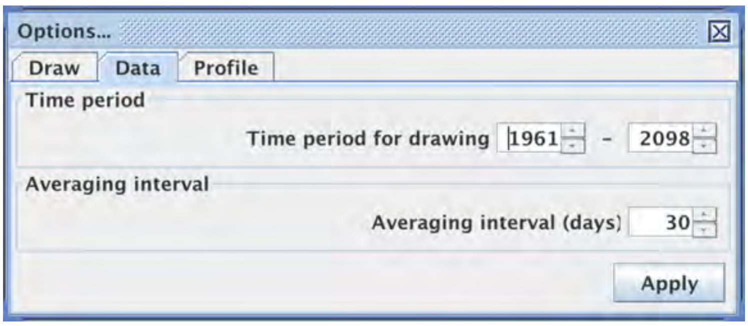
Data

The *Data tab* shows a contour plot of the variable you have selected, by default for the entire time and depth interval. The user can then analyze/display the data in similar ways as in the *Distributed marine databases* module of Nest. As usual, you can see the actual numbers in the plot in the lower left corner of the Nest main window, by moving the cursor over the plot.

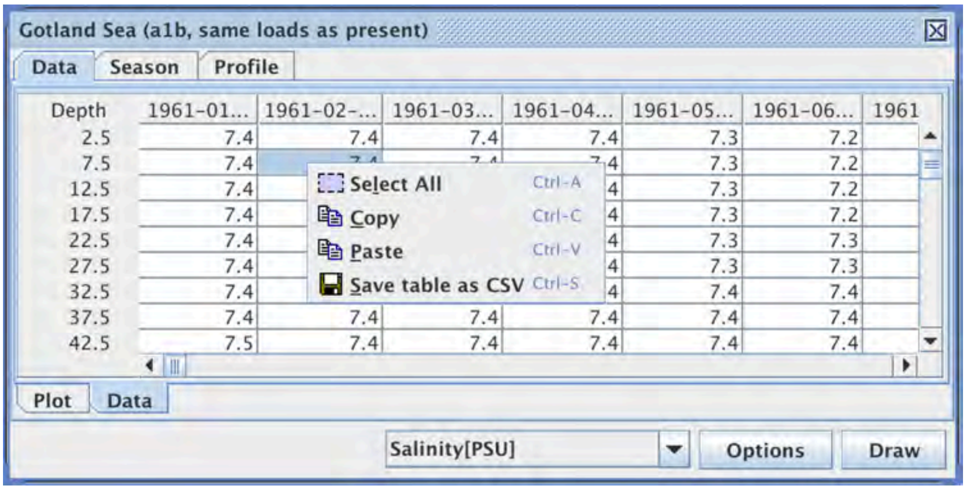
You can change the color scale and depth range in the *Options/Draw* tab.



The *Options/Data* tab allows you to select the time period for the plot as well as averaging (days) interval. The model data are saved with a 5-day interval and you can then choose an averaging interval for outputs, used in the plots.

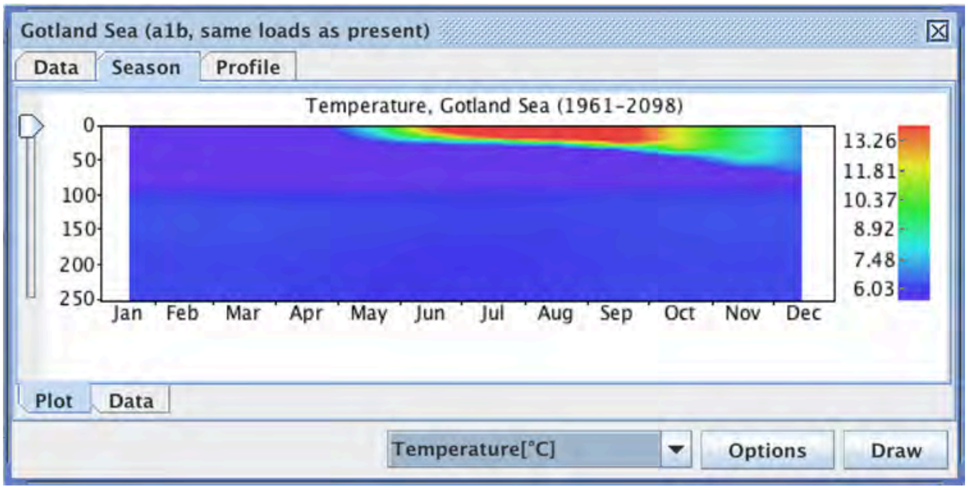


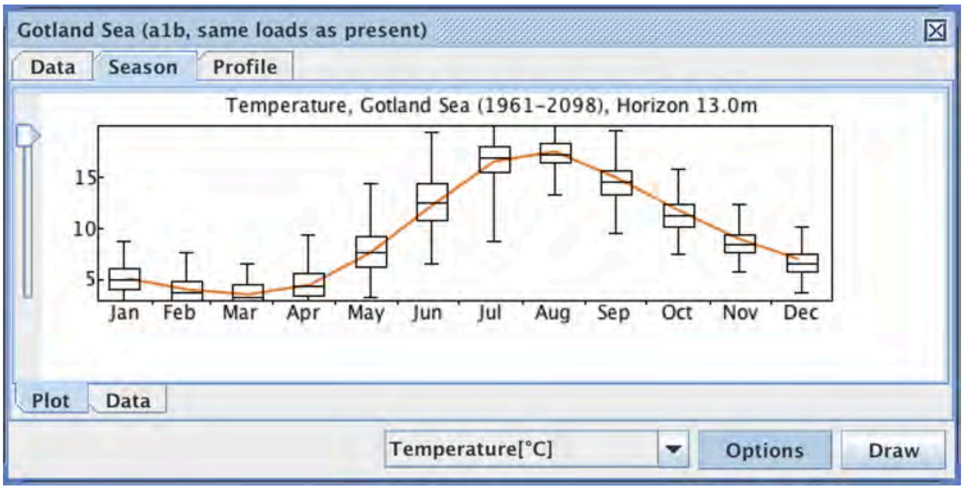
If you chose the *Data* tab in the graphics window, you will see the actual numbers. By right mouse button clicking on the table, you can, as usual, copy and store these values.



Season

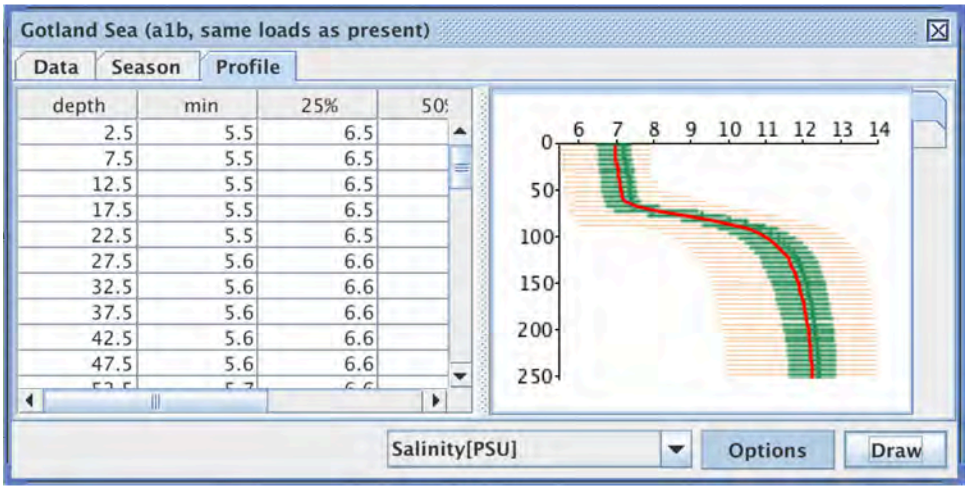
You can also evaluate long-term seasonal (monthly) averages, either as contour plots or, by using the slider, as XY-graphs of simple statistics for a specific depth: average (line) and box-and-whiskers (minimum and maximum, 25% and 75% quartiles, as well as median).





Profile

This panel shows the simulation statistics as a table to the left and as a graph to the right, aggregated to specific depths and minimum, 25%, 50%, 75% and maximum. The red line shows mean value while the green line represents the median (50%).



Literature

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Gustafsson, B. G., F. Schenk, Blenckner, T., Eilola, K., Meier, H.E.M., Müller-Karulis, B., Neumann, T., Ruoho-Airola, T., Savchuk, O.P., Zorita, E. 2012. Reconstructing the Development of Baltic Sea Eutrophication 1850–2006. *Ambio* **41**(6): 534-548.

IPCC SRES. 2000. Emission scenarios (summary for policymakers). A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. 12 pp. ISBN: 92-9169-113-5

Meier, H. E. M., H. C. Andersson, Eiola, K., Gustafsson, B.G., Kuznetsov, I., Müller-Karulis, B., Neumann, T., Savchuk, O.P. 2011. Hypoxia in future climates: A model ensemble study for the Baltic Sea. *Geophysical Research Letters* **38**.

Meier, H., Andersson, H., Dieterich, C., Eilola, K., Gustafsson, B., Höglund, A., Hordoir, R., Schimanke, S. 2011. Transient scenario simulations for the Baltic Sea Region during the 21st century. *Rapport Oceanografi, 108*

Meier, H. E. M., Höglund, A., Döscher, R., Andersson, H. C., Löptien, U. and E. Kjellström. 2011. Quality assessment of atmospheric surface fields over the Baltic Sea from an ensemble of regional climate model simulations with respect to ocean dynamics. *Oceanologia*, *53*(1-TI), 193–227.

Meier, H. E. M., H. C. Andersson, Arheimer, B., Blenckner, T., Chubarenko, B., Donnelly, C., Eilola, K., Gustafsson, B.G., Hansson, A., Havenhand, J., Höglund, A., Kuznetsov, I., MacKenzie, B.R., Müller-Karulis, B., Neumann, T., Niiranen, S., Piwowarczyk, J., Raudsepp, U., Reckermann, M., Ruoho-Airola, T., Savchuk, O.P., Schenk, F., Schiimanke, S., Väli, G., Weslawski, J-M., Zorita, E. 2012. Comparing reconstructed past variations and future projections of the Baltic Sea ecosystem—first results from multi-model ensemble simulations. *Environmental Research Letters* **7**(3): 034005.

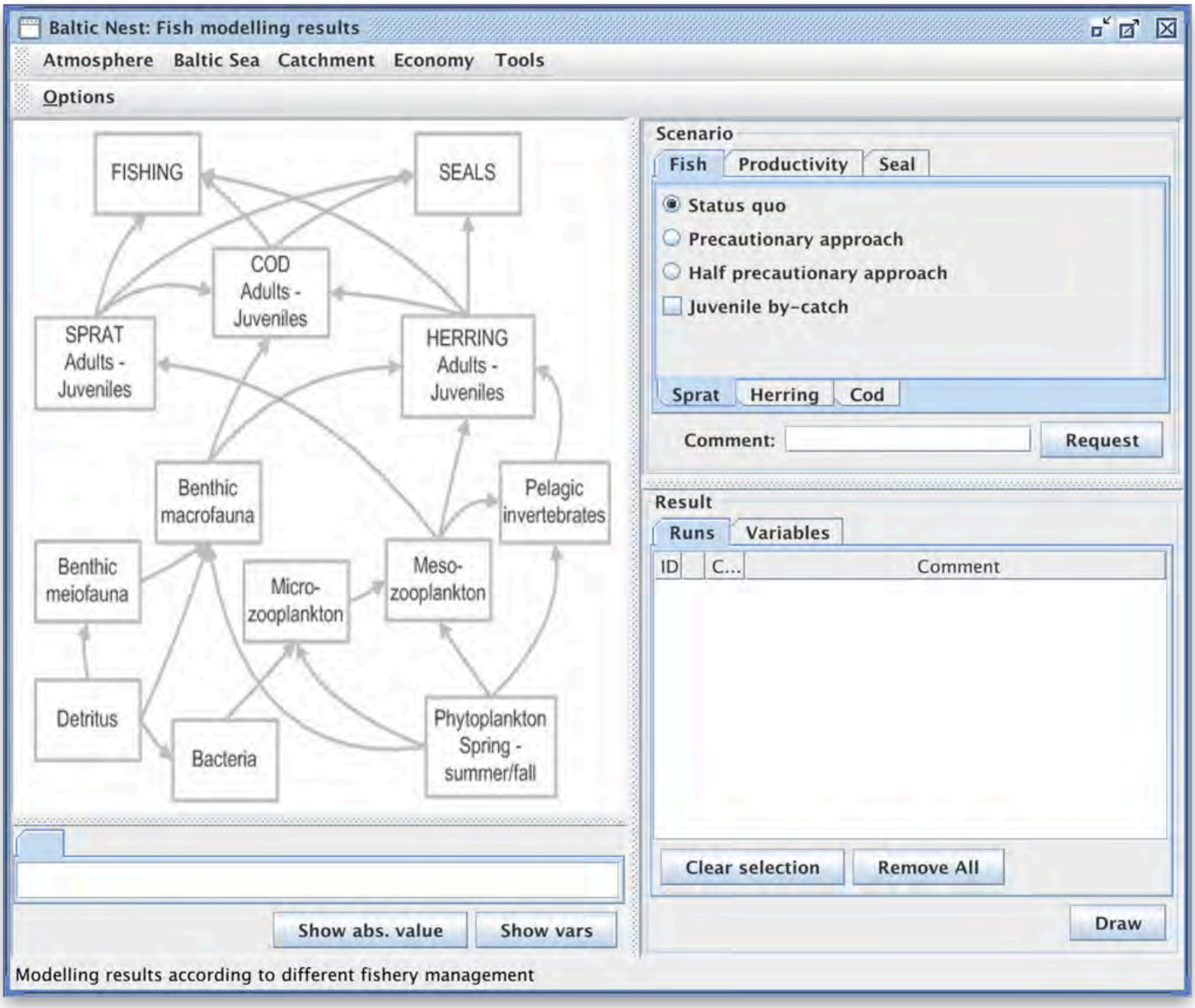
Müller - Karulis, B., B.G. Gustafson, V. Fleming-Lehtinen and S. G. H. Simis. 2012. Secchi depth calculations in BALTSEM - October 2012. *BNI Technical Report* No 8. Stockholm, Baltic Nest Institute.

Savchuk, O. P., B. G. Gustafsson, M. Rodríguez Medina, A. V. Sokolov and F. V. Wulff. 2012. External nutrient loads to the Baltic Sea, 1970-2006. *BNI Technical Report* No 5. Stockholm, BNI.

Savchuk, O. P., K. Eilola, B. G. Gustafsson, M. Rodríguez Medina and T. Ruoho-Airola. 2012. Long-term reconstruction of nutrient loads to the Baltic Sea, 1850-2006. *BNI Technical Report* No 6. Stockholm, BNI

Savchuk, O. P., B. G. Gustafson, and B. Müller – Karulis. 2012. BALTSEM - a marine model for decision support within the Baltic Sea Region. *BNI Technical Report* No 7. Stockholm, BNI.

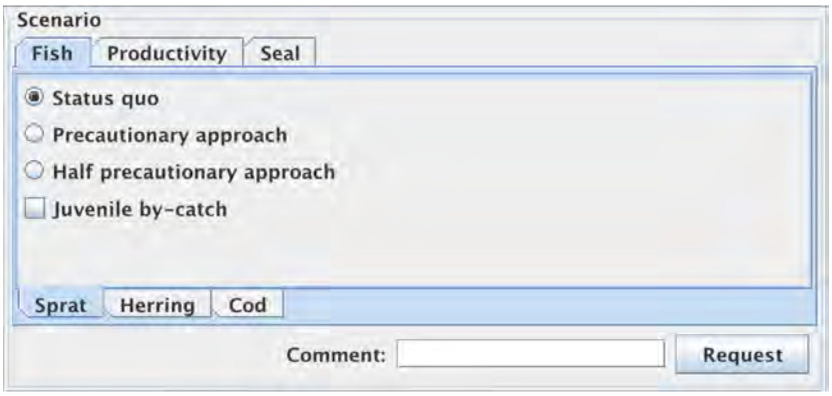
Fish modeling results



In this module, you can explore the effect of various fishing strategies on future stocks and yields of the three major commercial fish species in the Baltic proper: cod, herring and sprat. It has been argued that the drastic changes that have occurred in fisheries are not caused by fishing only, and with this model you can also study the effects of seal predation and of changes in primary productivity.

