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Research, part of a Special Feature on A Systems Approach for Sustainable Development in Coastal Zones

Participatory Social-Ecological Modeling in Eutrophication Management: the Case of Himmerfjärden, Sweden

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ABSTRACT. Stakeholder participation is increasingly seen as central in natural resource management. It is also required by the European Union Water Framework Directive, which identifies three levels of participation; information, consultation, and active involvement. In this paper we discuss the active involvement of stakeholders, using our experience from a case study in the Himmerfjärden region, which is a coastal area southwest of Stockholm, Sweden. Our study used the systems approach proposed by the European Union research project called Science and Policy Integration for Coastal System Assessment (SPICOSA), in which local stakeholders and a study site team constructed an integrated simulation model of a crucial coastal management issue. In this case the issue was nitrogen enrichment. We showed how stakeholder participation in the modeling process helped identify interesting and currently relevant management scenarios, and how the modeling process facilitated communication of the likely ecological, economic, and social effects of these scenarios to the stakeholders. In addition, stakeholders also reported social gains in terms of network building. We managed to actively involve local stakeholders in water issues, and the research process clearly strengthened the social capital in the Himmerfjärden region, and created a basis for future collaboration regarding water management. Our experience indicates that the approach we tried is a useful tool for promoting active stakeholder involvement in water management projects. Also, the results of our science and policy integration approach indicated that the study site team assumed a leadership role, which is a commonly recognized factor in successful natural resource management.

Key Words: *adaptive management; Baltic Sea region; coastal eutrophication; Himmerfjärden; integrated modeling; social-ecological modeling; SPICOSA; stakeholder participation; Water Framework Directive; water management*

INTRODUCTION

Water management is a very important issue in most societies and is essential for creating sustainable social-ecological systems. It concerns many people in various ways, making stakeholder participation and collective actions important in water management. Stakeholder participation is increasingly seen as central in natural resource management (Human and Davies 2010), for at least three reasons. It can (1) enhance democracy, as emphasized in the Aarhus Convention (1998); (2) lead to agreed policies becoming more socially accepted (Visser 1999); and (3) strengthen locally evolved institutions that are adapted to the specific social-ecological context (Ostrom 1990).

The European Union's recommendation on Integrated Coastal Zone Management (European Parliament 2002) and its Water Framework Directive (European Parliament 2000) emphasize the role of stakeholder participation as key for successful implementation of sustainable water management. The Water Framework Directive aims to achieve good water quality in all inland and coastal waters by 2015. It identifies three levels of public participation: (1) information, (2) consultation, and (3) active involvement (European Commission 2003). Active involvement means that stakeholders are engaged in water management—for example, by developing action plans or commenting on management plans proposed by authorities. This level of participation is the focus of this paper and is of special interest because it calls for innovation and for new practices and institutions to emerge (Kaika 2003). We used a systems approach of integrating science and policy in a process that involved coastal stakeholders in water quality management (Hopkins et al. 2011). This gave us the opportunity to study the process of stakeholder involvement, and also created a potential for stakeholders to collaborate beyond the end of the project.

From 2007 to 2010 we conducted a study in the coastal region Himmerfjärden, southwest of Stockholm, Sweden, as part of the European Union's funded research project called Science and Policy Integration of Coastal System Assessment (SPICOSA) (Hopkins et al. 2011). During our study, we collaborated closely with a local stakeholder group to develop a simulation model for assessing policy options for eutrophication management in the Himmerfjärden coastal region. The model also served as a tool for communicating ecological, economic, and social effects to stakeholders. In this paper we explore the possible advantages and complications of the science and policy integration approach that we used, i.e., concerning (1) the effects of stakeholder participation on the modeling process and results, and (2) evidence of knowledge gains and social gains by stakeholders. Further, we discuss the roles of science and policy integration

