

# IBAM: Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland

2<sup>nd</sup> year report (1.1.2010–31.12.2010, months 13–24)

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## 1. Work conducted in the project in 2010

### 1.1. WP 1: Geographical analysis of the spread of the common reed (*Phragmites australis*) in the Gulf of Finland

The general aim of WP 1 is to model the historical and future development of the common reed (*Phragmites australis*). The WP leader is Dr. Heikki Pitkänen (SYKE). The work conducted in WP1 in 2010 includes:

Task 1. Data collection. In 2009, altogether 7 data sets on reed coverage were found. Two locations in the Gulf of Finland, Svartbäck and Espoonlahti, were chosen for ArcGis-analysis: Svartbäck (2 data sets) was analyzed and delivered to TKK/Aalto University for geographical and historical modeling in 2009, and the corresponding results regarding Espoonlahti (2 data sets) in spring 2010.

Task 2. Modelling of the ecology of the common reed. The input for the spatial modeling on the ecology of reed and effects of reed productivity changes on littoral communities will be based on literature information (mostly compiled in 2010) and specialist interviews. The interviews are going on, and will be completed by March 2011. The predictive model on the ecological effects of the productivity changes of the common reed on the littoral community is done by the Aalto University. The selection of species and modeling the effects of reed on them is under process at the moment. Mostly the same species as in the OILECO and OILRISK projects will be used.

Task 3, spatial modelling of the common reed, can be broken down into three parts; study of the reed ecology (completed in the first year), analyses of the reed expansion factors, and building a simulation model.

With regard to the second part, three variables were found to be explanatory; depth of water, proximity to river outlets, and openness of the sea. The correlation of each variable and the density of reed settlements in a given location were examined, using the available data sets. Although the association hypothesis was built on a solid understanding of reed ecology, the distance to river outlets was the only variable to yield a significant correlation coefficient at first. The available data sets of bathymetry (a digital depth model (DDM) of 100 m resolution) and openness (determined geometrically based the abstraction of fetch lines) were considered for refining. A new 5m-cell DDM was interpolated for Svartbäck and Espoonlahti sites using available records of water depth at some locations in the sea together with the shoreline and few contours on the land. In addition, the Wave Exposure Model (WEMo)<sup>1</sup> was used to produce openness estimation for sea areas taking into account, along with the fetch lines abstraction, the detailed interpolated bathymetry as well as the exceedence wind speed and direction. The analysis results of the new data sets seem to agree more with the association assumption and, therefore, can be used to derive more accurate rules for the Cellular Automata (CA) model.

The other fold of the analyses of reed expansion is the neighbourhood analysis. Historical reed coverage data sets were used for this purpose; 2003 and 2006 coverage for Svartbäck site, as well as 1979 and 1999 coverage for Espoonlahti. The reed coverage from different years were combined and compared to the neighbourhood status for every location (cell) within the two study sites. Additionally, the analysis was repeated for different scale configurations (cell size and neighbourhood size). In line with the hypothesis of reed expansion mechanism, the results of the analyses revealed a strong association between the presence of reed in a cell and the susceptibility of the surrounding cells. The derived neighbourhood rules were therefore provided as distribution functions linking the probability of reed expanding/disappearing into/from a cell to the status of its neighbouring cells.

Regarding the third part, a CA model was developed using Python, numeric Python, and GDAL libraries. In its current stage, the model reads a raster grid of reed coverage, apply the neighbourhood rules to determine the initial grid for the next iteration, and writes the results of every iteration into raster grids representing the predicted reed coverage for the corresponding iteration (year). Rules from the other aforementioned explanatory variables are still to be incorporated in the model, for which the work is still in progress.

Task 5. Impacts of productivity changes of the reed on other species and on private properties. The work has been started in the beginning of 2011.

### *1.2. WP 2: Herring fisheries analysis by Bayesian quotas and by stakeholder specific risk models*

WP 2 concentrates on developing an alternative for the current TAC policy in the EU. The WP leader is prof. Noël Holmgren (US).