There are two major panels:

Scenario

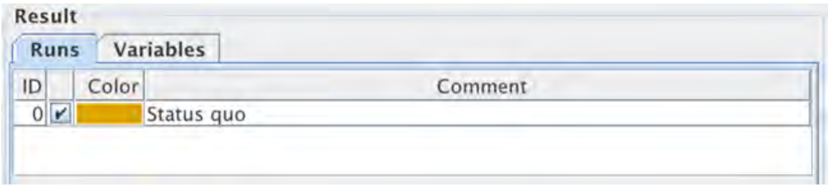


In the *Fish* panel, you can select different fishery management options for sprat, herring and cod. Explanations will appear in the lower left corner when you move the cursor over the options. The status quo situation for year 2000 is default for all stocks and seals, as well as for the primary productivity level of the Baltic.

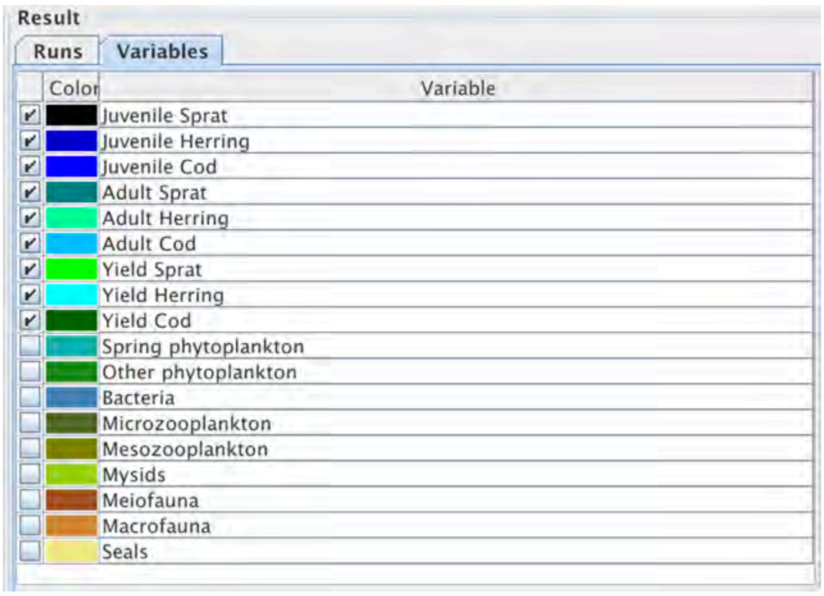
When you select the *Productivity* scenario options, *Status quo* or model runs with conditions of the *early 1900 level* can be chosen, which as much lower productivity and/or higher oxygen levels compared to today (you can find the same scenario in the SANBALTS model). You can specify *Spring phytoplan*kton, *Other phytoplankton* and *Cod reproductive volume* separately.

Results

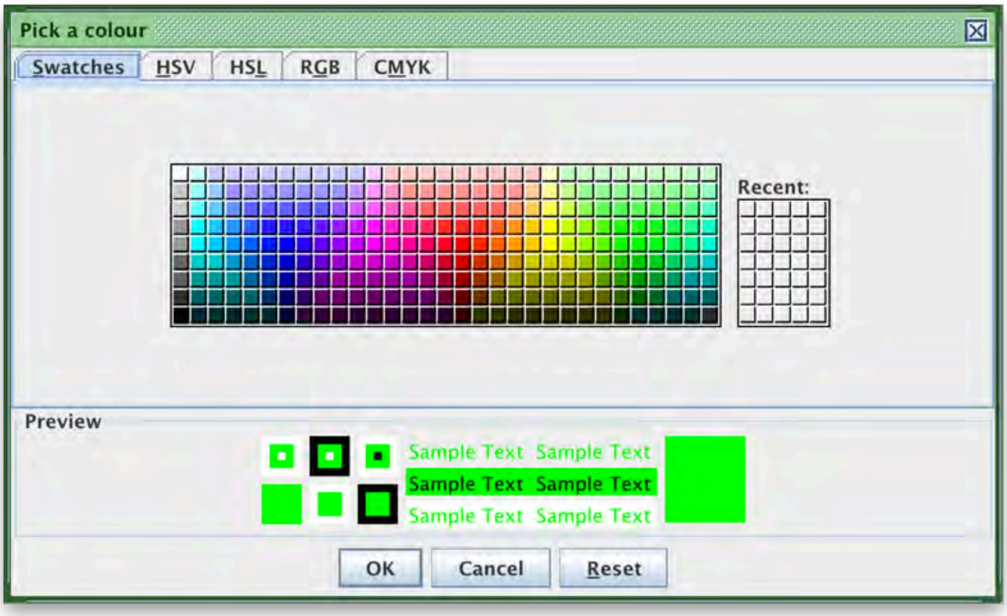
When you press *Request*, the model run that you selected in the *Scenario* panels will appear in the Result panel. You can request several scenarios, corresponding to different combinations of driving forces, for further inter-comparisons, and these results will appear in the *Runs* panel, as well with separate ID and different color.



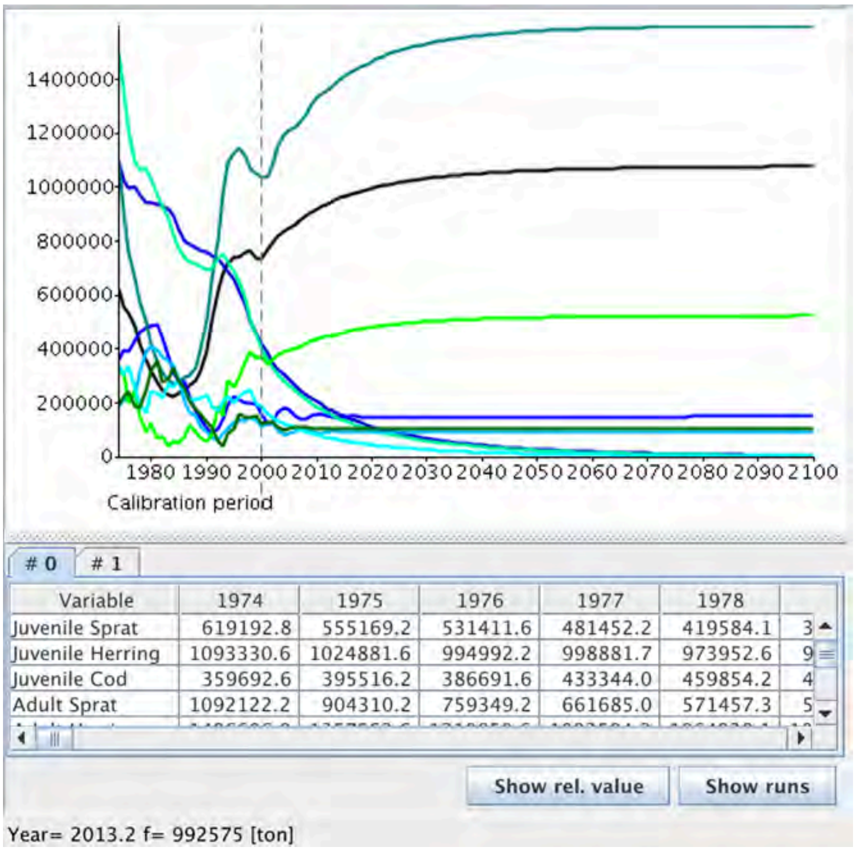
If you select Variables, you can see the nine default variables. All the variables in the model can be shown if you choose *Expert Mode* from the *Tool* menu.



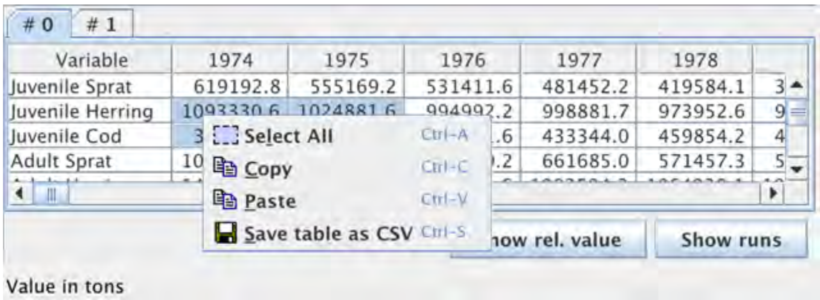
You can click *Clear selection* to clear all variables, and thereafter check the boxes of only those variables that you are interested in for your model run before you press *Draw*. By clicking on a colored box, a color editor will appear that allows you to change color of a variable.



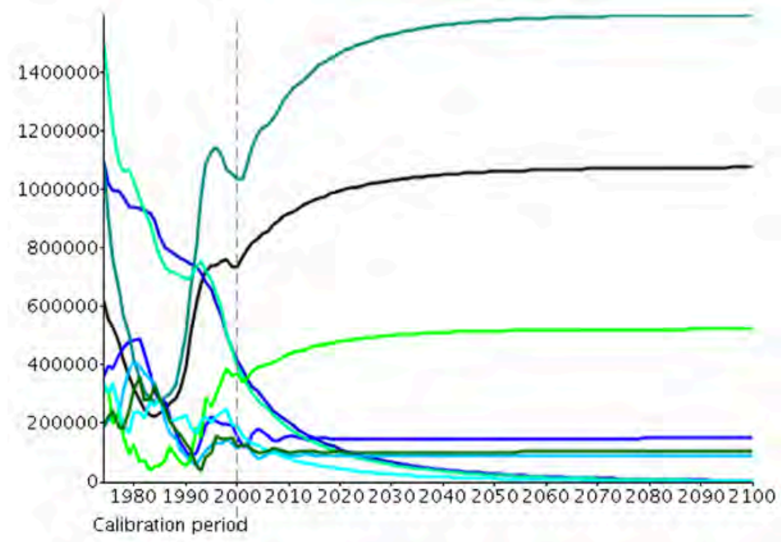
When you select *Draw* in the *Results* panel the temporal variations of the variables that you selected will appear in the left hand panel.

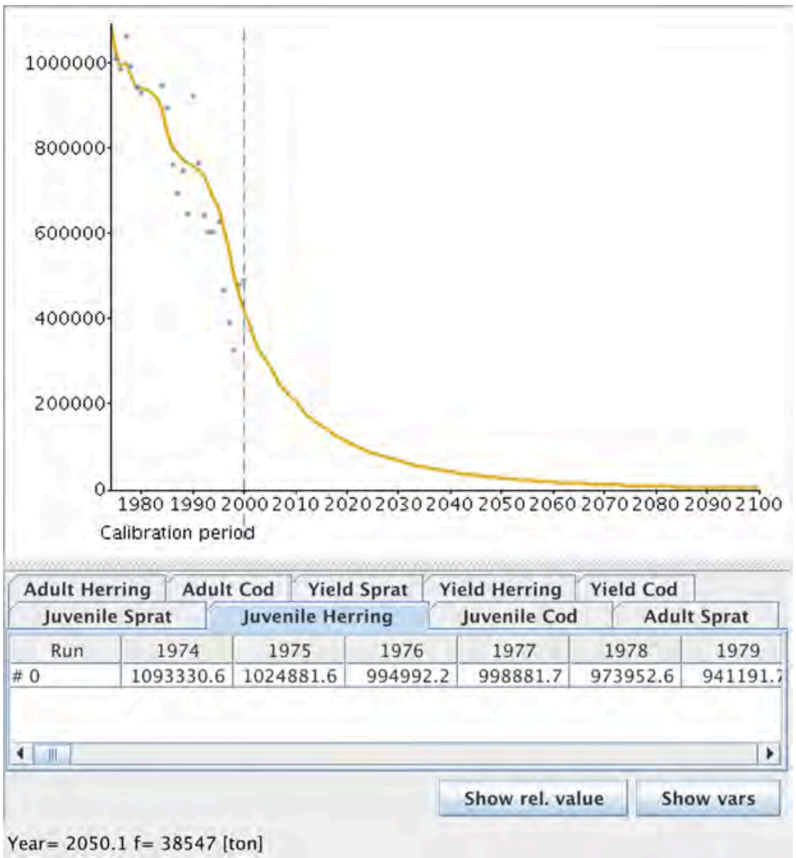


In the lower left corner you will see the values corresponding to the position of the cursor. The actual values for all the variables are shown in the table below. Select and save the whole, or a part of the, table for use in other programs, for instance Excel, by 'right-click' on it.

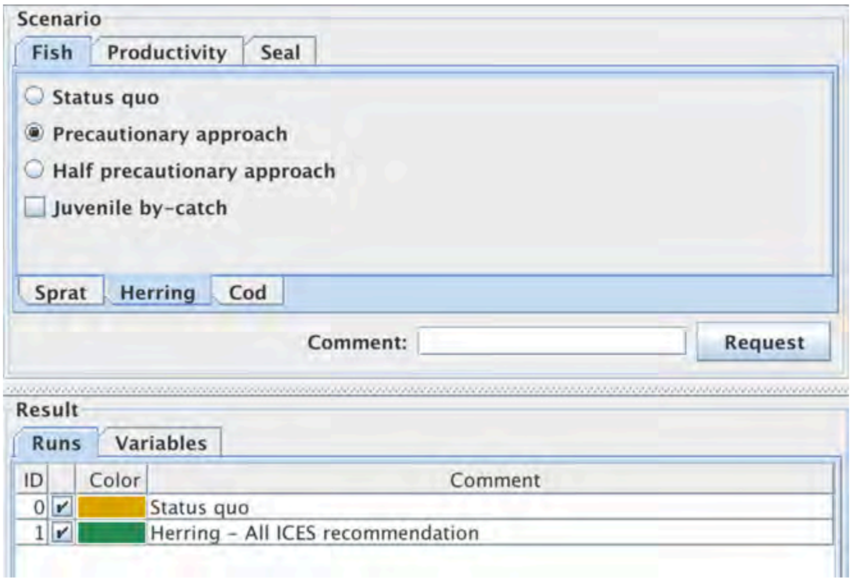


The module allows you to analyze several model runs. In the figure above two tabbed panels (#1 and #2) contain results from two model runs. A user can draw several variables of one model run, or one variable for all model runs (see the two figures below). The button *Show runs/Show vars* switches between those modes. The button *Show rel. value/Show abs value* changes the form of data presentation (relative to initial value (1974) in per cents or absolute value in tons).

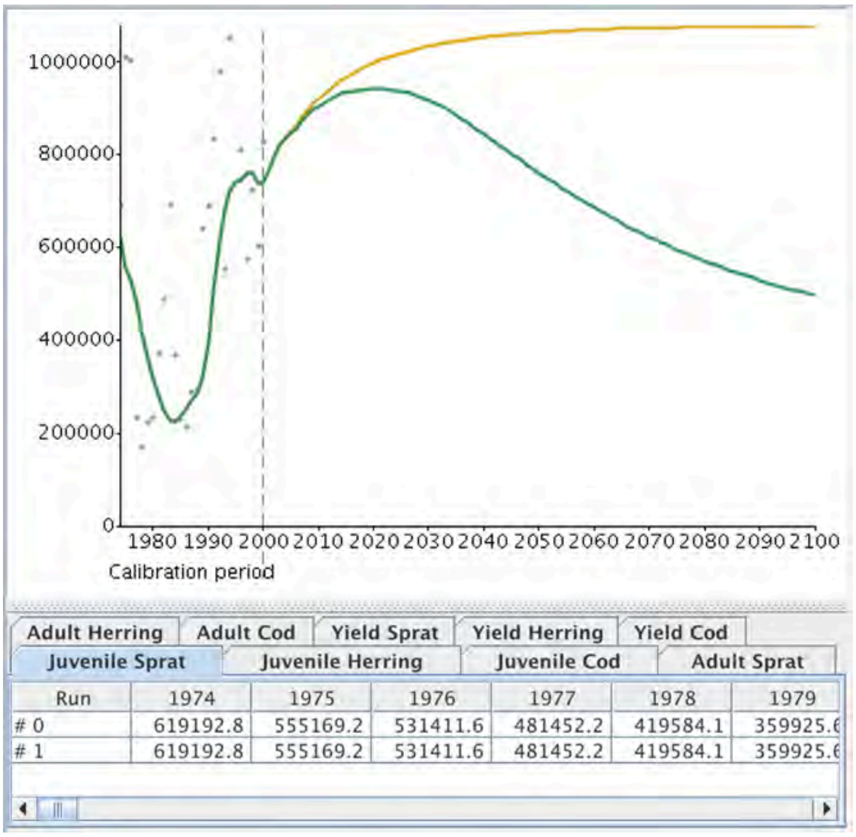




The actual observations, used to calibrate the model, are then shown for the period prior to 2000. Select another fishery management option in the Scenario panel, and the result will be shown by another color in the *Result* panel.