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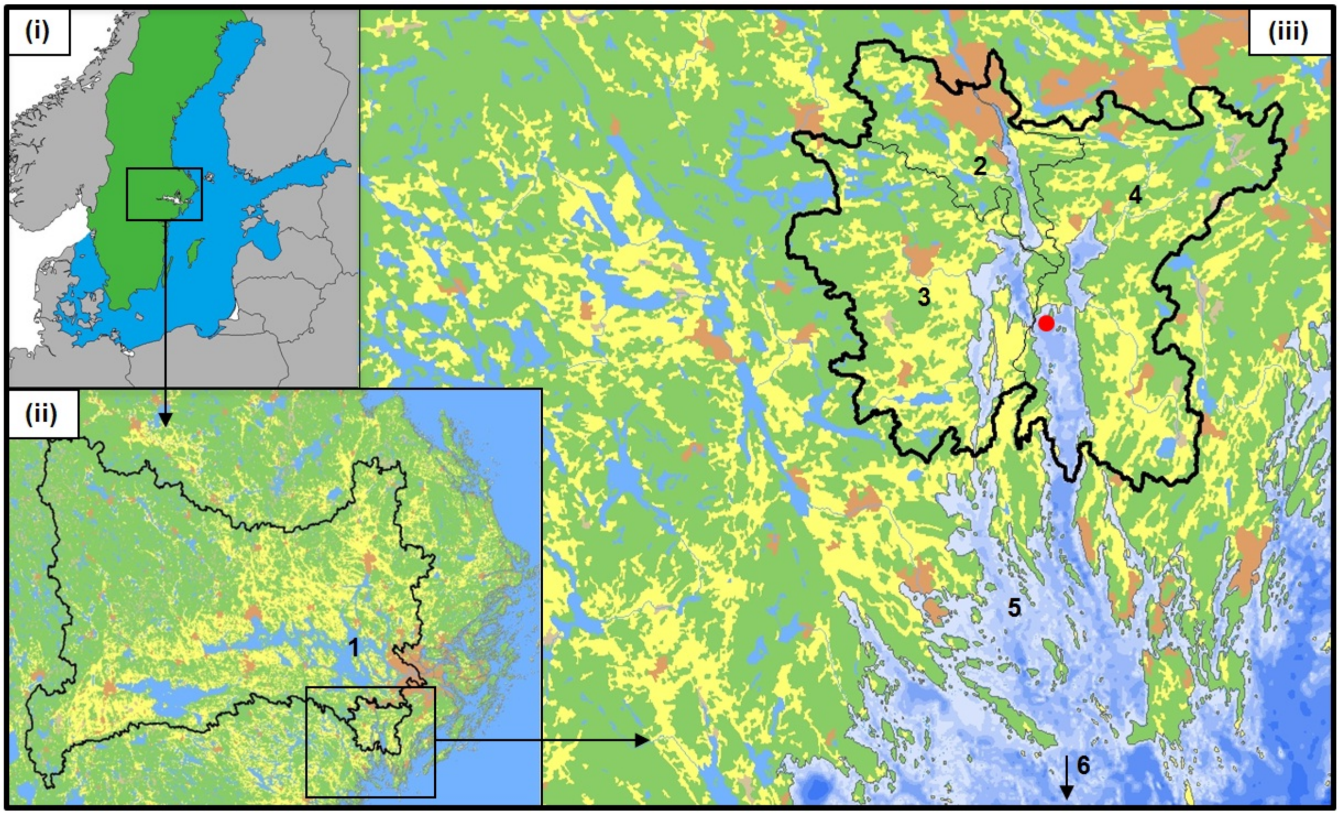
Fig. 1. Location of the study site: (i) Sweden, located in the Baltic Sea; (ii) the Swedish Northern Baltic Sea River Basin District, including Lake Mälaren (1); and (iii) the Himmerfjärden study site area; divided in the model areas “Hallsfjärden” (2), “Näslandsfjärden” (3), and "Himmerfjärden proper" (4). Via "Svärdsfjärden” (5) the study site area is connected to the open Baltic Sea (6). The red circle in "Himmerfjärden proper" is the discharge point of the Himmerfjärden sewage treatment plant. The colors in the study site map indicate: blue = water (dark is deeper for marine areas), green = forest, yellow = arable land, orange = urban area. ©Lantmäteriet, permission I 2011/0094



in relation to factors for successful natural resource management, such as social learning, social capital, and leadership.

Natural resource management can be seen as a learning process in which stakeholders should be given the opportunity to express their opinions and to exchange ideas and knowledge (Mostert et al. 2007). The learning process is often referred to as social learning and is associated with changes in stakeholder awareness and perception, especially with changes in how individuals see their own interests in relation to those of others, or in relation to shared interests (Webler et al. 1995). Because this process involves trust-building, social learning is also linked to social capital, which could be described as the trust, leadership, and social networks within a group or a community (Folke et al. 2005). For example, Mostert et al. (2007) argue that social learning starts when stakeholders understand their interdependence and realize the benefits of common actions, while Pretty (2003) proposes that people in groups with strong social capital have the confidence to invest in collective action. Thus, stakeholder participation in natural resource management has the potential to strengthen social capital and social learning, and to facilitate economically, ecologically, and socially sustainable solutions.

The approach to science and policy integration used here is a form of participatory modeling, which presents both risks and opportunities (for example, see Jonsson et al. 2007, Andersson et al. 2008). In this paper we also relate science and policy integration to the issue of leadership, which is a commonly recognized factor in successful natural resource management (Ternström 2005, Folke et al. 2005, Hahn et al. 2006).

STUDY AREA

The study area is a Baltic Sea bay system situated about 40 km southwest of Stockholm, Sweden (Fig. 1). Himmerfjärden receives a minor part of Lake Mälaren’s freshwater outflow, and has a local catchment consisting of 536 km^2 of forests

(57%), agricultural land (33%), urban areas (5%), and lakes (4%) (Fig. 1). The Himmerfjärden region is used mainly for tourism and recreational housing. It includes several island nature reserves and a marine protected area. The Himmerfjärden Sewage Treatment Plant, which is the third largest in the Stockholm region and serves about 284 000 people (2010 data), is also located here. The commercial fishery has almost ceased, and recreational fishing is now more important (S. Hansson January 2011, *personal communication*). The main social and economic drivers are the increasing population of the Stockholm region, which creates a continuous increase in demand for permanent homes, recreational houses, sewage treatment, and water-related recreational activities.