The herring is managed today by target fishing mortality  $F_{MSY}$ , the fishing mortality that results in a Maximum Sustainable Yield (MSY). We have calculated target fishing mortalities using the operative model (constructed in 2009), depending on the state of the cod stock and the food-availability (controlled by salinity and/or sprat competition; task 2). The cod stock and food availability have exhibit large variations over the last 35 years. Some scientists claim that there has been a regime shift in the Baltic ecosystem. For the herring, the food-availability dropped dramatically, causing a rapid halving of the weight-at-age (WAA) from 1987-1990. The significance of this drop in WAA for setting a management target has during the project turned out to be more prominent. We therefore had to devote more time to model weight dynamics than said in the original plan.

We have developed a management tool for setting state-dependent targets of  $F_{MSY}$ . We have applied it to historical data, which shows an over-fishing that began as a result of the regime shift in the Baltic. The market value of the net loss in yields is € 11-22 Billion compared to estimated yields applying the tool. The tool can be immediately useful for the ICES working group on the Baltic (WGBFAS). We will present the results to the WGBFAS during their annual meeting in April 2011. Members of the WP2 has participated in the meeting since the project start, and presented the research plans in 2009.

Research results showed that the uncertainty is an endemic condition of the Baltic Sea herring fishery management, first of all, being behind of the biological foundations of the management measures taken during the last decades. The scientific discussion on how best to establish the Baltic Sea herring assessment and management units in accordance with assumed different number of spawning components of this fish has been heated and many approaches have been taken over the years. Although, there is a number of studies published on the Central Baltic Sea herring recruitment-environment relationship and on substantial decrease in growth rate of the herring that has been observed since the beginning of the 1980s the casual links of these phenomena are still insufficiently understood. Despite of in-depth studies into the structure of the Baltic Sea clupeid fish otoliths the ageing of these fishes is still far too uncertain. The problem of the Baltic Sea herring's unaccounted fishing mortality caused by the fish selection through the trawl net has attracted attention of scientists and managers since 1990s but it is still not solved. A review of recovery of the depleted Baltic Sea fish stocks, including the Central Baltic Sea herring, showed that for all internationally regulated fish stocks the Total Allowable Catches (TACs) have been set systematically more than the scientific advice based on sustainable exploitation and this phenomenon is considered as the regulatory overfishing.

Fishing fleet overcapacity is generally considered to be a major cause of persisting overfishing, because it creates a strong incentive to catch more than is allowed and it undermines the control and enforcement efficiency. The Bayesian Belief Networks (BBNs) are used to communicate the major sources of uncertainty related to the management of the Central Baltic Sea herring fishery. Two scenarios for the Central Baltic Sea herring fishery management options are constructed and the Bayesian networks are used to represent and update uncertainties encountered in the process of the management related situation assessment. First scenario represents the current status of the fishery management under overcapacity conditions resulting in fishing mortality higher than  $F_{MSY}$ . The second scenario demonstrates the assumed potential impact of economic incentives (e.g. zoning, individual transferable quotas (ITQs), territorial use rights etc) on the reduction of excessive fishing capacity and bringing fishing mortality closer to  $F_{MSY}$ .

Studies on participation modeling are focused on the Baltic Sea Regional Advisory Council (BS RAC) related participatory processes. BS RAC's documentation is used to extract the argumentation of the fishing industry, NGOs and the other stakeholders involved. The Bayesian networks are used to construct the model of the BS RAC's decision making process and to communicate the related uncertainty. The BS RAC was set up in March 2006 with the aim to contribute to sustainable use of the Baltic Sea fishery resources under EU Common Fisheries Policy. The BS RAC is modelled as an international boundary organization mixing scientific and political elements, and mediating between the science institutions, fisheries' associations, producer organizations, processors, market organizations, environmental NGOs, aquaculture producers, consumers, women's networks and recreational and sports fishermen, and the institutions of politics. The boundary work of the BS RAC in balancing of stakeholder's interests when transforming the science-based advice into agreed management recommendations is considered to be an important element in setting the Baltic Sea Total Allowable Catches (TACs). Furthermore, the BS RAC acts as facilitator of dialogue between fishing industry, scientists and

decision makers to encourage research agendas that reflect the interests and needs of fishing industry.