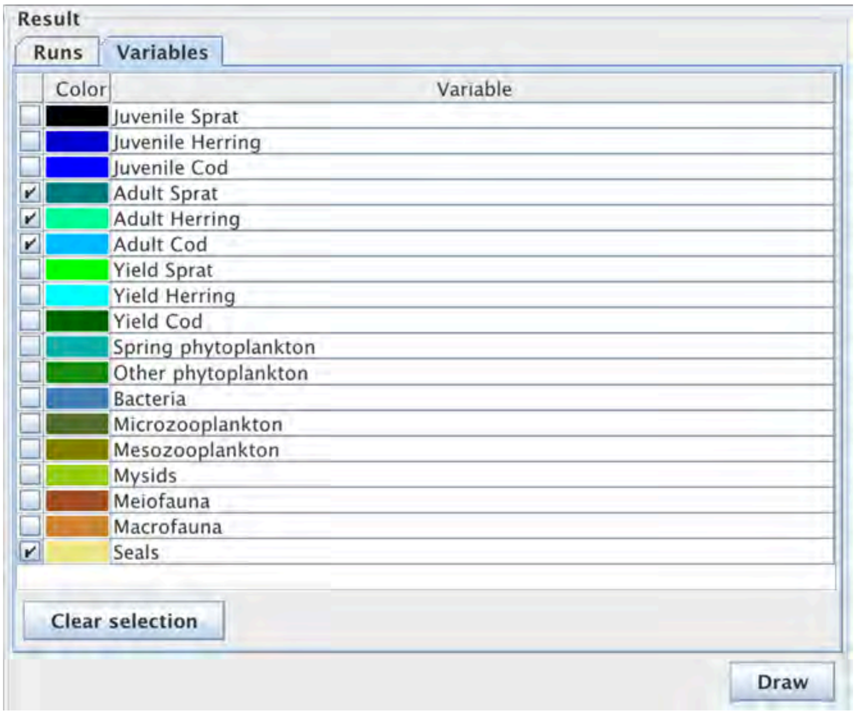


The graph will then show both scenarios in the graph panel:



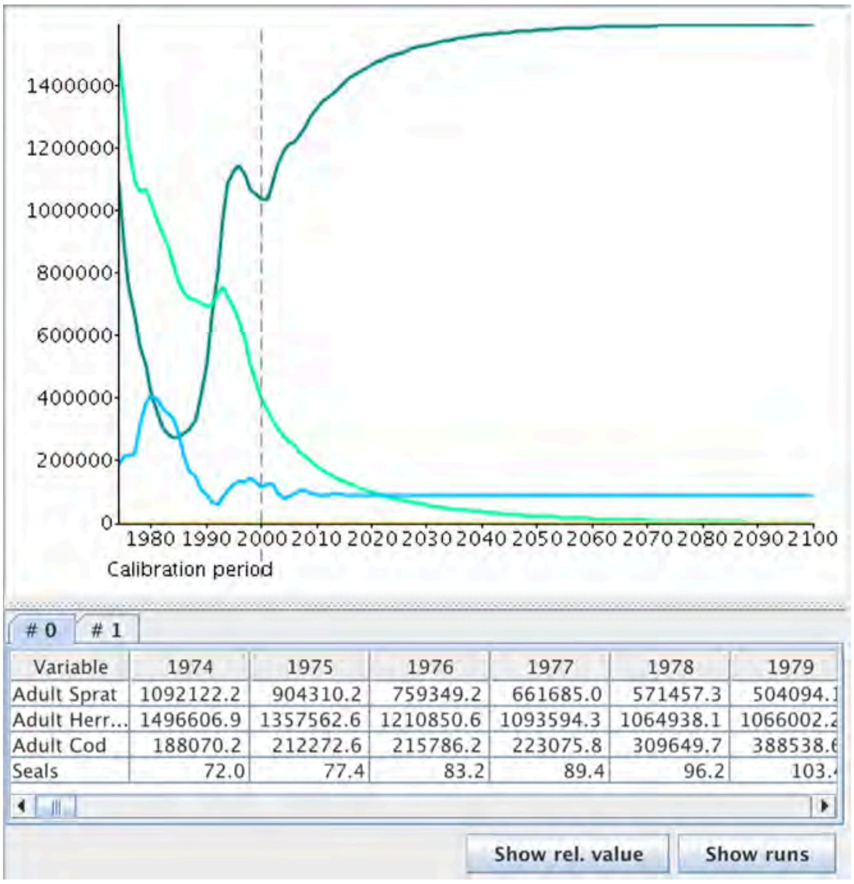
Again, you can select different variables to display by selecting them from the panels below the graph.

You can also go back to the *Result* panel under *Variables* in *Expert mode* and select additional variables that were not initially included. You can also deselect some of the initial variables, by clicking on the appropriate check boxes.



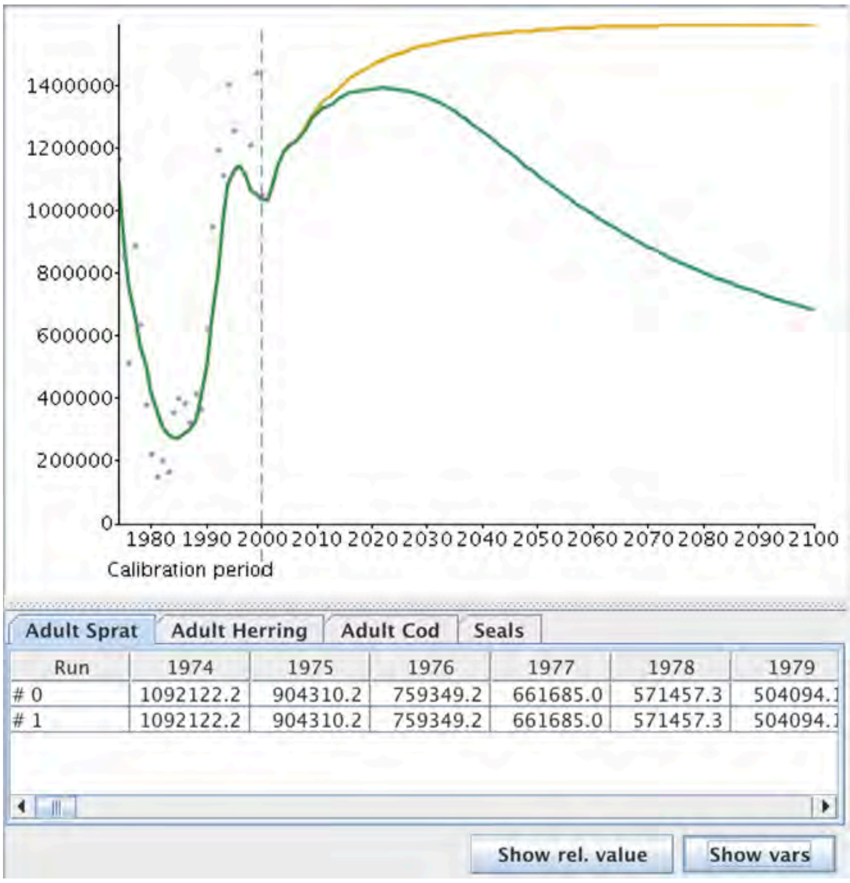
The panels below the graph will then display your new selection of variables.

You can display all variables for a particular run by selecting the tabs for these below the graph, after selecting *Show runs*.



Variable	1974	1975	1976	1977	1978	1979
Adult Sprat	1092122.2	904310.2	759349.2	661685.0	571457.3	504094.1
Adult Herr...	1496606.9	1357562.6	1210850.6	1093594.3	1064938.1	1066002.2
Adult Cod	188070.2	212272.6	215786.2	223075.8	309649.7	388538.6
Seals	72.0	77.4	83.2	89.4	96.2	103.4

Alternatively, you can see all runs for a particular variable by pressing the same (right) button again and it will display *Show vars*.



In both these modes you can show absolute and relative values for all variables. You can also go back to the *Scenario* panel and add more model runs.

Literature

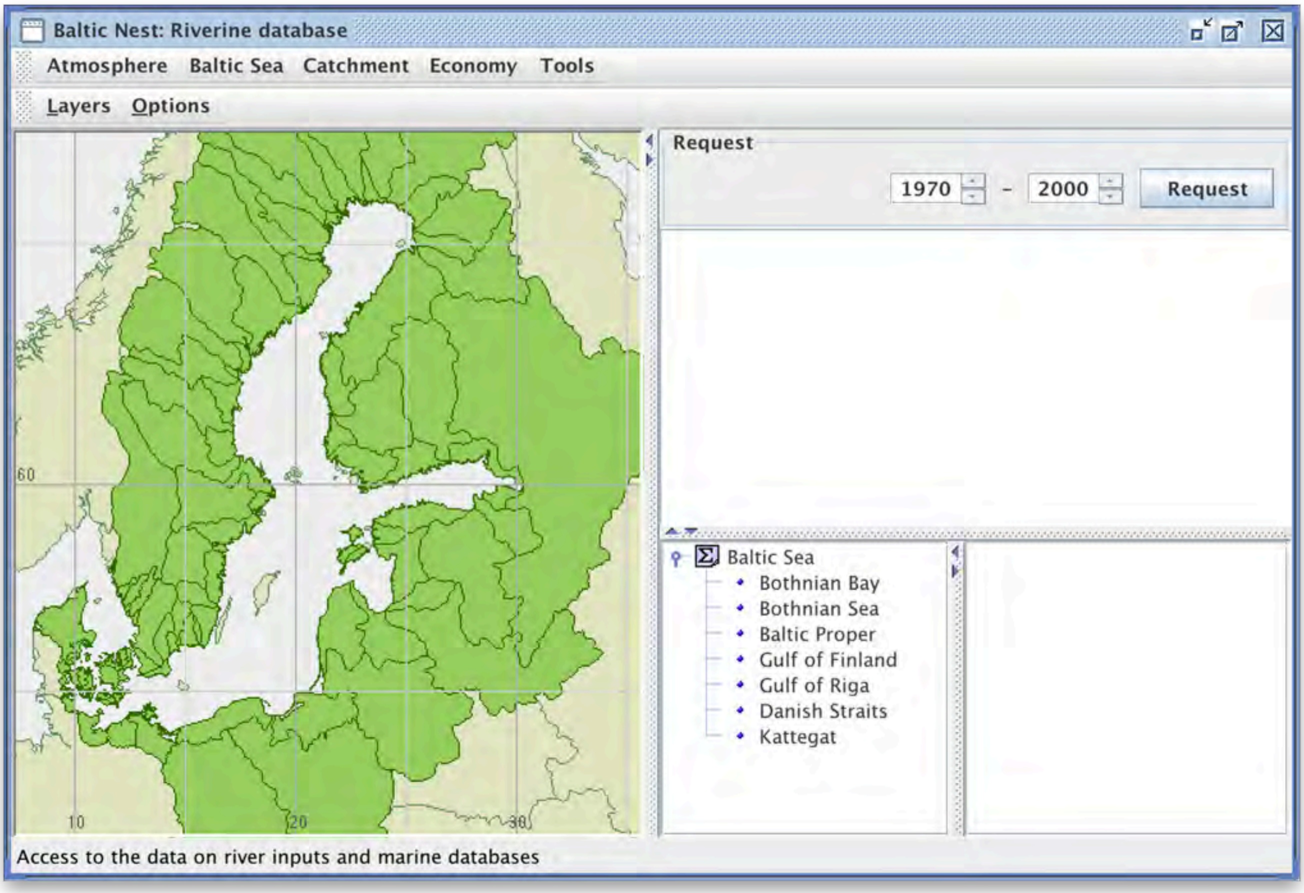
Harvey, C. J., S. P. Cox, Essington, T.E., Hansson, S. Kitchell, J.F. 2003. An ecosystem model of food web and fisheries interactions in the Baltic Sea. *Ices Journal of Marine Science* **60**(5): 939-950.

Hansson, S., O. Hjerne, Harvey, C., Kitchell, J.F., Cox, S.P., Essington, T.E. 2007. Managing Baltic Sea fisheries under contrasting production and predation regimes: Ecosystem model analyses. *Ambio* **36**(2-3): 265-271.

Catchment

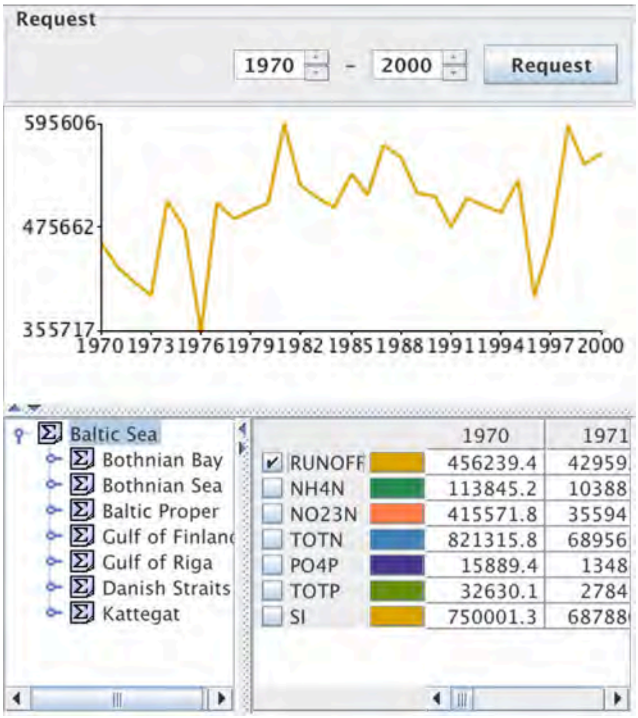
Riverine database

This interface describes freshwater runoff and nutrient loads for the period 1970-2000 in considerable detail: from single rivers to drainage areas of individual marine basins to the entire Baltic Sea.



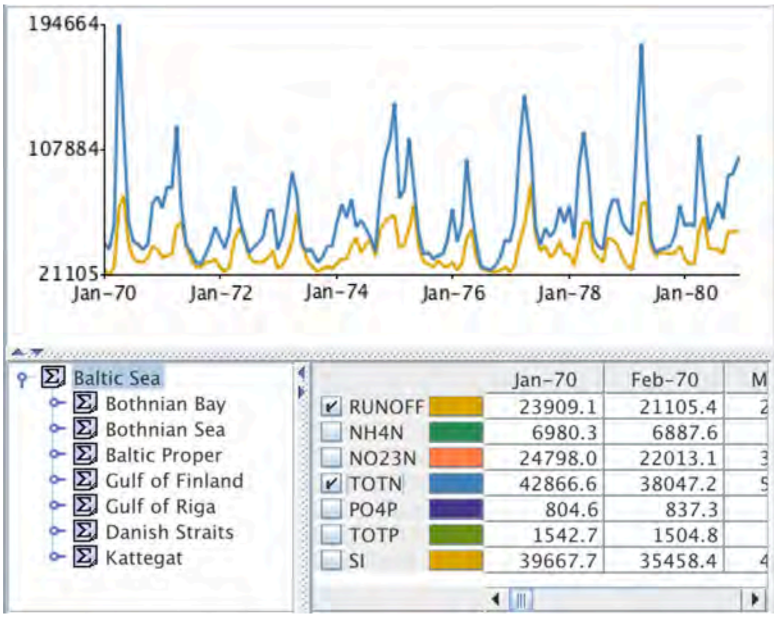
The map to the left shows the entire drainage basin with 81 sub-drainage basin boundaries. By clicking on any of these (the color will then change) you can select data on loads for this particular sub-basin from the database when you downloaded data from the *Request* panel.