With respect to implementing the Water Framework Directive, the Himmerfjärden drainage basin is considered part of Sweden's northern Baltic Sea river basin district. Three municipalities and two counties share the management of most of the local drainage basin (including the outer area).

The brackish Baltic Sea has experienced localized coastal eutrophication problems since the nineteenth century, with severe problems having occurred from the 1950s onwards. Himmerfjärden was less affected by local sewage discharges before the Himmerfjärden Sewage Treatment Plant started operating in 1974 (Elmgren and Larsson 2001). The treatment plant had efficient phosphorus removal (about 96%) from the start, and from 1998 it also had efficient nitrogen removal (up to about 85%) (Elmgren and Larsson 2001). Even so, the Himmerfjärden Sewage Treatment Plant still contributes a significant share of the total nutrient load to Himmerfjärden, particularly inorganic nitrogen. Other nutrient sources are Lake Mälaren, local agriculture, and households with private sewers (Elmgren and Larsson 1997). Salinity is slightly lower in Himmerfjärden than in the open Baltic Sea, and the water exchange with the sea is important both for the export and import of nutrients (Engqvist and Stenström 2009).

Stakeholder involvement in managing Himmerfjärden started with the opening of the Himmerfjärden Sewage Treatment Plant in 1974; eutrophication research in the region since 1975 has involved frequent contacts with local stakeholders. This research has focused on the relationship between nutrient loads and the occurrence of phytoplankton in general, and on nitrogen-fixing cyanobacteria in particular. The research has included full-scale experiments with changed loads from the Himmerfjärden Sewage Treatment Plant, which aimed to optimize the environmental results of the treatment through adaptive management.

METHODS

The systems approach of the SPICOSA project starts with a team of researchers, who together with interested stakeholders in the coastal area, formulate a major policy issue (or issues) for their coastal area and identify relevant policy options (measures) (Hopkins et al. 2011).

The Himmerfjärden study team, which included the authors of this paper, consisted of three environmental economists, one environmental scientist specializing in governance issues, and five systems ecologists. This team built a coupled simulation model suitable for ecological, economic, and social appraisal of scenarios consisting of combinations of policy options.

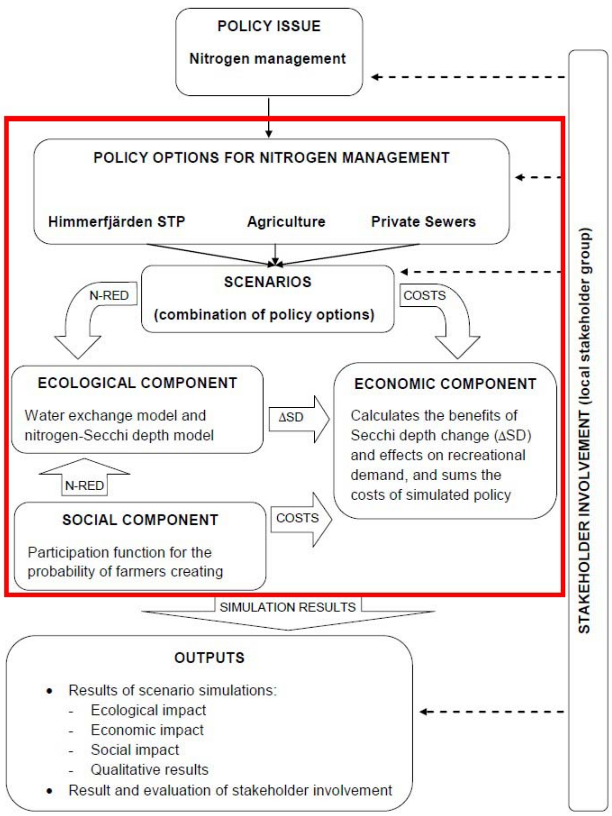
Given the transdisciplinary approach of the study, the methods section is divided into two parts. First we briefly describe the construction of the integrated ecological, economic, and social model to give an understanding of the communication tools we used at the study site, and then we describe how we collected evidence of knowledge and social gains for the participating stakeholders.

Conceptual model

The systems approach used in this study emphasizes the need to focus on ecological-social-economic interfaces (Hopkins et al. 2011). Hence, the Himmerfjärden simulation model was a coupled ecological, economic, and social model for evaluating policy options (i.e., potential measures) for nitrogen management in three main human activities: centralized sewage treatment at the Himmerfjärden Sewage Treatment Plant, sewage disposal from individual households (private sewers), and local agriculture. We limited the model to nitrogen management given that the Himmerfjärden phosphorus load is dominated by import from the open sea, and little is affected by local management.

The coupled model (Fig. 2) had several linkages between ecological, economic, and social components. First, scenarios were defined in the policy options component (see Table 1 for policy options). The nitrogen reduction (N-red), caused by the scenario chosen for simulation, affected the ecological component, which consisted of a water exchange model and a nitrogen model. A crucial link between the ecological component and the economic component was the change in Secchi depth caused by the nitrogen reduction associated with the chosen scenario. Secchi depth is a measure of water transparency and is a key indicator of water quality, which in turn affects people's well-being and demand for coastal recreation. The economic component included a cost-benefit analysis of the chosen scenario and the resulting increase in water transparency. The social component was a participation function that calculated the willingness of farmers to create wetlands, given different levels of support for wetland creation. This component was based on a survey of farmers in the region. The output of the social component was the extension of wetland that would likely be created, as well as the reduction in nitrogen that would result, which would in turn affect the ecological component.