### *1.3. WP 4: Development of the decision support system (DSS)*

The main aim of WP4 is to develop a decision support system (DSS) that can be used to analyze the risk management of four themes: climate change, eutrophication, oil spills and harvesting. The WP leader is prof. Ari Jolma (Aalto).

In WP 4.1, the development of the integrative model to be included in the DSS was continued as well as the work concerning the population submodels to be integrated into the final model. The common eider submodel was developed further and the effects of historical harvest rate and potential oil spills were examined. The population dynamics model is state-structured and encompasses the life stages of eiders both in Finland and Denmark. Birds are assumed to nest in the Gulf of Finland and winter in the Danish waters. The data used in population modelling consists of nest counts conducted in 1948–2005 in Söderskär, a bird sanctuary located in outer archipelago in the central Gulf of Finland. Harvest is assumed to diminish the number of birds at the beginning of each transition, and oil spills in the Gulf of Finland are assumed to affect breeding adults and recruits or breeding adults, recruits and fledglings, depending on the timing of the accident. Posterior distributions for model parameters were estimated using Markov Chain Monte Carlo (MCMC) simulation techniques. Preliminary results suggest that oil spills happening in spring or summer have a more severe effect on the population than spills happening in autumn, but the population will probably recover within 10 years. However, the recovery is much more uncertain, if harvest rates increase.

In addition, the work carried out in WP4 includes:

Task 1. Updating the current estimates of future eutrophication and implementation uncertainty of actions. The calibration of EIA-SYKE ecosystem model was continued and the different modeling scenarios to be used in the further work were decided. The final scenarios for the Bayesian analyses will be produced in spring 2011. The work also includes uncertainty analysis of the modeling.

Task 3. Transferring knowledge from simulation model outputs. The work in this task is led by UH and Aalto is expected to provide technical expertise. However, little work done in Aalto can be assigned to this task.

In addition, the work with managing knowledge in Bayesian networks (task 4) was carried out. The information and knowledge developed within the project will be stored in the form of Bayesian networks. The Bayesian networks will thus form the central knowledge base of the DSS to be developed. Also, inference with Bayesian networks will be the central tool behind the decision support in the DSS. Within this task the technical capability to manage Bayesian networks in an Internet server computer has been developed.

The following specific activities have been carried out:

- A subversion repository and version control system for IBAM models was set up at server [geoinformatics.tkk.fi](http://geoinformatics.tkk.fi), which is owned by the Aalto research team.

- A SQL database structure for storing Bayesian networks was developed and a database using this structure was set up in [geoinformatics.tkk.fi](http://geoinformatics.tkk.fi).
- The research team in Aalto University acquired a licence for a HUGIN Bayesian network engine (library) and software development kit.
- A foreign function interface (FFI) for this library for the Perl programming language, which is a popular and powerful programming language for web development, was developed.
- Using the Perl FFI to HUGIN three applications were written:
  - an application to store a Bayesian network to a database,
  - an application to retrieve a Bayesian network from a database, and
  - an application to create a web site from a Bayesian network.

Besides these technological steps, some advances were made in the overall DSS design. However, they remain mostly to be done in tasks 5 and 6. The websites that have been created as a part of this task use a secure protocol and require a valid username/password pair.

Task 6. Integration of the DSS. The work will be carried out in summer/autumn 2011.

#### 1.4. *WP 5: Management and dissemination*

The management and dissemination of the project has been conducted by the coordinator and other partners. The following activities were carried out in 2010:

The following official project meetings were held in:

- 4<sup>th</sup> meeting: Vilnius, Lithuania, UTartu, 19 January 2010
- 5<sup>th</sup> meeting: Helsinki, Finland, SYKE, 17–18 March 2010
- 6<sup>th</sup> meeting: Helsinki, Finland, UH, 7–8 September 2010

Also several Skype meetings were held.