The right side panel contains three sections. The *Request* panel at the top allows you to select a time interval between 1970-2000 and request data from the database. These data were originally compiled by Stålnacke (1996) and later extended by BNI. You will see the observations as a time series graph in the middle when you have checked a particular variable.

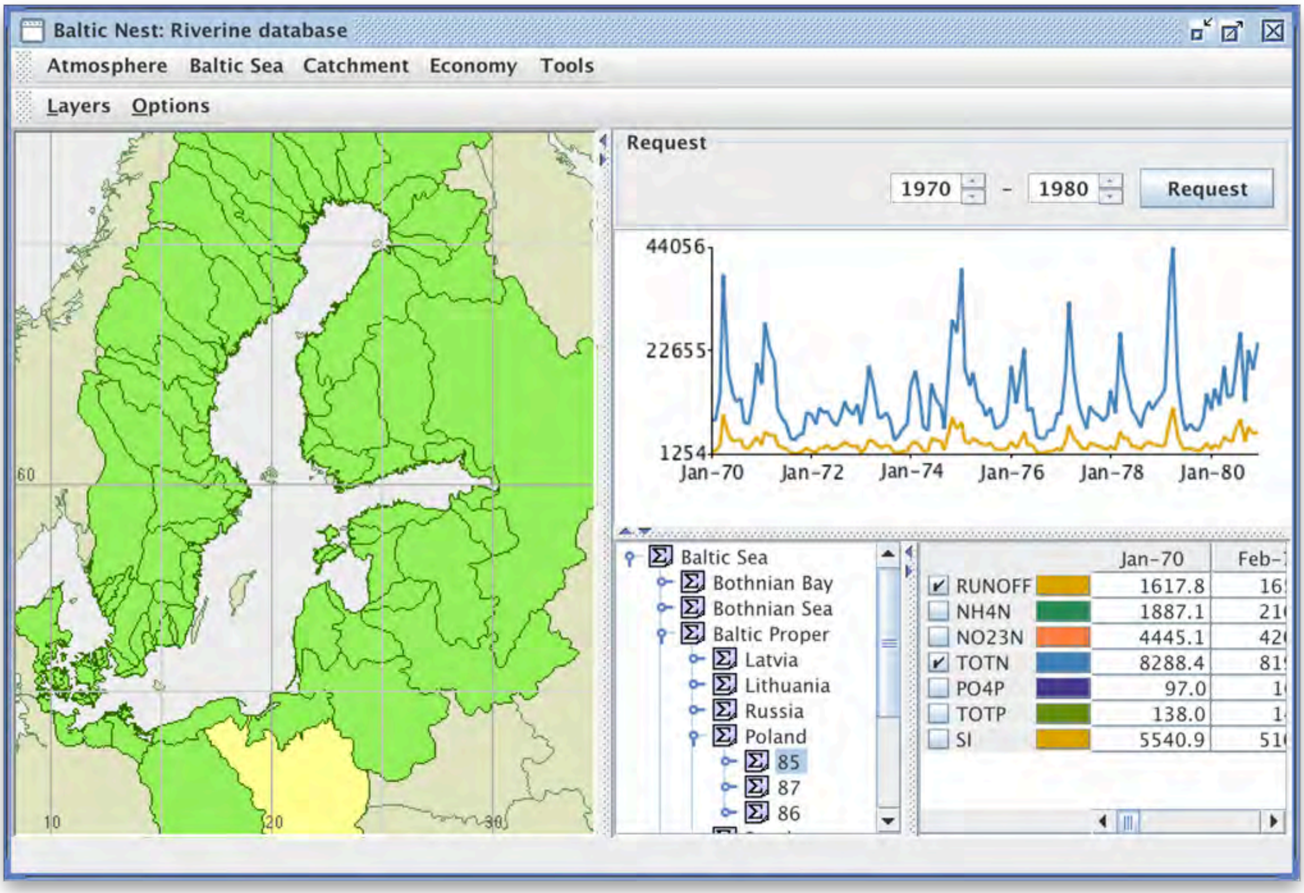


By default, you will get and see annual loads of the variables. If you choose *Expert* mode in the *Tools* menu in the menu bar of the Nest system, you will see the results with monthly resolution. You can also change the vertical scale in the *Options* menu, as well as presenting the results in absolute amounts or as concentrations.

Thus the total inputs of runoff (fresh water) for the entire Baltic, together with total nitrogen (TOTN) load, would look like this.



You select the variables to be displayed, but also the region of the Baltic, in the tree below the graph. Here you can select the sub-basin, country and even data for a particular drainage basin. In this case the Vistula basin is shown (Baltic Proper, Poland, nr 85). The Baltic drainage basin is divided into 81 sub-drainage areas, as developed by Grid-Arendal. The chosen drainage basin is highlighted on the map.



Literature

Savchuk, O., Gustafson, B., Rodriguez Medina, M., Sokolov, A. & F. Wulff. 2012. External nutrient loads to the Baltic Sea, 1970-2006. *BNI Tech. Report* No. 5.

Ruoho-Airola, T., Eilola, K., Savchuk, O. P., Parviainen, M. and V. Tarvainen. 2012. Atmospheric Nutrient Input to the Baltic Sea from 1850 to 2006: A Reconstruction from Modeling Results and Historical Data. *Ambio* 41, 549-557, doi:10.1007/s13280-012-0319-9 (2012).

Gustafsson, B.G., Schenk. F, Blenckner, T., Eioloa, H.E., Meier, M.E.H., Müller-Karulis, B., Neumann, T., Ruoho-Airola, T., Savchuk, O.P., Zorita, E. 2012. Reconstructing the Development of Baltic Sea Eutrophication 1850–2006. *Ambio* 41, 534-548, doi:10.1007/s13280-012-0318-x .

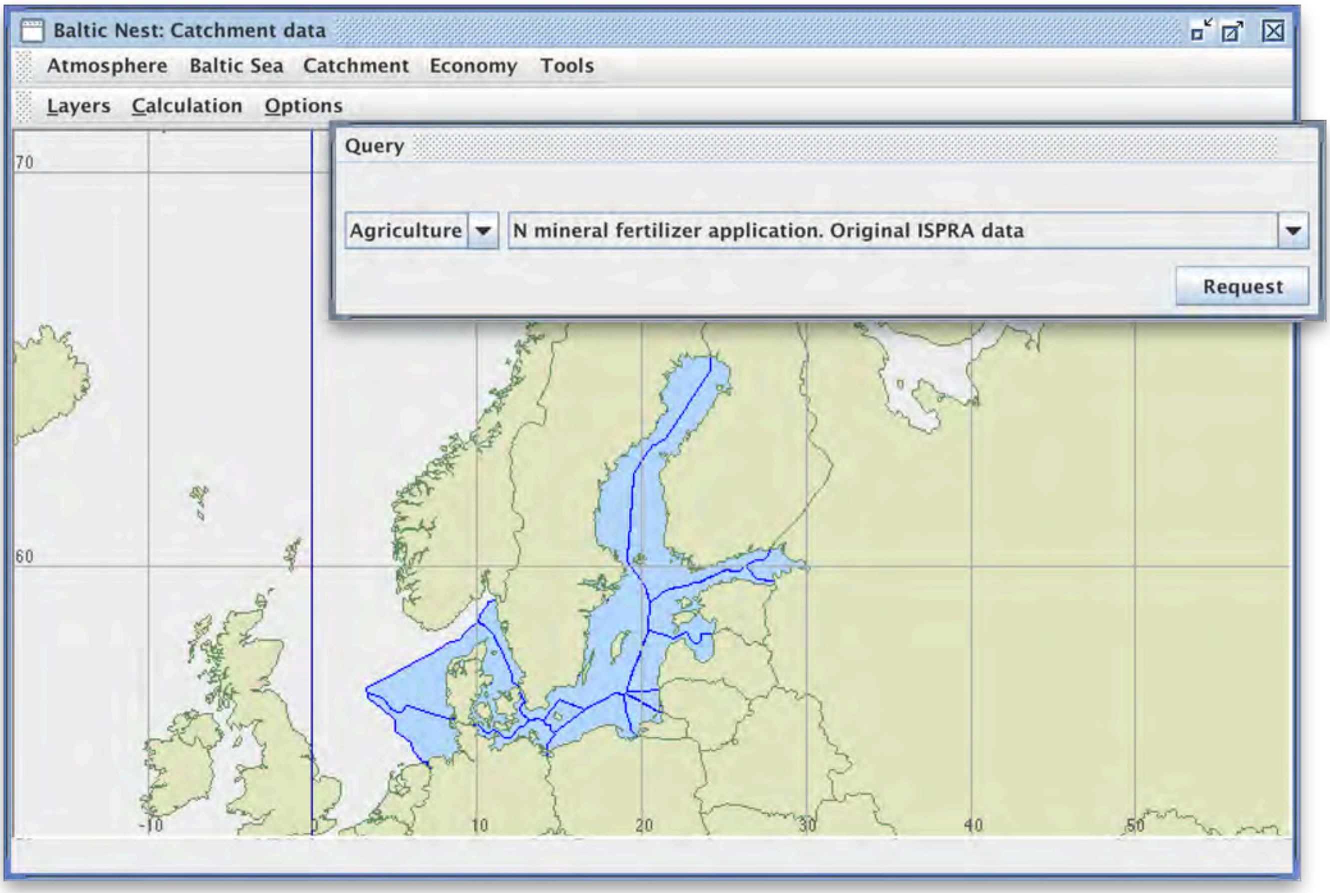
Meier, H. E. M. H. C. Andersson, Arheimer, B., Blenckner, T., Chubarenko, B., Donnelly, C., Eilola, K., Gustafsson, B.G., Hansson, A., Havenhand, J., Höglund, A., Kuznetsov, I., MacKenzie, B.R., Müller-Karulis, B., Neumann, T., Niiranen, S., Piwowarczyk, J., Raudsepp, U., Reckermann, M., Ruoho-Airola, T., Savchuk, O.P., Schenk, F., Schiimanke, S., Väli, G., Weslawski, J-M., Zorita, E. 2012. Comparing reconstructed past variations and future projections of the Baltic Sea ecosystem—first results from multi-model ensemble simulations. *Environmental Research Letters* 7, 034005, doi:10.1088/1748-9326/7/3/034005.

Stålnacke, P., 1996. Nutrient loads to the Baltic Sea. Ph.D. Thesis. Linköping Studies in Arts and Science 146: 78 pp.

Stålnacke, P. and A. Grimvall, Sundblad, K. and Tonderski, A. 1999. Estimation of riverine loads of nitrogen and phosphorus to the Baltic Sea, 1970-1993. *Environmental Monitoring and Assessment* **58**(2): 173-200.

Catchment data

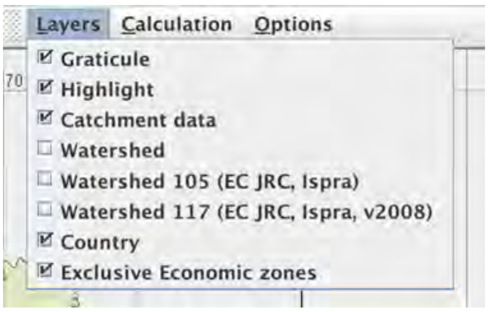
This is an interface to spatially gridded data describing sources of nutrients in the drainage basin of the Baltic Sea. Some of these loads will eventually reach the Baltic Sea. When you open the interface you will see the following window:



There are three menu boxes for this interface found on the second row of the menu bar, as well as a *Query* window that can be placed anywhere on the screen.

Layers

Here you can select sets of layers that you want to see and use on the map



Where:

☐ *Graticule* draws latitudes and longitudes, 10° apart on the map in the default scale.

☐ *Highlight* allows highlighting the area you have chosen when you click on the map to calculate an integral values for this area (see *Calculation*).

☐ *Watersheds* of the Baltic. By default a total of 81 sub-drainage basin boundaries, developed by Grid-Arendal, are used.

☐ *Watershed 105 (EC, JRC, Ispra)* Boundaries defined by the Joint Research Centre of the European Commission at Ispra, Italy. These 105 boundaries are currently used in the **Watershed model** used in Nest. You must deselect previous watershed layers in order to see these watershed boundaries.

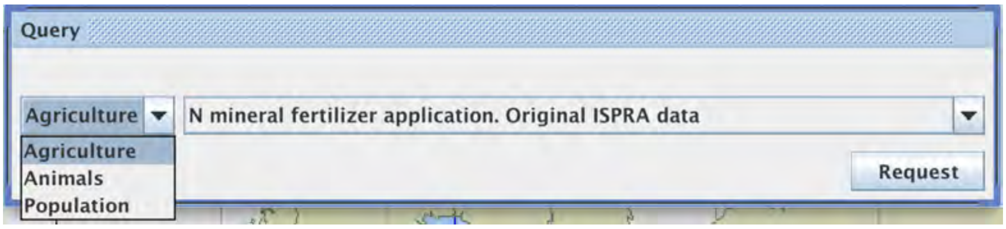
☐ *Watershed 117 (EC, JRC, Ispra, v2008).* The current, officially defined version of watersheds, also developed at Ispra.

☐ *Country* layer shows boundaries for all countries in the world.

☐ *Exclusive Economic zones*. As defined by the United Nations, these stretches from the seaward edge of a state's territorial sea out to 200 nautical miles from its coast. When an overlap occurs, it is up to the states to delineate the actual boundaries. The boundaries for the Northern seas, used here were extracted from the KnowSeas project. The reasons why these are included as a boundary are explained below.

Query

This movable window is always shown on the screen. Here, you have three major data categories to select from, i.e. *Agriculture, Animals*, and *Population* (all in a 10x10 km grid).



The *Agriculture* option includes nitrogen (N) and phosphorus (P) fertilizer and manure applications and crop type data for the year 2000. The data has been compiled by the European Commission's Joint Research Centre at Ispra.

The N and P mineral fertilizer application, as well as the N and P manure application, only covers EU countries. However, the data set "N mineral fertilizer application (reduced for Poland with 40%)", is expanded to partly cover Russia and Belarus and is corrected for Poland, see details in the "NANI toolbox" section 3.3.

The Crop data covers the entire Baltic drainage basin, including Russia and Belarus.

The *Animal* option includes numbers of cattle, pigs, poultry etc. Animal classes are of two main types. The classes from EuroStat are more specific, e.g. "Piglets with a live weight of less than 20 kg" etc., and cover only EU countries. The more general types, e.g. "Pigs" etc., cover the whole Baltic catchment.

Data on animal numbers for the EU countries were calculated as median values for the years 2000-2005, except for NUTS areas in Denmark where 2009 values were used.

Data were derived from EUROSTAT on NUTS level 2. The NUTS classification (EU nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU for collection and harmonization of regional statistics.

For Belarus animal data were derived for 2008 from regional statistics on a Voblast (province) level and from national statistical yearbooks.