Fig. 2. Conceptual model for coastal zone modeling in Himmerfjärden. The red square encloses the components in the simulation model. Solid arrows indicate the data input on which the simulations are based. Dashed arrows indicate where stakeholders were involved and influenced the model and research process.



The overall purposes of the model were to simulate and illustrate potential ecological, economic, and social results of different combinations of policy options for nitrogen management. The spatial dimension of the model was based on three main water basins and their respective drainage areas (see areas 2, 3, and 4 in Fig. 1).

The simulated policy options are listed in Table 1. The Himmerfjärden Sewage Treatment Plant is the dominant nitrogen emitter, but leakage from agriculture and private sewers would also have local effects. For each human activity different policy options were available, but only such that could be implemented within the study area, i.e., there were no scenarios with decreased nutrient inflow from the open sea or Lake Mälaren.

The two policy options for the Himmerfjärden Sewage Treatment Plant were: (1) establish different levels of nitrogen removal, and (2) move the location of the outfall to the open Baltic Sea by means of a pipeline. The policy options for decreasing nitrogen leakage from agricultural activities were: (1) catch crop cultivation, including high and low estimates of potential nitrogen retention and of extension of the activity, and (2) creation of wetlands in the agricultural landscape. Both of these options have been suggested as potential measures to reduce nutrient leakage from agriculture activities (Aronsson and Torstensson 1998, Kirchmann et al. 2002, Arheimer et al. 2004). The policy option for private sewers was to connect the private sewers to a larger sewage treatment plant. For each policy option we varied the number of private sewers that were supposed to be connected.

Different policy options can be chosen for agriculture and for private sewers for each of the three drainage basins used in the model (see Fig. 1). The model can therefore simulate many combinations of policy options, each giving a different scenario, but only a selection was chosen for the final simulations, after consultation with the stakeholder group.

Ecological component

The ecological model explicitly included only the aquatic ecosystem, which was spatially divided into three water basins, each corresponding to a drainage area (see areas 2, 3 and 4 in Fig. 1). The vertical structure is a euphotic surface layer that is 7 to 10 m in depth, a subsurface layer, and a bottom layer.

An estuarine water exchange was modeled, with a seaward flow of surface water and a landward deep-water inflow. The water exchange was calculated from a mass-balance for salt and water. The Knudsen (1900) equation was modified to fit a dynamic nonequilibrium model with measured salinity and fresh water flow as inputs, which is similar to the approach of Hagy et al. (2000), with a 1-day time step. This water exchange model simulated winter concentrations of total nitrogen and the sum of inorganic nitrogen species quite well (no biological activity assumed).

The total nitrogen and dissolved inorganic nitrogen concentrations were modeled for all three basins and depth layers, using inputs calculated from concentrations and volumes of freshwater, the Himmerfjärden Sewage Treatment Plant's discharge, and boundary flows. In the spring, biological uptake and loss of the dissolved inorganic nitrogen pool were assumed. Because dissolved inorganic nitrogen in the study area is usually consumed to low levels in the spring, and remains low in the surface water in summer, all inorganic nitrogen present or added to the surface layer (from upwelling, mixing, and fresh water inputs) was assumed to be taken up by phytoplankton during a defined productive period from April to October. In the spring and summer, half of this net dissolved inorganic nitrogen uptake (and corresponding total nitrogen) was assumed to sink out, with the rest recycled to the total nitrogen pool in the surface layer. This factor of 0.5 was derived from calibration with data and it was used in all simulations. A simple empirical correlation was then used to calculate Secchi depth from total nitrogen. The average

Table 1. Policy options for the simulation model (including policy options for the reference scenario).

Human activities Himmerfjärden Sewage Treatment Plant	Agriculture	Private sewers
Policy options for the Himmerfjärden Sewage Treatment Plant: effluent nitrogen concentration and other possible measures	*Policy options for agriculture: wetland creation or catch crop cultivation*	*Policy options for private sewers: share of private sewers connected to the sewage treatment plant*
10 mg/L (reference scenario)	No additional measures undertaken (reference scenario)	0% (reference scenario)
4 mg/L	Catch crops – low estimation	25%
4 mg/L plus move outfall to the open Baltic Sea by building a pipeline	Catch crops – high estimation	50%
	Wetland creation (area calculated by the participation function, based on level of support for wetland creation)	100%

summer Secchi depth was used as one ecological–economic model link (see Fig. 2).

This simple water exchange–ecological model produces reasonable results and is easily understood and communicated. At high nitrogen loads the model may be less reliable if seasonal phosphorus limitation is induced. Inclusion of phosphorus would be needed to model nitrogen-fixing cyanobacteria.

Economic and social components

The economic component sums the costs and calculates the benefits of a simulated scenario.