The presentations/posters on the project work held at international conferences/workshops include:

- “Bayesian approach as a collective learning tool”, BONUS Annual Conference 2010, Vilnius, Lithuania, 19–21 January 2010 / Sakari Kuikka (UH)
- “Updating the 3D Baltic Sea biogeochemical model for better estimates of future management actions”, BONUS Annual Conference 2010, Vilnius, Lithuania, 19–21 January 2010 / Heikki Pitkänen (SYKE)
- “Managing systems of uncertain states - the case of fisheries”, BONUS Annual Conference 2010, Vilnius, Lithuania, 19–21 January 2010 / Niclas Norrström (US)
- “Spatiotemporal modeling of the common reed on the Finnish coast”, a poster, BONUS Annual Conference 2010, Vilnius, Lithuania, 19–21 January 2010 / Anas Altartouri (Aalto)
- “Consensus building as an element of science-policy co-production”, a poster, BONUS Annual Conference 2010, Vilnius, Lithuania, 19–21 January 2010 / Robert Aps (UTartu)

- “Spatiotemporal modelling of the spread of common reed on the Finnish coast”, International Congress on Environmental Modelling and Software, iEMSs 2010, Ottawa, Canada, July 5–8 2010 / Anas Altartouri (Aalto)
- “From population modeling to management: Integrating different risk factors affecting a seabird living in the Gulf of Finland, the Baltic Sea”, ICES Annual Science Conference 2010, Nantes, France, 20–24 September 2010 / Inari Helle (UH)
- Talk on reed modeling, International Symposium on Advanced Methods of Monitoring Reed Habitats in Europe, Illmitz, Austria, 25–26 November 2010 / Ari Jolma (Aalto)

Five manuscripts have been produced for publication:

- Aps, R., Fetissov, M., Holmgren, N., Norrström, N. & Kuikka, S. Central Baltic Sea herring: effect of environmental trends and fishery management. – In C. Brebbia (Ed.) Ecosystems and Sustainable Development, WIT Press. In press.
- Uusitalo, L., Kuikka, S., Kauppila, P., Söderkultalahti, P. & Bäck, S. 2011. Assessing the roles of environmental factors in coastal fish production in the northern Baltic Sea: A Bayesian network application. – Integrated Environmental Assessment and Management. In press.
- Helle, I., Lecklin, T., Jolma, A. & Kuikka S. 2011. Modeling the effectiveness of oil combating from an ecological perspective - A Bayesian network for the Gulf of Finland; the Baltic Sea. – Journal of Hazardous Materials 185(1):182-192.
- Levontin P., Kulmala S., Haapasaari P. & Kuikka S. Integration of biological, economic and sociological knowledge by Bayesian belief networks: the interdisciplinary evaluation of potential Baltic salmon management plan. – ICES Journal of Marine Science. Accepted.
- Lehtikoinen, A., Klemola, E., Mäntyniemi, S. & Kuikka, S. 2010. Probabilistic assessment tool for Water Framework Directive – application to the Gulf of Finland. – ICES ASC, Nantes, France, CM2010/B:12.

Other relevant presentations and stakeholder meetings related to IBAM work include:

- “How to handle uncertainty in future projections?”, Uncertainties of scenario simulations workshop, SMHI, Norrköping, Sweden, 14 October 2010 / Samu Mäntyniemi (UH)
- “Reversing the Burden of Proof in Fisheries: Methodological Challenges”, ICES ASC, Nantes, France, September 2010 / Sakari Kuikka (UH)
- “Experiences in applying BN to fisheries and environmental management support”, CEFAS, UK, June 2010 / Sakari Kuikka (UH)
- “Baltic Sea fishery management: Bayesian uncertainty communication”, Uncertainties of scenario simulations workshop, SMHI, Norrköping, Sweden, 14 October 2010 / Robert Aps (UTartu)
- Participation in WGBFAS (ICES) annual meeting in April 2010 / Robert Aps (UTartu)

## 2. Comparison with the original research and financial plan

WP 1: Task 1 was completed in May 2010 (original plan: June 2009). A part of the financing planned to be used in 2009 was used in 2010.