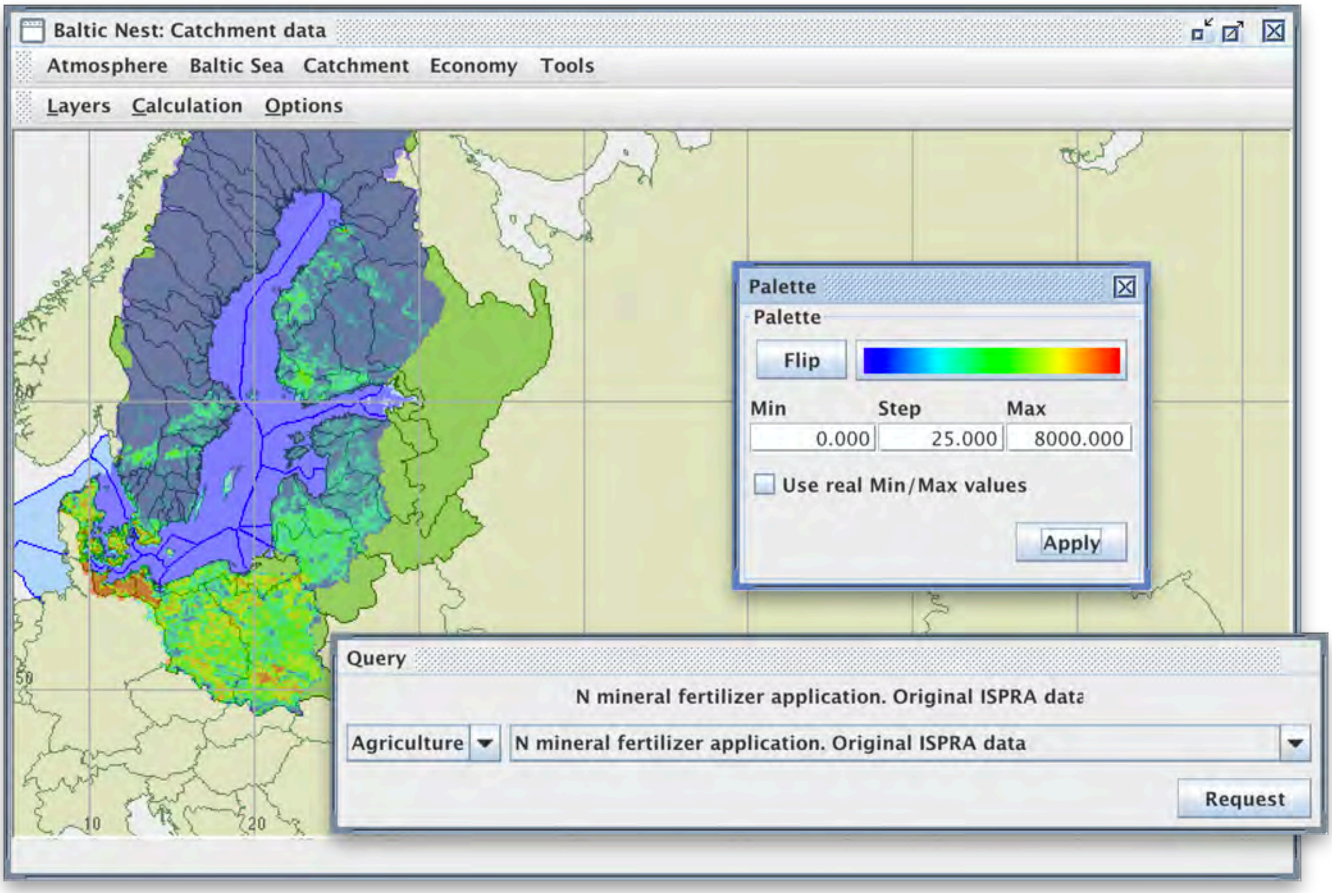
For Russia animal data for 2009 were derived from regional statistics on an oblast (province) level.

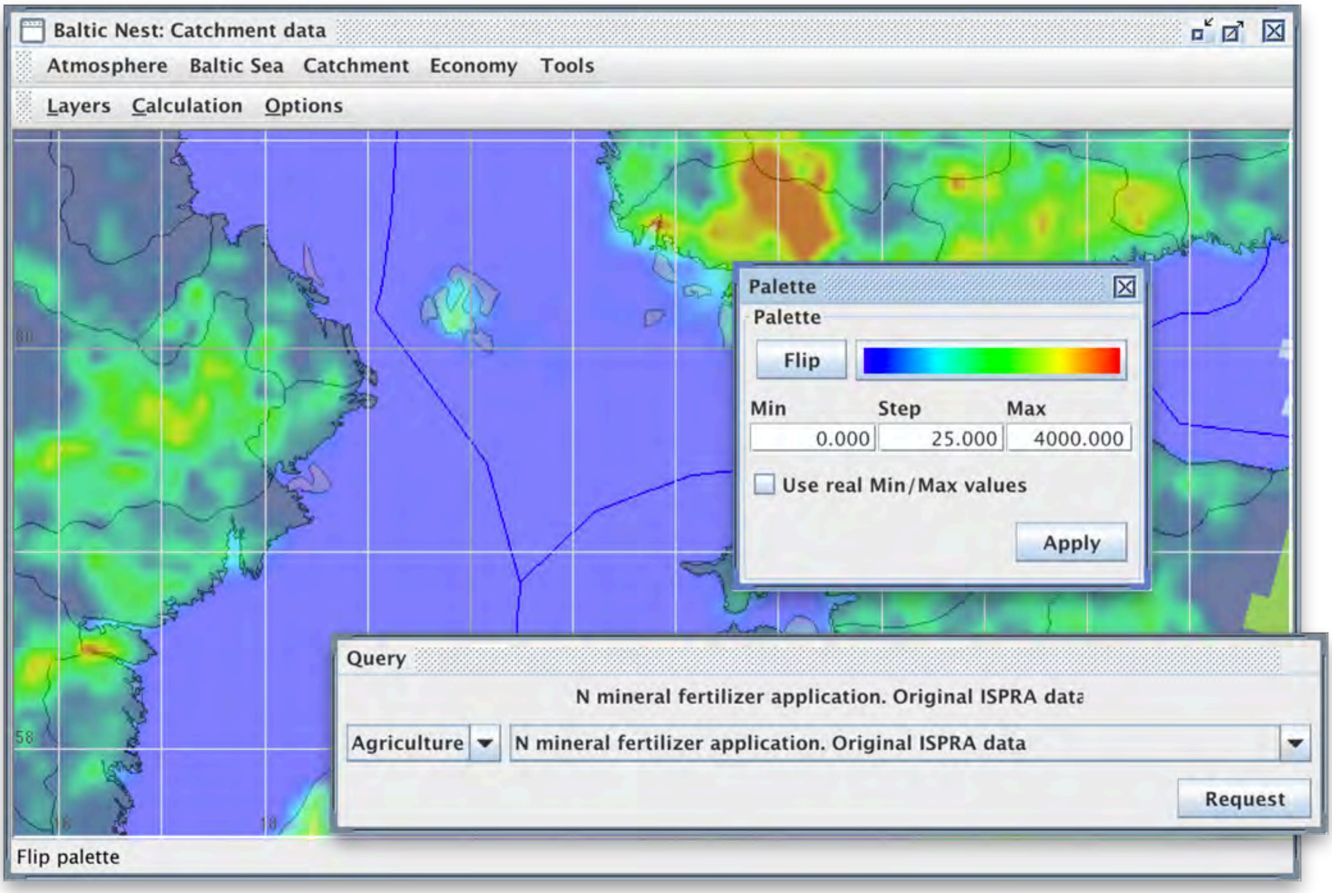
For some oblasts that were lacking data, animal numbers were calculated based on animal number correlations with rural population in neighboring oblasts where data is available.

The *Population* option includes total, urban and rural data for the year 2005. These were derived from the HYDE database, developed under the authority of the Netherlands Environmental Assessment Agency. The data on a 5' x 5' latitude/longitude grid were downloaded and redistributed into a 10x10 km grid.

Also included in the *Population* option are the number of people connected to different levels of waste water treatment (primary, secondary and tertiary), as well as the number of people NOT connected to any type of waste water treatment. These are based on calculations done by BNI.

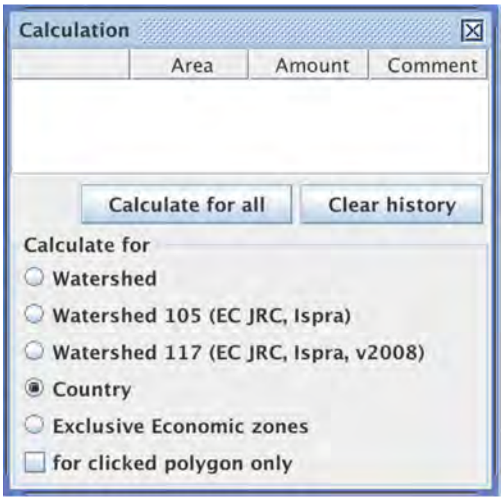
More information regarding the population, animal and crop data can be found in Hong at al. (2011). It is possible to create various detailed maps by altering the Nest window, magnification, and the color scales. Here are a few examples, using data on N mineral fertilizer applications from Ispra.



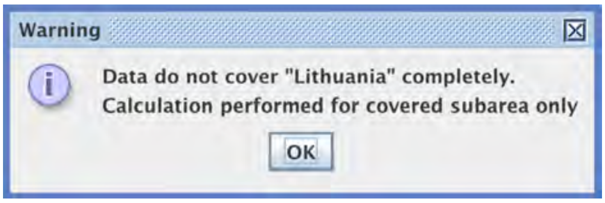


Calculation

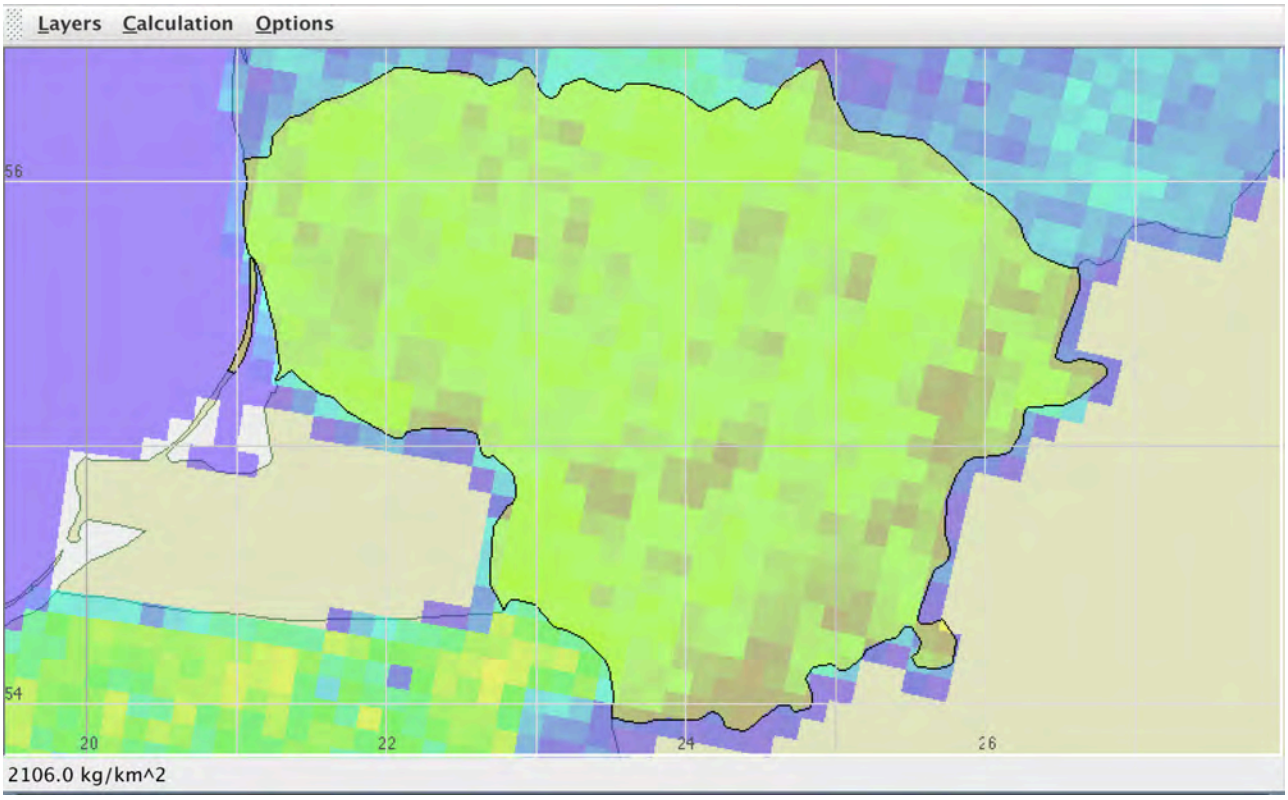
A new window appears when you click on this item in the menu. This window can, according to the users convenience, be placed anywhere on the screen.



Here you can calculate total amounts of the variable you requested in the *Query* panel for different polygons on the map (watershed, country, etc.). Remember to select the same layer under the *Layers* menu. It is important to understand that the gridded data, with a resolution of 10 x 10 kilometers, often varies compared to the much higher resolutions of the boundaries of countries or watersheds. For instance, if you select Lithuania (by clicking on the map (highlighted when the calculation is done), you will get a warning:



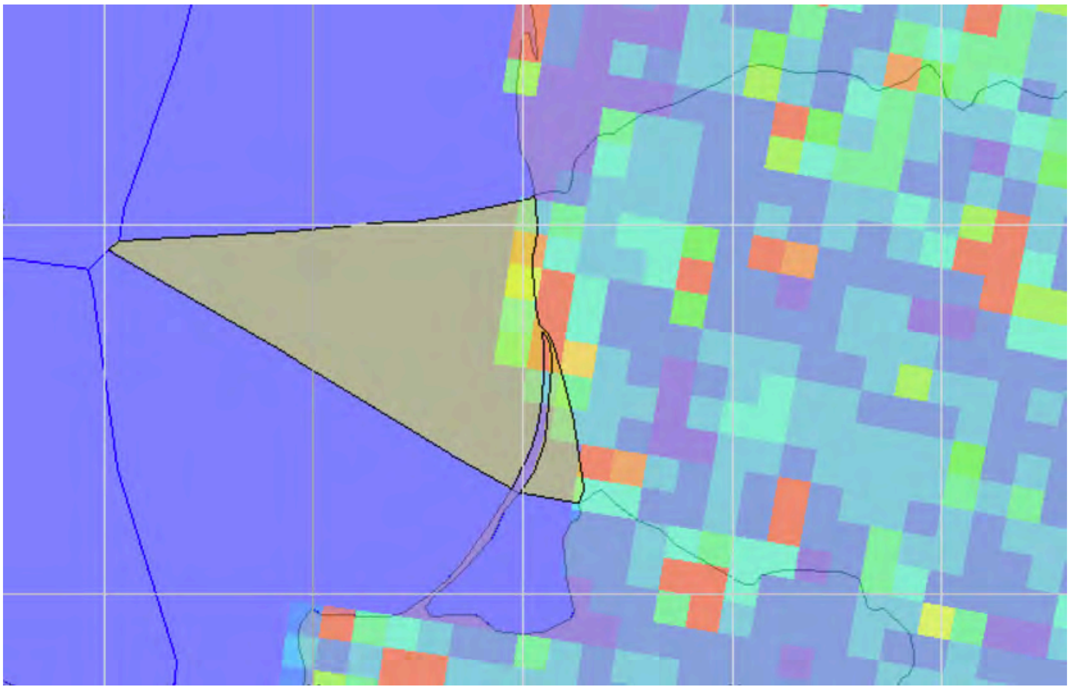
By examining the (enlarged) map, you will understand why:



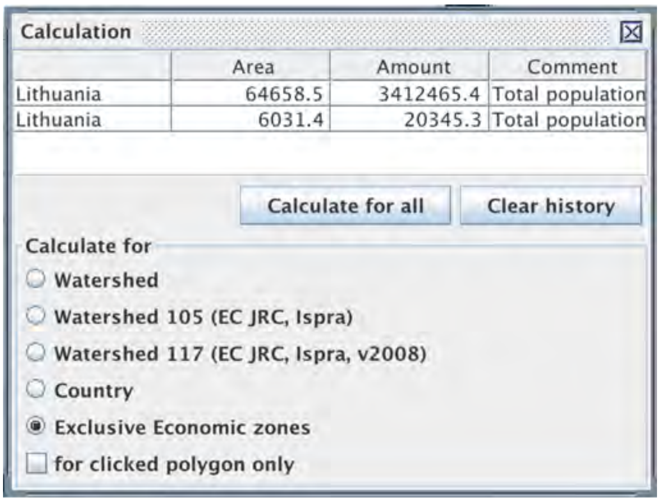
Due to the coarse resolution of the gridded data, tiny proportions in the southeast region (Dieveiskés), as well as the peninsula bordering the Curonian Lagoon, are not covered (hence the warning). You have to judge yourself whether these omissions are important or not. In other cases, these omissions are correct; the drainage basin to the Baltic does not cover the entire country, such as for Russia and Sweden, and you will get the same warning.