The cost for a scenario was calculated as the amount above the cost for current undertakings or minimum efforts corresponding to current legislation, which is the reference scenario (Tables 1 and 2). The Himmerfjärden Sewage Treatment Plant costs for the policy options are known (J. Bosander, July 2008, *personal communication*); for private sewers and agriculture, a wide range of cost data, based on literature and experience, were used (Focus on Nutrients 2003; Hasselström 2007; J. Holmström, December 2008, *personal communication*; S. Jonsson, December 2008, *personal communication*). All investment costs were assumed to be financed by loans and calculated as an annual installment and interest rate for wetlands, private sewers, and the Himmerfjärden Sewage Treatment Plant, using an interest rate of 6.5% (Swedish Institute for Transport and Communications Analysis 2009).

The benefits of the Secchi depth improvement in the scenarios were estimated using results in Östberg et al. (2011), who carried out a choice experiments study for estimating the willingness-to-pay for several water quality attributes in the Himmerfjärden study area. Based on these estimates, Kinell et al. (2011) calculated the benefits of the Secchi depth improvements following from the scenarios in Table 2.

Summed present values of costs and benefits were computed based on a social discount rate of 4% (Swedish Institute for Transport and Communications Analysis 2009); for further details on the cost-benefit analysis see Kinell et al. (2011).

The social component simulates factors that affect the willingness of farmers to participate in wetland creation. This is because much of the study area is considered favorable for wetland creation (P. Stålnacke, October 2008, *personal communication*). Further, farmers were a key group for reaching water quality objectives because the diffuse nutrient leakage from agriculture was regionally significant. The simulation in the social component was based on a choice modeling approach similar to that of Carlsson et al. (2003), however, the monetary valuation weighting was exchanged for different policy settings and levels of support for wetland creation. A participation function was estimated by using data from a 2009 questionnaire to farmers in the study area (F. Franzén, *unpublished data*) which means that stakeholders (farmers) had a strong influence on the model. Also, the results of the questionnaire provided the model with specific data on both wetland area and location.

Stakeholder participation

Recruiting coastal zone stakeholders

Invitations to an initial stakeholder meeting in November 2007 were based on a mapping of human activities, stakeholders, and institutions in the Himmerfjärden region. This meeting was co-organized with the regional River Basin District Authority and the Stockholm County Administrative Board, as part of a process of consultation on local water quality issues. At the meeting we recruited a group of twelve people who were willing to participate actively in the Himmerfjärden study and who represented a range of local stakeholder categories (Table 3).

The stakeholder group met once or twice each year (Table 4). In 2009 we held an extra meeting to discuss the suggested

Table 2. Results for the three main scenarios.

Source of Nitrogen	Reference Scenario	“Most Likely” Scenario	“Pipeline” Scenario
Himmerfjärden Sewage Treatment Plant, effluent nitrogen concentration	10 mg/L	4 mg/L	4 mg/L plus offshore outfall
Agriculture	No additional measures	Wetland creation (25 ha)	Wetland creation (25 ha)
Private sewers connected to sewage treatment plant	0% (no additional measures)	25%	25%
Mean summer Secchi depth	3.1 m	3.7 m	4.1 m
Secchi depth change	-	0.6 m	1 m
Benefits of Secchi depth improvement (summed present values)	-	309 MSEK	516 MSEK
Costs of scenario (summed present costs)	-	133 MSEK	539 MSEK
Net benefit	-	176 MSEK	- 23 MSEK

Programmes of Measures for the implementation of the Water Framework Directive. The study site team collected opinions and comments at the meeting and submitted a statement of comments to the River Basin District Authority.

In the fourth year we also co-organized a meeting at which study results were communicated to an additional group of national level stakeholders from three Swedish River Basin District Authorities, the Swedish Environmental Protection Agency, the Stockholm County Administrative Board, and the Swedish Meteorological and Hydrological Institute. The local stakeholder group proposed such a meeting because of the project’s scope of integrated modeling and because the example of active stakeholder involvement should be of interest to these national actors.

Each meeting was hosted by a different stakeholder or by representatives of the study site team (see Table 4), to provide venue variety. The meetings were half-day in length, followed by a free lunch, to provide opportunity for informal discussions. They included an initial presentation of the project’s progress and related research in the study area (maximum half the meeting), with an effort by the study site team to use language understood by all stakeholders—thus the modeling, project progress, and results were communicated using conceptual models, diagrams, and snap shots of the simulation model rather than details of model structure. Each meeting ended with stakeholder discussions, including questions and requests for the future work (minimum half the meeting). Meetings were documented in minutes by a study site team member and subsequently sent to the stakeholder group for review.

Evidence of stakeholder influence

Stakeholder participation was mainly assessed in two ways. First we used the discussions at the meetings and the minutes listed in Table 4 to study evidence of stakeholder influence on formulation of the policy issue, policy options, and scenarios for modeling. The minutes were taken by one selected member of the study site team, and after each meeting were sent by e-mail to the rest of the study site team and the stakeholder group for comments. Second, we distributed two questionnaires to the stakeholders; the first at meeting 2 and the second at meeting 5.