Task 2, modeling the ecological effects of the productivity changes of the common reed on the littoral community, is still going on (original plan: second half of 2009). The work will be finalized during the first half of 2011. The allocated financing is used in 2010 and 2011 instead of 2009. It is probable, that results of ecological modelling are spatially too rough to be directly used in the analysis of likely nutrient conditions for reed.

Task 5. The work has been started according to the schedule of the research plan.

WP 2: For US: The BONUS source has been under-utilized with € 3 500 compared to the budget for 2010. In 2009, however the BONUS source was over-utilized with € 10 000. US has financed less than budget so far, but will compensate for this during 2011 enabling the project to stay on budget.

For UTARTU the travel costs are overspent. In order to correct the situation UTARTU approached BONUS EEIG and received the approval for moving appropriate funds from the personnel costs to travel costs. Thus, balance will be reached by the end of the 2011.

WP 4: Task 1. Scenario modelling is clearly late compared with the original schedule, and will be completed during spring 2011.

WP 5: There are no deviations in the management plans. The financial plan is somewhat underutilized due to the family leave of Dr. Laura Uusitalo.

These minor differences between the original research plan and the realization have been acknowledged and the corresponding adjustments to the Gantt chart will be done.

## 3. Changes in research plan and/or deliverables

Deliverable	Type	Content	Due month
2.1	MS	Herring fisheries analysis by Bayesian quotas and by stakeholder specific risk (T2.3; US)	36
2.2	MS	The effect of the environmental trends and fishing on Baltic herring (T.2.5; UTARTU)	20
2.3	MS	Stakeholder modeling (UTARTU)	30
2.4		WP 2 outputs reported to the ICES WG BFAS, to be incorporated into ICES draft advice (UTARTU)	36

Deliverable 2.1 is continuing according to plan. We do not intend to make the comparison between areas of the Baltic, but rather put effort into make a more full management strategy

evaluation. For this purpose NN participated in the ICES course on stock assessment (introduction) in June to learn the current stock estimation methods.

Deliverable 2.2 - article manuscript (T.2.5) on the effect of the environmental trends and fishing on Baltic herring was accepted for the Eighth International Conference on Ecosystems and Sustainability (11-13 April 2011, Alicante, Spain) and for publication in the peer reviewed Conference Proceedings.

Deliverable 2.3 Article manuscript (T.2.9) on stakeholder modeling is under preparation and it is expected to be submitted for publication in due time.

Deliverable 2.4 is planned to be delivered at the WGBFAS (ICES) annual meeting in April 2011.

#### 4. The influence of third parties on the working program

No results of third parties will have influence on the working programme.

#### 5. Expected changes in the working plan or deliverables

There are no major changes to be expected in the work plan or in deliverables. At the moment it seems that some of the modelling results will be delayed during the spring 2011, which leaves a relatively short period for 2011 to complete the model and to carry out the deliverables of WP4.2 (D9 and D10).

#### 6. Links to other projects

Suomenlahden rehevöitymisen hallinta (SUHA) –project ("Controlling the eutrophication in the Gulf of Finland"), funded by Ministry of the Environment, Finland. The project calibrated the SYKE-EIA 3D physical-biogeochemical model to a new five year period, which will be used to update the estimates on future eutrophication in IBAM.

PROBAPS - Protection of the Baltic Sea: Benefits, costs and policy instruments. EIA-SYKE –model is used also in the scenario work of this project. PROBAPS will continue with the IBAM model by adding the costs of management actions to the model.

#### 7. Top 3 highlights of 2010 for the project

- Publication of the book "Itämeren tulevaisuus" by Gaudeamus, where Sakari Kuikka, Inari Helle and Heikki Pitkänen were authors in three sections, and the selection of the book as a candidate for "Tieto Finlandia" award in Finland.
- Organizing of the theme session P: "Reversing the burden of proof in fisheries" in ICES ASC by Sakari Kuikka, Doug Wilson and Paul Degnpol as conveners.
- Developing a method to set  $F(MSY)$  for the Baltic herring.