Thus, it is important to understand the fundamental logic and limitations of extracting information from these GIS calculations, where different data sets have different resolutions. In the example above, parts of the grid cells lies outside the country borders in regions where there are no data (the Sea, in the Kaliningrad region and in Belarus). This means that the calculated total amount is lower than the 'true' value. You must yourself judge whether these calculations are reasonable approximations by inspecting the map and the magnitude of the values found in these grid cells.

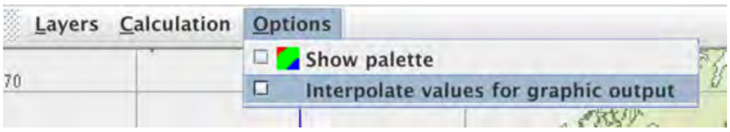
These omissions may create underestimates for some parameters, in particular those regarding populations. These data cover the entire drainage basin, including non-EU countries. Using the example of Lithuania, you can see a complete coverage of the country. However, due to the size of the grid cells, some people living close to the Sea end up in the Sea (in the Klaipeda region). This could be a serious underestimate for some countries, since many people live near the coast! However, this can be corrected by performing a separate calculation, summing up also the people living in the Exclusive Economic Zones (by using this layer).



The total population is then 3 232 810, of which approximately 20 000 people 'live in the Sea' in this case.



Options



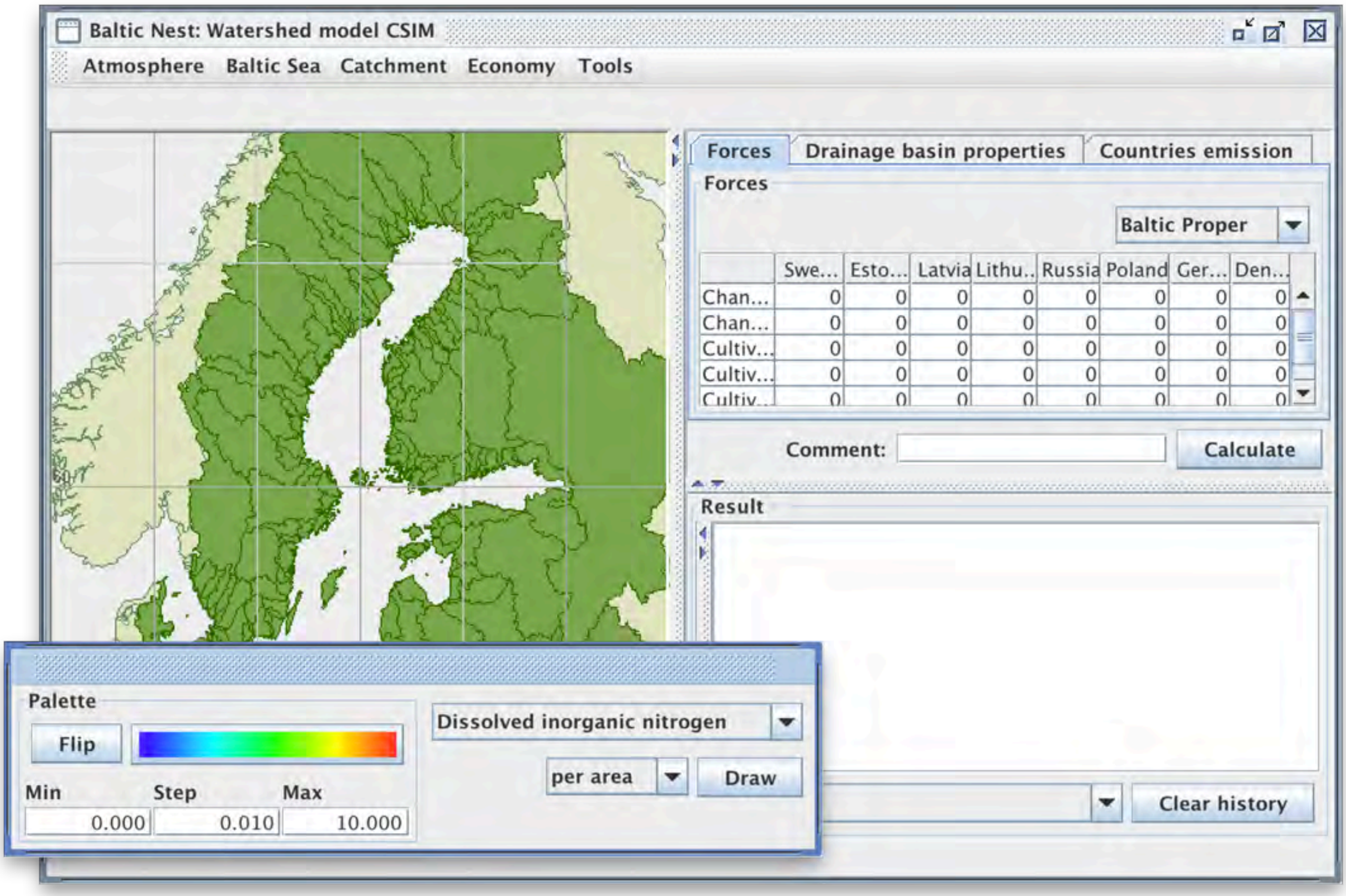
By selecting *Show palette*, a palette is shown in a window on the map and it can be used to change the color scale of the data shown. By default gridded values are not interpolated for graphical presentations. You can select this in order to show interpolated fields.

Literature

Hong, B., D.P. Swaney, C. - M. Mörth, E. Smedberg, H.E. Hägg and C. Humborg. 2011. NANI/NAPI Calculator Toolbox version 2.0 documentation: Net Anthropogenic Nutrient Inputs in Baltic Sea catchments. *BNI technical report series*, No 3.

Watershed model CSIM

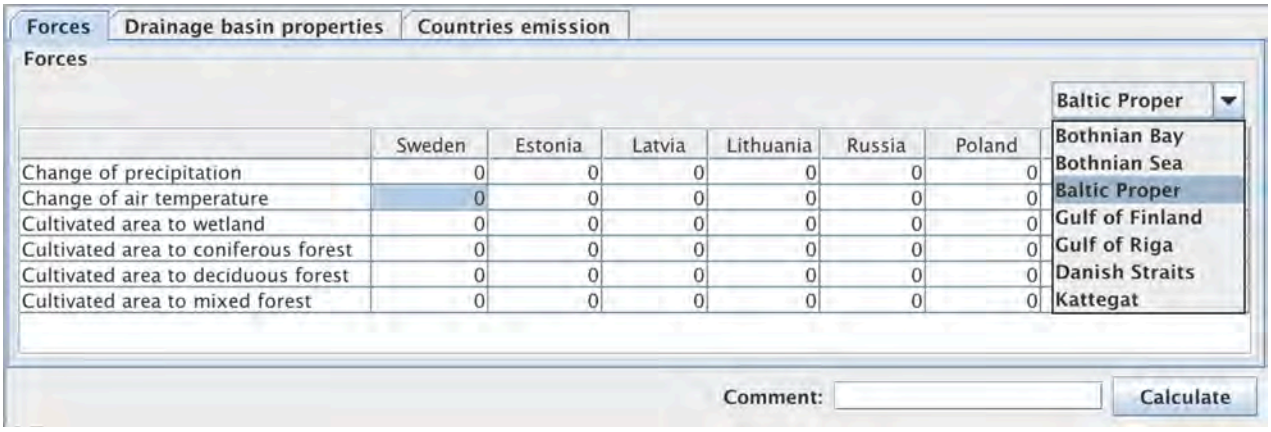
Measures to reduce loads to the Sea primarily occur on land. A model describing nutrient loads and how these are affected by changes in hydrology, land use including agriculture and sewage treatment is therefore necessary. The watershed model used in the Nest system here is the CSIM model of Mörth et al (2007), simultaneously simulating the nutrient land-sea fluxes from all 105 major watersheds within the Baltic Sea drainage area. This was used in the original BSAP calculations to calculate the effects of improved sewage treatment in the different countries on nitrogen and phosphorus loads. When you open up this interface you will see the following window:



To the left is a map of the Baltic region with the drainage basin, split into 105 sub-drainage basins (the same as in the *Catchment data* interface). To the right there are two panels; the top is used to set *Forces, Drainage basin properties* and *Countries emissions. T*he lower right panel will show *Result* from the calculations. A free-floating *Palette*, that can be placed anywhere on the screen, is also shown.

Forces

This panel can be used to change (in per cent) precipitation, air temperature and land use, for each of the nine countries bordering the Baltic Sea, as well as for each marine basin.



	Sweden	Estonia	Latvia	Lithuania	Russia	Poland
Change of precipitation	0	0	0	0	0	0
Change of air temperature	0	0	0	0	0	0
Cultivated area to wetland	0	0	0	0	0	0
Cultivated area to coniferous forest	0	0	0	0	0	0
Cultivated area to deciduous forest	0	0	0	0	0	0
Cultivated area to mixed forest	0	0	0	0	0	0

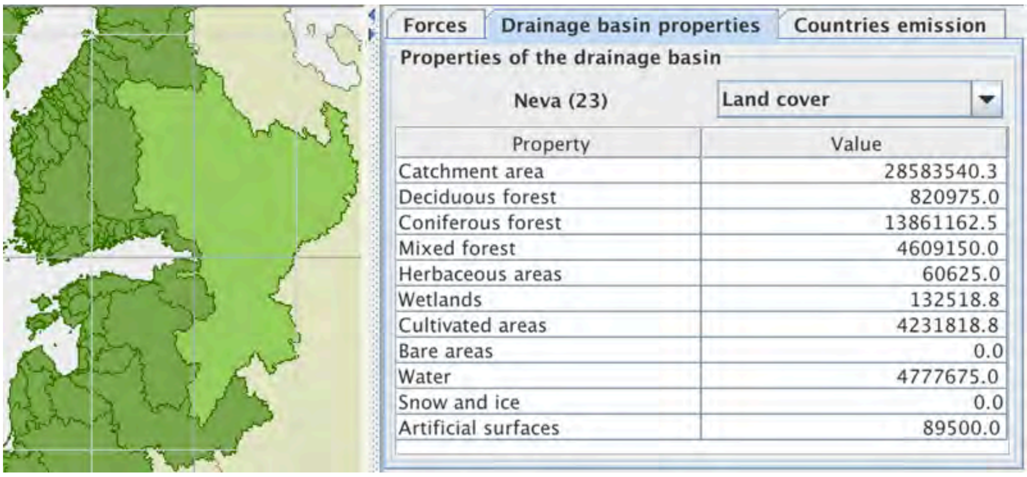
You can change, within a pre-defined interval, the default values by clicking on any of the numbers in the table.

Properties of the drainage basin

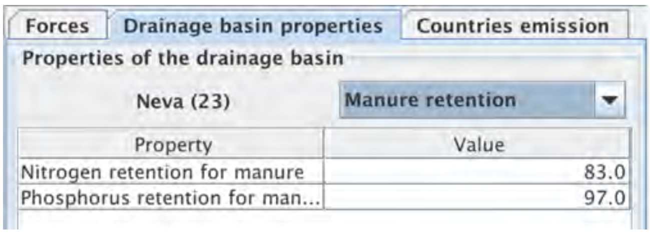
Here, you select any of the drainage basins on the map, by clicking on it, and a table is displayed showing the properties of that region. In the upper right corner you can choose between additional variables.

Property	
Catchment area	
Deciduous forest	
Coniferous forest	
Mixed forest	
Herbaceous areas	43.8
Wetlands	6837.5
Cultivated areas	96143.8

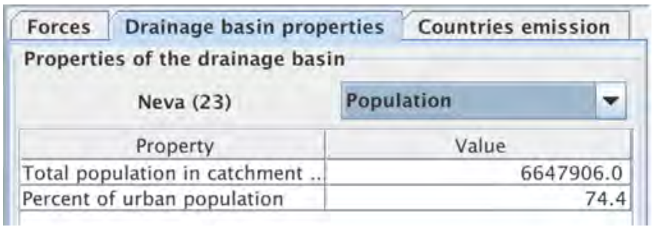
Below examples of the initial properties for the Neva drainage basin are shown.



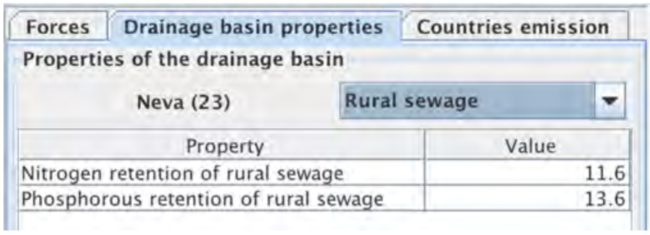
Property	Value
Catchment area	28583540.3
Deciduous forest	820975.0
Coniferous forest	13861162.5
Mixed forest	4609150.0
Herbaceous areas	60625.0
Wetlands	132518.8
Cultivated areas	4231818.8
Bare areas	0.0
Water	4777675.0
Snow and ice	0.0
Artificial surfaces	89500.0



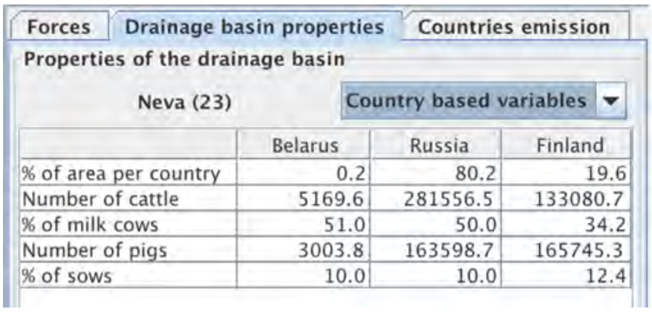
Property	Value
Nitrogen retention for manure	83.0
Phosphorus retention for man...	97.0



Property	Value
Total population in catchment ..	6647906.0
Percent of urban population	74.4



Property	Value
Nitrogen retention of rural sewage	11.6
Phosphorous retention of rural sewage	13.6

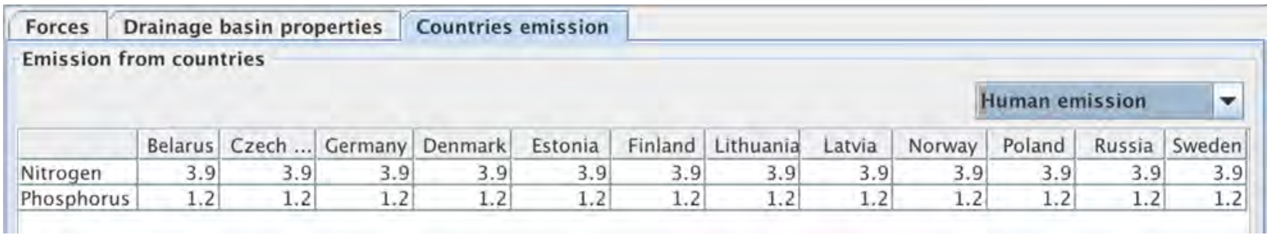


	Belarus	Russia	Finland
% of area per country	0.2	80.2	19.6
Number of cattle	5169.6	281556.5	133080.7
% of milk cows	51.0	50.0	34.2
Number of pigs	3003.8	163598.7	165745.3
% of sows	10.0	10.0	12.4

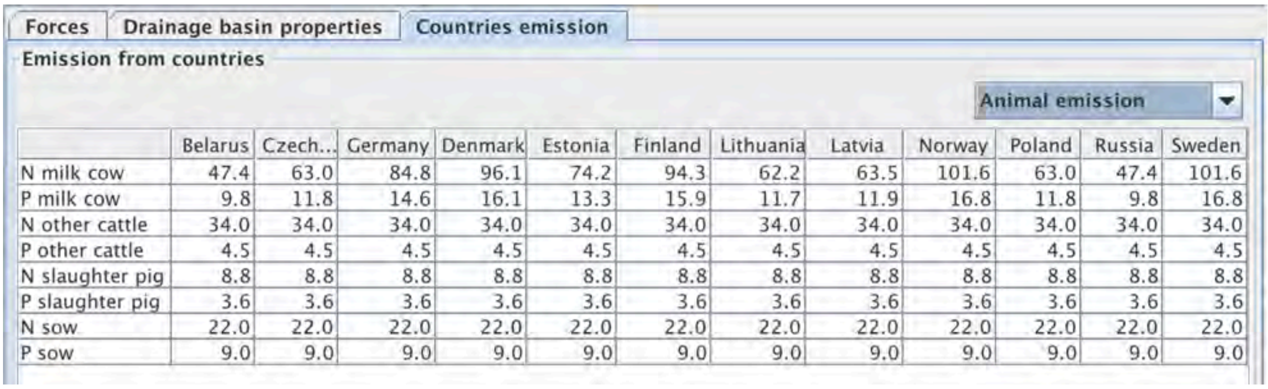
These are the default values. You can change any of these by typing in new values, except for land cover, which is static.