Questionnaire 1 gave group members an opportunity to complement what they had said during the first two meetings, by focusing on the most urgent policy issue in the study area and its impact on the local environment, economy, and society. Questionnaire 2, which followed up questionnaire 1, had the particular purpose of capturing potential changes in stakeholder knowledge and perceptions. In addition to repeating the questions in questionnaire 1, it included new questions about the stakeholders’ experiences of participating in the study.

RESULTS

In this section we present some general results of (1) how participation by stakeholders influenced the research process and modeling results, and (2) the effects of the research process on the stakeholders, especially in terms of knowledge gains and social gains made by the stakeholders.

Stakeholder participation

Agreements for establishing the simulation model

The first stakeholder meeting (Table 4, meeting no. 1) identified eutrophication as the main environmental policy issue in the Himmerfjärden region. This was confirmed by answers to questionnaire 1, which indicated that the outcome of the meeting truly reflected stakeholders’ opinions. The study site team agreed, but found the issue too broad for modeling purposes. A narrowing of the issue to nitrogen management was accepted by the stakeholder group.

On the whole, there was good agreement between the views of the stakeholders and the study site team on urgent policy

Table 3. Stakeholder group representatives.

Category	Representing	Role	Comment
Governmental policy makers and/or environmental regulators	Stockholm County Administrative Board	Official (environmental analyst)	Changed representative in 2008
	Södertälje Municipality	Official (ecologist)	2 representatives, 1 after the 3rd meeting.
	Botkyrka Municipality	Official (environmental analyst)	2 representatives
	Nynäshamn Municipality	Official (environmental investigator)	Dropped out in 2008 due to reorganization of the municipality
Actors	Himmerfjärden sewage treatment plant	Process manager	
	Local industry sewage treatment plant	Process engineer	2 representatives
	Land owner	Owner of Mörkö Manor	Also a farmer
	The Swedish Farmers Union	Representative of local chapter	Dropped out in 2009 due to lack of time
Customers	Himmerfjärden Nature Conservation Association	Chairman of the association	

options. At an early stage (questionnaire 1 and meeting 2), stakeholders also indicated an interest in linking fishery issues and fish stock modeling to eutrophication management, but the study site team found this unrealistic due to lack of data on fish stocks.

At the second meeting (Table 4), the stakeholders influenced the choice of policy options to be modeled. For example, stakeholders wanted policy options for several nutrient sources, such as private sewers and agriculture, included in the modeling. Clearly, investigating scenarios in which responsibility for nutrient reduction is shared among actors was important to the stakeholder group, and this might have minimized possible conflict within the group. The local nature conservation association has long wanted a pipeline to be built to move the outfall of the Himmerfjärden Sewage Treatment Plant out of Himmerfjärden, but this was previously seen as unrealistic due to high cost. Increased mitigation demands due to implementation of the Water Framework Directive may change this, and including this policy option made it relevant to simulate Himmerfjärden as being almost free of sewage impact.

The study site team could not realize all of the stakeholders' suggestions for simulating policy options. For example, desired analyses of more refined policy options for agriculture and private sewers, involving a larger variety of abatement measures, could not be made due to lack of time and resources for gathering the detailed data required.

Results of main scenarios

The integrated model constructed with stakeholder participation can simulate a large number of possible scenarios (i.e., combinations of policy options). In this paper we focus on the results for the three main scenarios that were selected in discussion with the stakeholders (Table 2). The reference scenario refers to the minimum effort corresponding to current legislation. To manage nitrogen in Himmerfjärden for better water quality and reach the requirements of the Water Framework Directive, the stakeholder group and the study site team agreed that the “most likely” scenario was implementation of the listed combination of policy options in the study area, namely a high level of nitrogen reduction for the Himmerfjärden Sewage Treatment Plant, wetland creation in one of the drainage basins for agriculture, and connection of a quarter of the private sewers to a sewage treatment plant. The “pipeline” scenario was included after repeated requests by one stakeholder. It corresponds to the “most likely” scenario plus moving the outfall of the Himmerfjärden Sewage Treatment Plant to the open Baltic Sea. The “pipeline” scenario illustrates the study area with its dominant nitrogen emitter, the Himmerfjärden Sewage Treatment Plant, eliminated, thus making Himmerfjärden in this scenario similar to an average Baltic bay system.

The main results of the scenario simulations indicate expected Secchi depth improvement and net benefit for each scenario (Table 2). The model was simulated over a 30-year period with a yearly time-step. The “most likely” scenario results in a 0.6-m Secchi depth improvement and a net benefit of approximately 176 MSEK. The “pipeline” scenario results in a 1-m Secchi depth improvement; however, the costs associated with building a 25-km pipeline are substantial and the scenario resulted in a negative net benefit of 23 MSEK. Nevertheless, the pipeline scenario is still of interest because

Table 4. Stakeholder group meetings during the research process. The participants were the members of the study site team and local stakeholders..