Countries emissions

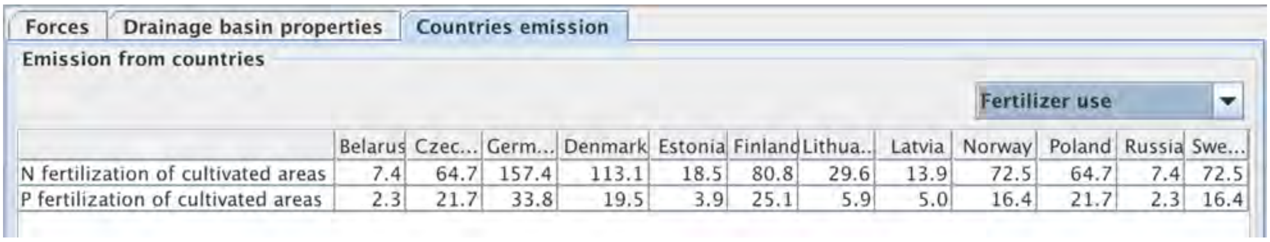
Here you can inspect and change a number of country specific variables, selectable in the upper right corner of the window. Each variable is explained in the lower left corner of the Nest main window.



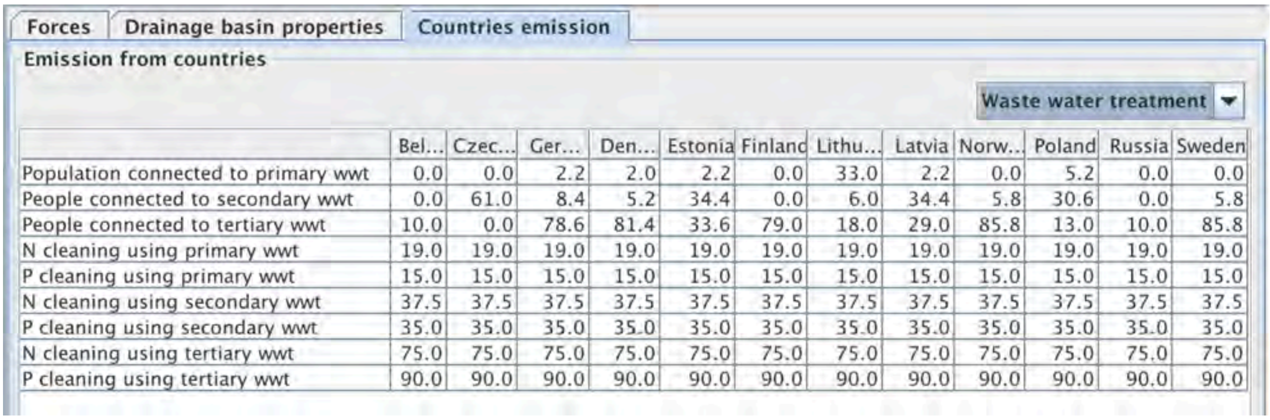
	Belarus	Czech ...	Germany	Denmark	Estonia	Finland	Lithuania	Latvia	Norway	Poland	Russia	Sweden
Nitrogen	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Phosphorus	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2



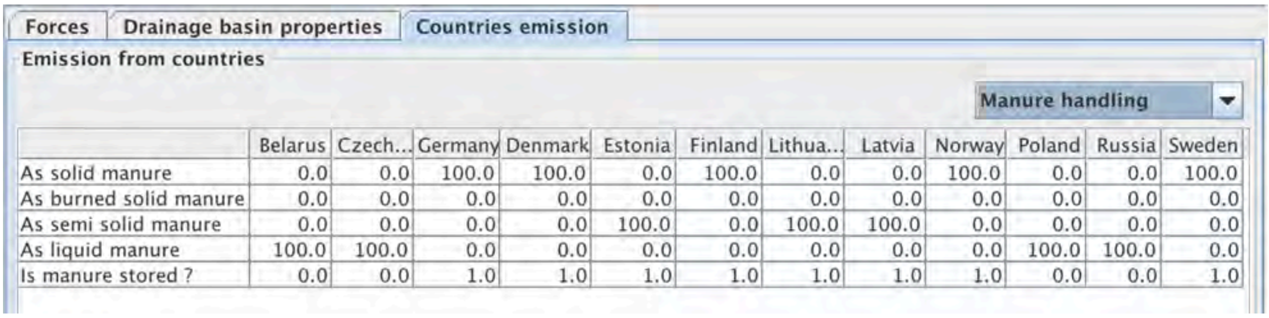
	Belarus	Czech...	Germany	Denmark	Estonia	Finland	Lithuania	Latvia	Norway	Poland	Russia	Sweden
N milk cow	47.4	63.0	84.8	96.1	74.2	94.3	62.2	63.5	101.6	63.0	47.4	101.6
P milk cow	9.8	11.8	14.6	16.1	13.3	15.9	11.7	11.9	16.8	11.8	9.8	16.8
N other cattle	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
P other cattle	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
N slaughter pig	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
P slaughter pig	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
N sow	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
P sow	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0



	Belarus	Czec...	Germ...	Denmark	Estonia	Finland	Lithua...	Latvia	Norway	Poland	Russia	Swe...
N fertilization of cultivated areas	7.4	64.7	157.4	113.1	18.5	80.8	29.6	13.9	72.5	64.7	7.4	72.5
P fertilization of cultivated areas	2.3	21.7	33.8	19.5	3.9	25.1	5.9	5.0	16.4	21.7	2.3	16.4



	Bel...	Czec...	Ger...	Den...	Estonia	Finland	Lithu...	Latvia	Norw...	Poland	Russia	Sweden
Population connected to primary wwt	0.0	0.0	2.2	2.0	2.2	0.0	33.0	2.2	0.0	5.2	0.0	0.0
People connected to secondary wwt	0.0	61.0	8.4	5.2	34.4	0.0	6.0	34.4	5.8	30.6	0.0	5.8
People connected to tertiary wwt	10.0	0.0	78.6	81.4	33.6	79.0	18.0	29.0	85.8	13.0	10.0	85.8
N cleaning using primary wwt	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
P cleaning using primary wwt	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
N cleaning using secondary wwt	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
P cleaning using secondary wwt	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
N cleaning using tertiary wwt	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
P cleaning using tertiary wwt	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0

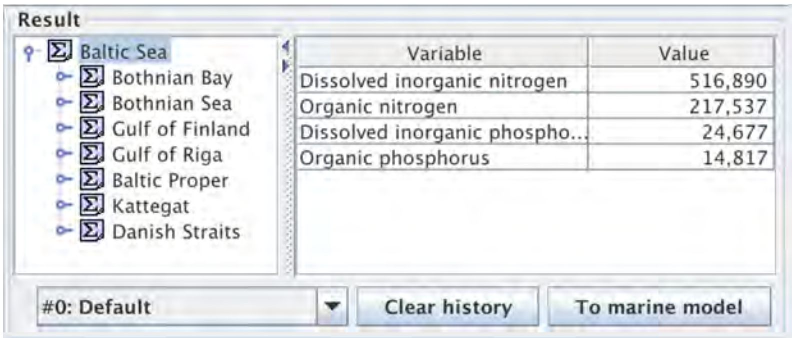


	Belarus	Czech...	Germany	Denmark	Estonia	Finland	Lithua...	Latvia	Norway	Poland	Russia	Sweden
As solid manure	0.0	0.0	100.0	100.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
As burned solid manure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
As semi solid manure	0.0	0.0	0.0	0.0	100.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0
As liquid manure	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0
Is manure stored ?	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0

Any of these values can be changed before you run any calculation, by pressing the *Calculate* button found below the tables.

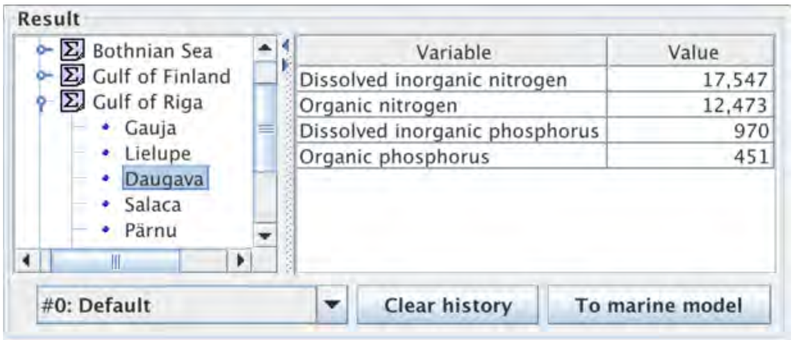
Calculate

Results, in terms of nutrient loads, are shown in the lower panel. Please remember to give the simulation a name in the *Comment* panel, before you press *Calculate*. The results can then be exported and used as nutrient *inputs to the marine model* (SANBALTS). If you press that button, the interface of the marine model is opened with the data you just calculated here. The results are shown in the marine model SANBALTS as riverine loads. Coastal points loads are set to zero, since this model doesn't distinguish between coastal point sources and riverine loads.

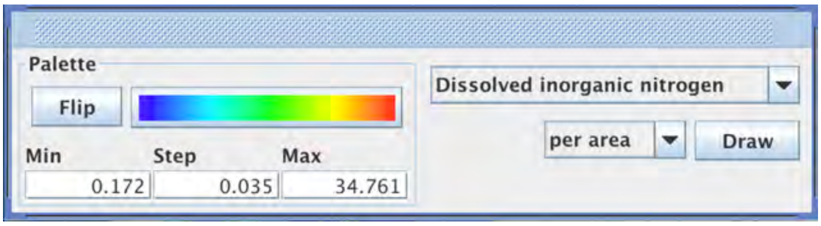


Variable	Value
Dissolved inorganic nitrogen	516,890
Organic nitrogen	217,537
Dissolved inorganic phospho...	24,677
Organic phosphorus	14,817

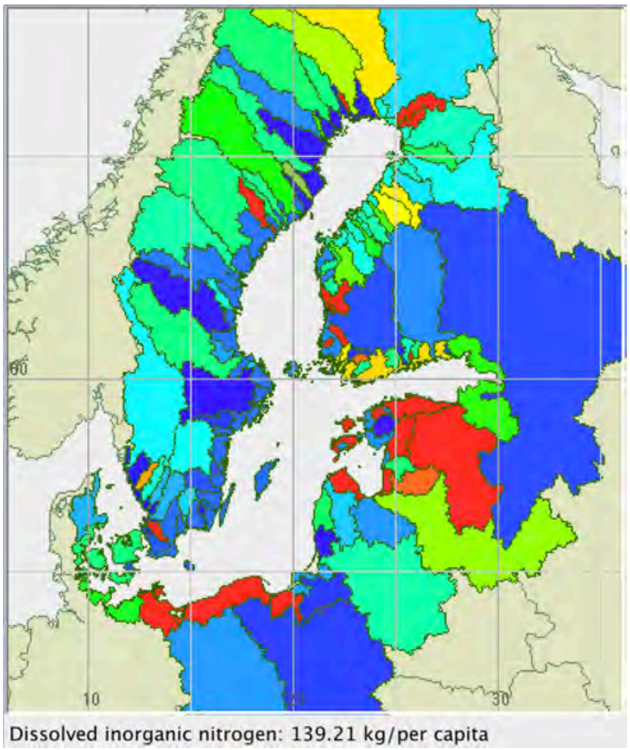
You can expand the resolution of the loads to drainage areas of marine basins or to singe river catchments in the same manner as in the *Riverine load* module. Just press the Σ icon.



To the right, the map will now display model-calculated concentrations of dissolved and organic nitrogen for all the 105 catchments, expressed per unit area or per capita. You can also change the color palette here.



Colors on the map represent the modeled results, which can also be seen in the lower left corner of the Nest main window by moving the cursor over the map.



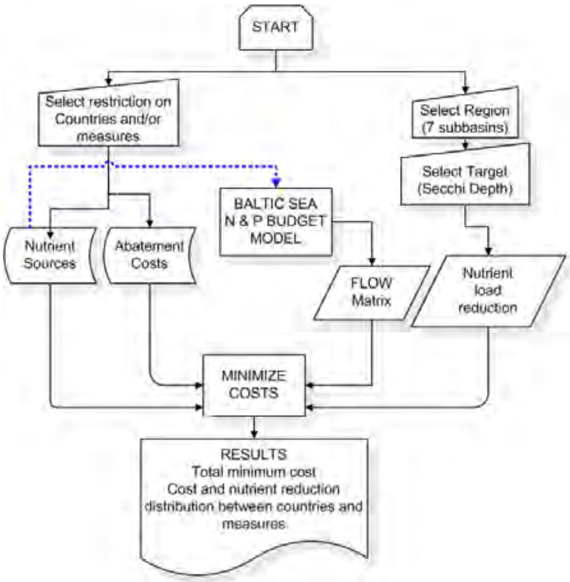
Literature

Mörth CM, Humborg C, Eriksson H, Danielsson Å, Rodriguez Medina M, Löfgren, S., Swaney, D.P., Rahm, L. 2007. Modelling riverine nutrient transport to the Baltic Sea – A large-scale approach. *Ambio* 36:119-28

Economy

Cost calculations

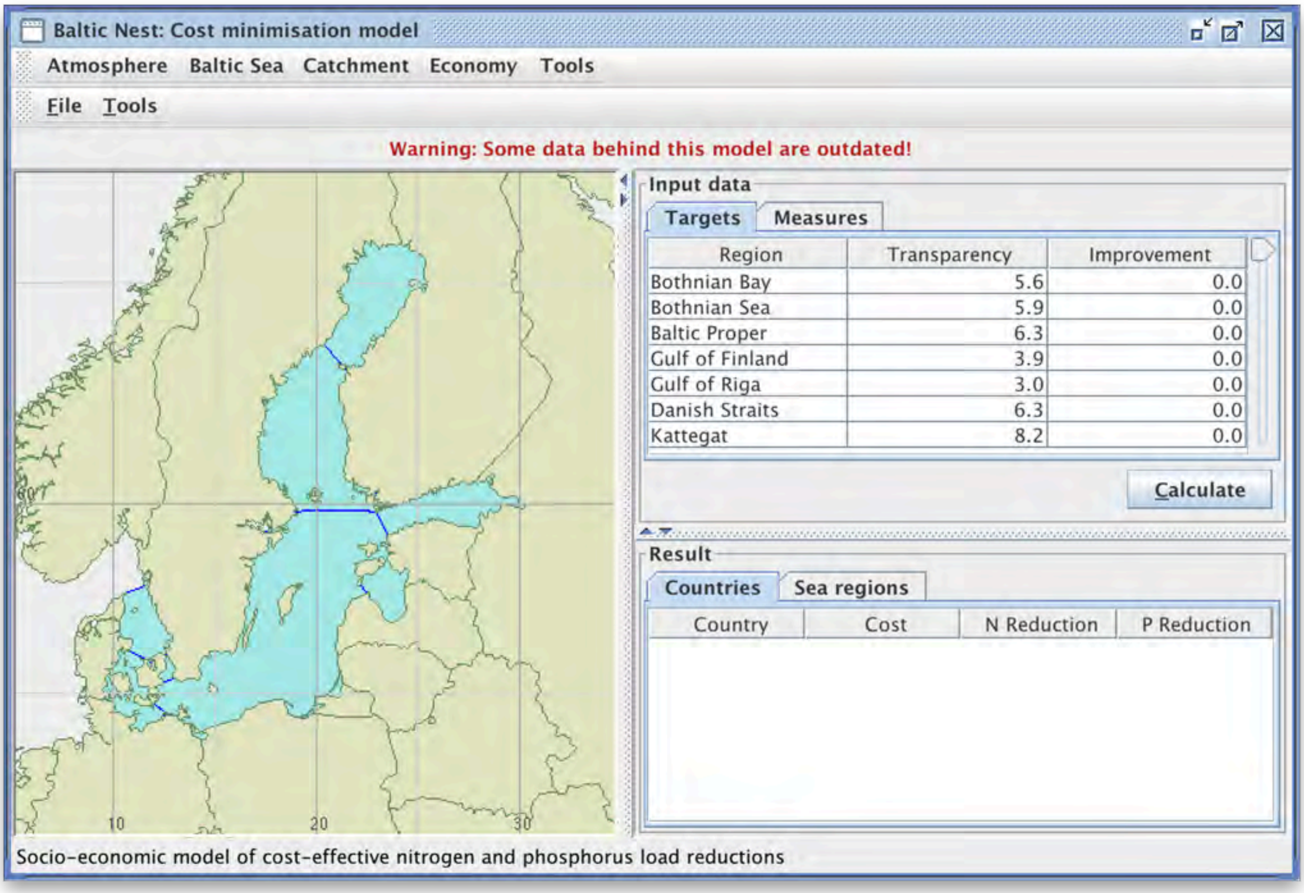
The costs for reducing nutrient loads to the Baltic are indeed large. However they are highly variable between different measures and between countries. It would undoubtedly be possible to reduce the total costs if the measures with the lowest costs were chosen. This cost calculation module provides a number of alternatives for calculating the most cost effective way to achieve a desired improvement in water transparency (Secchi depth, presently the only environmental target included). The basic logic is the following:



You are, in this module, primarily working in *Target* mode, i.e. you first set an environmental target - an improvement in water quality for one or several marine basins. You may also set restrains on what measures and what countries (and sub-drainage basins) that should be included. The model then calculates a minimum cost solution to reach this objective. You also have the option to change various parameters of the model and investigate whether these will affect the results.

The minimum-cost solutions are calculated from cost estimates of a number of different mitigation measures in a total of 23 catchments around the Baltic Sea, aggregated to a country-per-basin level. This module includes options to change various parameters and to exclude measures, as well as countries or sub-drainage basins in scenario analyses. However, the data behind these calculations are in many cases outdated and originate from the 1990-ties. Still, the model shows, in a qualitative sense, the effects of using cost minimizations for the distribution of measures between countries and stresses the strong interconnectivity of the regions.

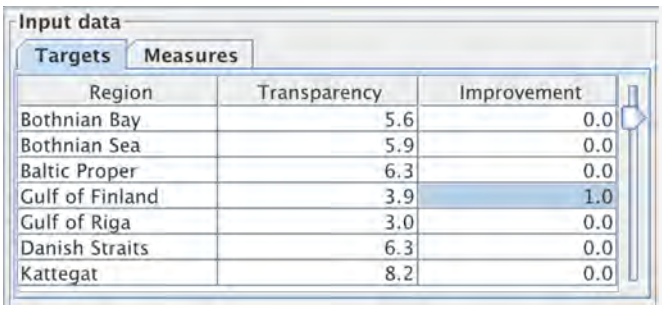
When you open the panel, you will see the following window:



To the left is a map showing the 7 major sub-basins of the Baltic Sea. To the right are panels for *Targets* and *Measures*, followed by a panel for *Results* below it. Please note the Warning: *Some data behind this model are outdated!*

Targets

Start by selecting a desired improvement in water transparency in one (or several) of the Baltic Sea basins. You do this by either typing a value of desired improvement into the cell, or by selecting the cell and then moving the slider to the far right. In the example below an improvement in the water quality in the Gulf of Finland by 1 meter has been selected.



Measures

Choose the combination of measures you would like to explore by deselecting the measures you want to exclude. These are aggregated in 7 major groups:

☐ Fertilizer use

☐ Sewage reduction

☐ NOx reduction

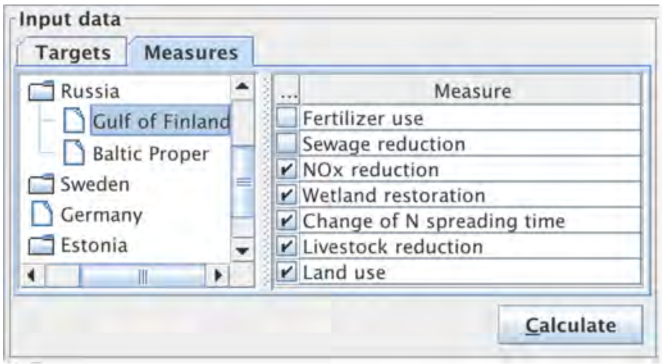
☐ Wetland restoration

☐ Change of N spreading time

☐ Livestock reduction

☐ Land use

You can also choose whether these measures should be taken in all countries around the Baltic Sea, or just in one or more countries. Countries, or specific sub-basins of that country, can be excluded by clicking and then deselecting all or some measures. In this case, fertilizer use and sewage reduction from Russia to the Gulf of Finland are excluded:



Calculate

If you click on the *Calculate* button, the cost-optimal solution is calculated. The *Countries* panel will show the costs distributed between countries, as well as the reduction in loads of nitrogen and phosphorus, expressed as per cent of current loads.

Result

Countries | Sea regions

Country	Cost	N Reduction	P Reduction
Total	38.8	5.8	0.7
Sweden	0.0	0.2	0.1
Finland	0.3	3.6	3.7
Russia	21.5	27.8	1.3
Estonia	11.8	20.4	3.3
Latvia	4.8	13.8	0.0
Lithuania	0.1	1.0	0.0
Poland	0.3	0.4	0.0
Germany	0.0	0.0	0.0
Denmark	0.0	0.1	0.0

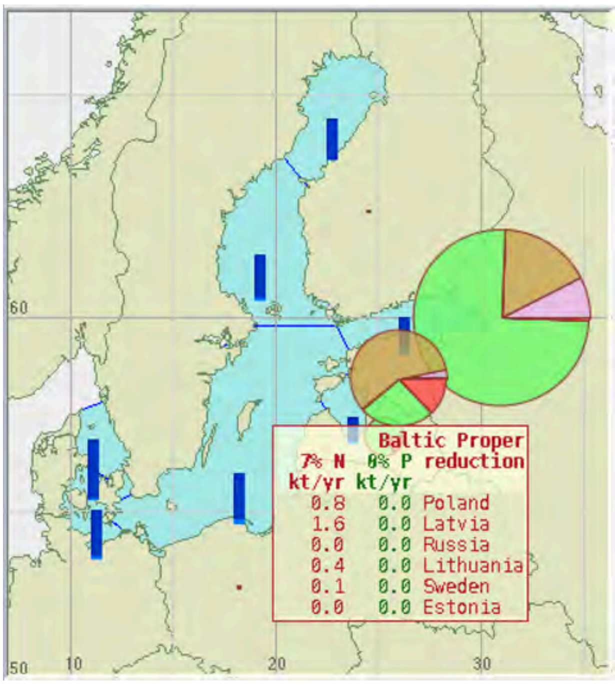
When you switch to the *Sea regions* panel you will see concentrations of nutrients, water transparency (Secchi depth) and improvements for all basins. Notice that conditions, in terms of water transparency, are improved in all basins, not only in the Gulf of Finland.

Result

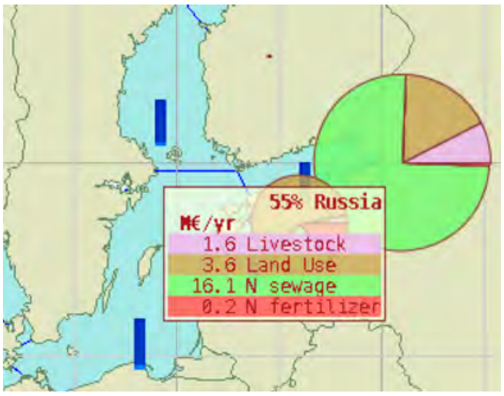
Countries | Sea regions

Region	Nitrogen	Phosphorus	Transparency	Improvement
Bothnian Bay	20.6	0.23	5.7	0.1
Bothnian Sea	18.4	0.45	6.3	0.4
Baltic Proper	20.3	1.04	6.9	0.6
Gulf of Finland	22.0	0.73	4.9	1.0
Gulf of Riga	31.4	0.97	3.6	0.6
Danish Straits	20.7	0.89	6.7	0.4
Kattegat	17.8	0.72	8.4	0.2

In the map panel, you will receive additional information. If you click on a basin, a table appears that shows nitrogen and phosphorus reductions to that specific basin.



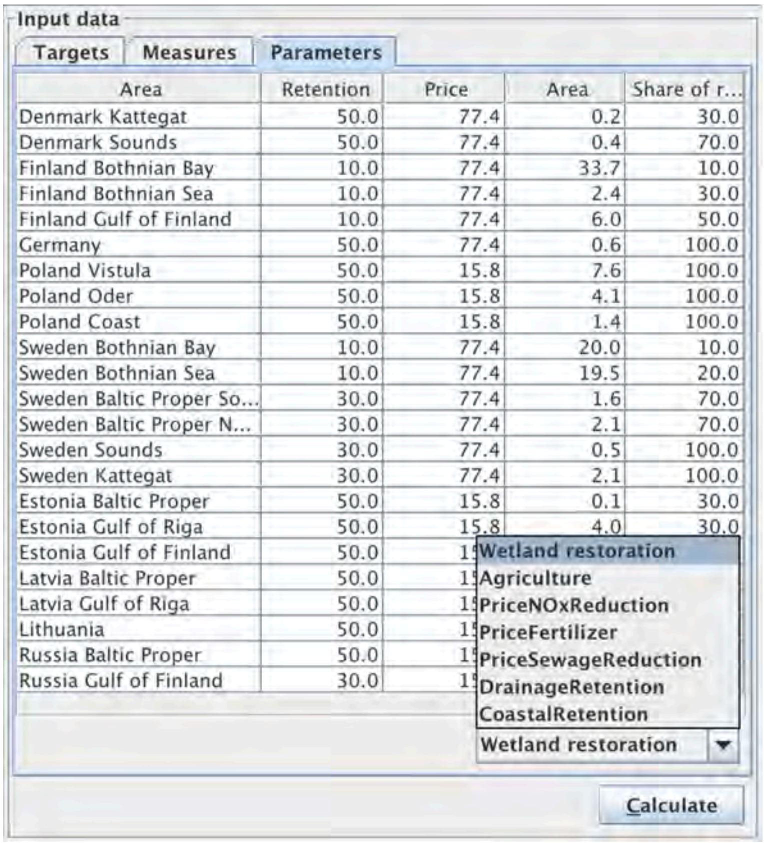
The blue bars show reference values (dark blue) and improvements (light blue) in water transparency in each basin (graphical presentation of the information from the *Sea regions* panel). The pie charts show where and how large the costs for nutrient reductions are. The size of the circles reflects the relative contributions to total costs. If you click on a country or a pie chart, you will see the distribution in M€ for different measures, in the minimum cost solution. In this case, 55% of the total cost will occur in Russia, with 16.1 M€ for additional reductions of nitrogen from sewage.



Please note that if you select too radical improvements it may generate infeasible solutions if the desired improvement cannot be achieved without measures being taken within a certain country or sector(s). For example, a large increase in transparency in the Gulf of Finland cannot be achieved without measures being taken in Poland. You will also receive a message if you choose an unrealistically large improvement of water transparency.

A more detailed choice of the parameters used in various measures can be found when you select *Expert mode* in the *Tools* menu (on the upper row). You will then see a third panel called *Parameters* in the *Input Data* panel.

The *Parameters* panel gives you the option to change a large number of parameters for all 23 sub-drainage areas. In the example below you can see the parameters that you can change related to Agriculture, after selection of this in the drop-down menu.



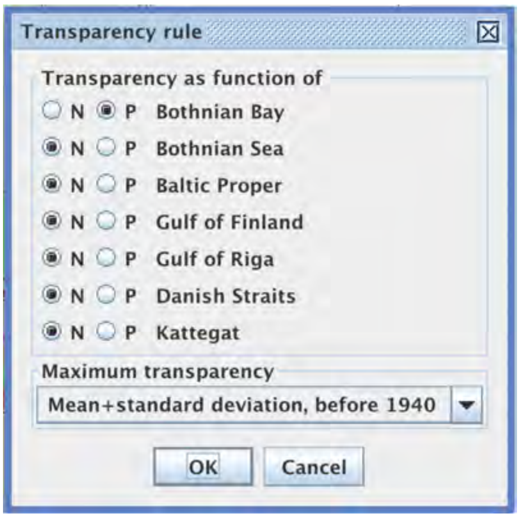
The meanings of all these parameters are explained in the lower left corner under the map.

In the *File* menu you have the options to store and read your own set of parameters from a file, or restore the default parameters.

In the *Tools* menu you can also see the effects of using the same parameter values for the larger regions, without having to key in each value separately. You select this by using *Set equal price*.

You will then see a new panel where you can select prices and regions as shown below:

It is also possible, in the *Tools* menu, to change which nutrient, nitrogen or phosphorus, that will affect water transparency (and productivity) the most when you change the loads.



You can also set a maximum transparency, i.e. you will limit the user possibility to increase these values to be within reasonable bounds; it is not possible to reach water transparencies similar to those in the blue Mediterranean Sea!

The basic assumption used in this context is that transparency is a function of the concentration of total nitrogen in all basins, expect for the Bothnian Bay, where it is determined by the concentration of phosphorous. You can change these assumptions using the "Transparency rule…" under *Tools*. The empirical relationships between concentrations of total nitrogen and water transparency have been determined using data from many years of monitoring in the Baltic Sea. Please also note that the values of water transparency given in Nest refer to the annual average transparency of seawater in the open sea.

It is also important to note that the concentrations of nitrogen and phosphorus are calculated independently of each other, which is of course not the case in nature. A linking of the two occurs in the marine model modules but is not yet implemented in the Cost model.

You will often see reductions in both N and P, since many measures will reduce the load of both nutrients.

Literature

Gren, I. - M. & F. Wulff. 2004. Cost-effective nutrient reductions to coupled heterogeneous marine water basins: An application to the Baltic Sea. Regional *Environmental Change* **4**(4): 159-168. (Online) DOI: 10.1007/s10113-003-0063-6

Gren, I. M., K. Elofsson and Jannke, P. 1997. Cost-effective Nutrient Reductions to the Baltic Sea. *Environmental and Resource Economics* **10**: 341-362.

Gren, I. M., Wulff, F. Turner, K.R. 2000. *Managing a Sea: The Ecological Economics of the Baltic.* London, Earthscan, 138 p.

Savchuk O.P. 2005. Resolving the Baltic Sea into seven subbasins: N and P budgets for 1991-1999. J. Mar. Syst., 56: 1-15.

Feedback from users of the Nest system is essential and very welcome!

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