Meeting no.	Date	Venue	No. of participants (no. of local stakeholders in parentheses)	Main tasks
1	November 13, 2007	Södertälje Town Hall	26 (19)	Stakeholder group formed. Policy issue discussion.
2	April 17, 2008	Himmerfjärden Sewage Treatment Plant, Grödinge	14 (9)	Policy issue and policy option discussion. Questionnaire 1.
3	November 6, 2008	Xenter, Tumba	15 (8)	First result of simulation model. Discussion of scenarios.
4	May 28, 2009	Enveco office, Skärholmen	11 (7)	Discussion of Programmes of Measures for Water Framework Directive.
5	November 19, 2009	Enveco office, Skärholmen	14 (7)	First result of scenario simulation. Discussion of use of the model. Ouestionnaire 2.
6	March 23, 2010	Stockholm County Administrative Board, Stockholm	17 (9)	New stakeholder group with potential end-users.
7	December 9, 2010	Södertälje Town Hall	12 (6)	Summary of SPICOSA experience, and discussion of future possibilities. Creation of interim board for a possible Water Council for Himmerfjärden.

it may be the only means of reaching the water quality goals for Himmerfjärden as legally required by the Water Framework Directive. To achieve the 25 ha of wetlands simulated in the model would require increased support for wetland creation, for example higher subsidies for wetland creation.

Evidence of gains for stakeholders

The meetings and questionnaires allowed us to assess the stakeholders' own perceptions of the knowledge gains and social gains they derived from their participation. By knowledge gains we mean that stakeholders learned from the process or increased their understanding of marine issues or of the opinions of other stakeholder categories. Social gains refer to social advantages for stakeholders from participation, for example in network building. The concept of social learning can be linked to both knowledge gains and social gains because one usually considers social learning to describe exchanges of ideas, changes of perceptions, and understanding of other stakeholders' opinions. We illustrate this with quotes from the meetings' minutes and from questionnaire 2 (Table 5).

Knowledge gains

The results show that the stakeholders valued participation as a resource for improved knowledge and understanding (Table 5, column 1). Several stakeholders reported that they gained new knowledge about coastal systems and modeling in general. Further, the quotes confirm that our modeling approach has facilitated knowledge gains for the members of the stakeholder group rather than preventing their understanding of the complex coastal systems.

The approach also resulted in a coupled model with ecological, social, and economic components, and this coupling was recognized and valued by the stakeholders (Table 5). At meeting no. 6, stakeholders emphasized the advantages of our model's simplicity; also, one stakeholder thought that the model was unique because it included social, economic, and ecological components. Thus, our application of the SPICOSA systems approach has been successful as an integrated approach to the coastal system, with the stakeholders seeing the social and economic components as important contributions of the model, even though many stakeholders had backgrounds in the natural sciences (Table 3). The stakeholders also gained knowledge on present policy legislation; one stakeholder cited "better understanding of the Water Framework Directive" as a specific gain.

Social gains

The quotes in the second column of Table 5 indicate that members of the stakeholder group found their participation socially valuable. The stakeholder involvement in the Himmerfjärden study created a forum with representatives of both affected and affecting stakeholders. Participation in the group clearly provided opportunities for new contacts and building of networks. Such collaboration was seen as desirable for meeting future water management challenges in the Himmerfjärden region. At meeting no. 5, the stakeholder group also voiced a desire to continue working together.

Table 5. Examples of stakeholder views regarding participation in SPICOSA. The quotations are translated answers to questionnaire 2; they are in random order and do not correlate across rows.

Knowledge gains	Social gains
"A lot of knowledge on what modeling could be used for."	"A good network of contacts."
"Good source for information, especially about models. Interesting ideas for the future."	"It is important to have a broad dialogue."
"Better understanding of the implications of the Water Framework Directive .... Better understanding of water flows and the factors that impact the nitrogen and Secchi depth."	"Personal contacts with persons who have knowledge about and interest in improved coastal waters."
"Better knowledge of coastal waters in Himmerfjärden and the surrounding basins, and awareness of research projects in these areas."	"Fine with collaboration in groups such as [...] and SPICOSA. Unfortunately, they all finish in one or two years."
Good that the model is simple."	"[In the future] collaboration between municipalities, River Basin District Authorities, and County Boards is necessary."
"Participating in the stakeholder group has given me hope that we will be able to better understand complex environmental problems in the future. Better understanding of the impact of the sewage treatment plant (that the stakeholder represented) on all of the basins in the study area..."	"[In the future], a continued close collaboration between scientists and other stakeholders will hopefully take place."
	"[In the future] it is important to continue to work like this in similar projects."

It is important to point out that there were no strong conflicts in the group and that the process was characterized by an informal and friendly atmosphere. However, as mentioned above, one important means of minimizing conflicts may have been the choice to include all emitting activities that the stakeholders wanted to study among the policy options in the simulation model.

The quotes in Table 5 also show that a broad representation in the stakeholder group and the relation to the study site team were appreciated by the group. Regarding social gains, we can also note from meeting 7 (Table 4) that an interim board for a possible future water council for the Himmerfjärden catchment was created.

Critique and comments

Stakeholders were also invited to criticize the simulation model, and the research and participation process. Most of their comments were about the result of the model, the advantages and drawbacks of the simplifications used in the model, and the narrowed focus of the modeling from eutrophication in general to nitrogen management. As mentioned above, stakeholders also wanted more policy options to be evaluated than the study site team could accomplish. In addition, the accessibility and future of the model were important issues for the stakeholders. The scale of the model was also questioned because stakeholders were also concerned about the open Baltic Sea and other environmental problems of larger ecological scope. The applicability of the model to other areas was of interest at meeting 6, at which several Swedish River Basin District Authorities were represented.

FINAL DISCUSSION AND CONCLUSIONS

We conclude that the application of the SPICOSA systems approach in Himmerfjärden resulted in a rewarding process of stakeholder participation, both in terms of the research process and stakeholders' own experience. Our initial research questions concerned how stakeholders influenced the research process and modeling results, and also how stakeholders were affected by participating in the project. The results show that the research process gained from stakeholder participation, especially by introducing interesting policy options and by making the modeling understandable. The results also show that the stakeholders felt that they gained from participating, both in terms of extended knowledge and extended social networks. In this section we discuss the role of stakeholder participation in science and policy integration and social-ecological modeling, the impact on social learning and social capital, and finally, the role of leadership in participation processes.

Roles of social-ecological modeling in science and policy integration

Our approach to the social-ecological modeling was to build a simple model based on mainly existing data that included ecological, social, and economic components. The results of increased stakeholder understanding of complex systems and of linkages between natural and social systems strongly indicate that the approach was successful in identifying scenarios for nitrogen management that the stakeholders found interesting and understandable. However, there are also challenges and risks in participatory modeling approaches. Jonsson et al. (2007) question whether research groups working with participatory modeling will value local opinions as highly as those of established experts. In our case the stakeholder group had broad local representativeness, and there was no obvious disparity between experts and nonexperts.

Clearly, stakeholder participation in research projects or policy settings is not always simple. The mostly active and persistent participation in this study was facilitated by having a relatively good coherence of knowledge perceptions among the stakeholders and the study site team at the outset, and by the availability of a large database. Earlier studies on engaging stakeholders in the early phase of planning scientific programs have shown that too wide a disparity between the perceptions of stakeholders and scientists can seriously hamper collaboration and the achievement of results (Human and Davies 2010). Fortunately, this was not a serious problem in the initial discussions in our case study application. Rather the opposite occurred, i.e., the study site team gained local knowledge and ideas for policy options for the simulations. One example of this was a suggestion about simulating the effects of a pipeline to move the outfall to the open sea. This was earlier seen as an unrealistic solution, but the requirements of the Water Framework Directive might force such drastic solutions in order to fulfill the goal of good water quality status.

Effects on social learning and social capital

The approach of letting stakeholders influence the research and modeling processes seems to have increased their interest in participating in the process, as well as their acceptance and awareness of the opinions and perceptions of other stakeholder categories. The results on both knowledge gains and social gains in our study agree with Andersson et al. (2008), who argue that participatory modeling can help stakeholders better understand other stakeholder groups, and even make them share a common view of the policy issue.

Because social learning processes among representatives of different stakeholder groups and scientists are crucial factors for successfully adapting to new demands and for managing participation processes, the experience of our study hopefully created opportunities for future collaboration (Pahl-Wostl et al. 2008). At the concluding (i.e., seventh) stakeholder meeting, an interim board for a possible future water council for the Himmerfjärden catchment area was created. Hence, in this case the research process clearly enhanced the social capital and created an opportunity for future collaboration. Kaika (2003) argues that the implementation of the Water Framework Directive is a top-down approach of creating social capital, and further that changes in the social capital are crucial for adapting to the new requirements of the directive. However, in our case the research project and stakeholder group started the changes in the social capital.

Role of leadership in the stakeholder participation processes

The relative ease with which we achieved stakeholder involvement in the Himmerfjärden study poses a question: Why is there so little formal collaboration in place, when the opportunity obviously exists? The stakeholder participation in this study started off as an ordinary consultation meeting, co-organized with Swedish authorities. However, the participation process would probably have stopped there if the research project had not continued to encourage a deepened collaboration and active participation, corresponding to the third level of participation in the Water Framework Directive. This level is not as well implemented in Swedish practice as the two other levels; information and consultation (Jöborn et al. 2005).

A necessary component for activating local actors—and a general key to successfully involving locally evolved institutions—is the presence of leadership (Ostrom 1990, Olsson et al. 2004, Ternström 2005, Hahn et al. 2006). In our case the study site team took the lead, by arranging meetings and involving local stakeholders in a co-operative research process dealing with locally interesting issues. The local water councils that the Swedish River Basin District Authorities have proposed as an important tool for achieving active participation of local stakeholders, should preferably be initiated at the local level (Swedish River Basin District Authorities 2008). Still, it is possible for County Boards and River Basin District Authorities to facilitate such initiatives by taking supportive measures. However, both of these agencies were involved in our project to some extent without suggesting the creation of a water council. The regional River Basin District Authority's lack of interest in the establishment of water councils leads one to wonder whether it sees active stakeholder participation as a priority. The experience of collaboration in the Himmerfjärden study area during the SPICOSA project has hopefully created the potential for active stakeholder participation in future water management.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol16/iss4/art27/responses/

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