ÖSTRA SANNORNA
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A STUDY OF A WETLAND AREA IN LIDKÖPING MUNICIPALITY, CENTRAL SWEDEN

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MASTER'S THESIS AT LUMES;
LUND UNIVERSITY INTERNATIONAL MASTER'S PROGRAMME IN ENVIRONMENTAL SCIENCE

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SUMMARY

This study concerns the Östra Sannorna area in Lidköping Municipality; a wet lakeshore forest where ecological and socio-economic interests are conflicting. Should this rare biotope be protected for the benefit of nature or exploited for the benefit of people? Factors such as social and economic good, natural values and health concerns are addressed and evaluated. The conclusions of this study are that small-scale exploitation could bring socio-economic benefits to the municipality, but that there are many factors against exploitation. Instead it is suggested that the area be made into a nature reserve to ensure that it is protected now and in the future.

INTRODUCTION

The discussion on what one could, or should, do with the marshy area of lakeshore forest east of Lidköping, has been going on for many years. Ecological values are often opposing economic and social values. Some want it to be protected from exploitation - perhaps as a nature reserve. Others would like to take advantage of its beautiful location on the shore of Sweden's largest lake and develop it into a more attractive and useful area for the inhabitants and visitors of the municipality. Others yet would prefer a compromise between the two, but then the question is how much or little of the area could be exploited to reasonably satisfy all parties. At present no decisions have been taken that would support either alternative.

In the Physical Plan from 1991, for Lidköping Municipality, it is stated that a detailed plan should be established for the area Östra Sannorna (Översiktsplan 1991). This has not been done, however, and as the municipality is to revise the old Physical Plan it is important that the issues relevant to the future use of this area are considered and included in the new plan.

SCOPE AND OBJECTIVES

The study aims to evaluate the environmental consequences of three different landuse alternatives for the wetland area *Östra Sannorna*, east of Lidköping. The three alternatives includes construction of a residential area, a beach area and a combination of both beach and residential areas. These alternatives were chosen because they are the exploitation alternatives most often discussed for the area. Another alternative is to preserve the area as it is today; relatively untouched. The study also includes other considerations of importance for human and eco-system health. Consequences on ecological, economic and social factors have been considered. A computer model has been used to investigate the long-term development and environmental effects of the different landuse alternatives. The focus of the study is necessarily local, but the regional importance of wetland areas, such as this one, will also be discussed since the importance of the area, from an ecological viewpoint, cannot be evaluated from its local significance alone.

Methods and Limitations

Information for this project has been gathered through studies of literature relevant to the issues described herein and complemented by interviews with people with knowledge of the issues in general or the area in particular. The studies of literature relevant to the subject has mainly been limited to documents supplied by the Municipality of Lidköping, since much of it is site specific. The written descriptions of the area have been confirmed and complemented through visits to the locality.

Through an analysis of the Östra Sannorna ecology-anthropology system, the main influencing factors were determined and their interaction simulated in a computer model (made with the Stella® software) under the three scenarios mentioned above.

The study is mostly limited to the discussion of issues directly related to the land-use in the Östra Sannorna area and their probable effects. Some issues necessarily crosses the physical boundaries of the area and they will be addressed where this is relevant, but it is not the intention of this study, to go in depth into these "external issues".

This study is not an Environmental Impact Assessment. It merely aims to point out important issues that should be taken into consideration, and to provide guidelines for making appropriate decisions regarding the Östra Sannorna area.

THE AREA ÖSTRA SANNORNA

Östra Sannorna is an area along the southern shore of lake Vänern, east of the town of Lidköping (Figs. 1 and 2). It is approximately 500 meters wide and 2600 meters long - in total about 130 ha. A marshy area with zones of reeds close to the water, and forest (mainly alder, willow and pine trees) further away. It is used for some forestry, but apart from this the main human influence is the railway that runs through the forest. The southern limit follows the road towards Mariestad (*Riksväg 44*). On both the eastern and the western end of the Östra Sannorna area there are beaches and at the eastern end there is also a small community with a camping area (*Filsbäck*). South of the area is the city dump and recycling station, *Kartåsen*. The soil is sandy, and the area contains some three sand-dunes, about three to four meters high (Stagen, 1994)[1]. The sand was deposited and reworked into dunes after the last glaciation, whereas the vegetation to a large extent has developed since the beginning of the present century, after the lake level had been lowered in the 1930ies. A further feature of the area is the medieval gorge that once was the main road between Skara and Lidköping. Originally the Östra Sannorna was part of a considerably larger area along the lake shore , but as the city of Lidköping has grown during especially the latter half of the 20th century, the forest along the lake shore has become more and more exploited. An inventory of the area, made in 1972[2], states that although similar areas exist on other Swedish lake-shores, here it is unusually large, well developed and unexploited.

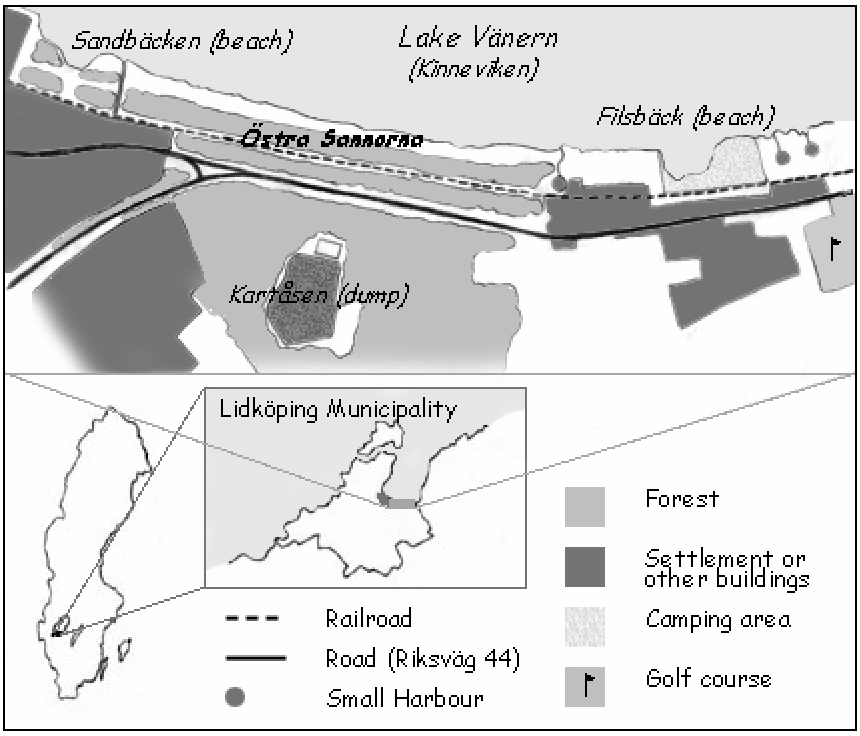


Fig. 1: Map of the Östra Sannorna area east of Lidköping. The area borders are made up of the beaches to the east and west (*Filsbäck* and *Sandbäcken*) and the road (*Riksväg 44*) to the south.

[1] The description of the area, as follows in this paragraph, is all from Stagen, 1994.

[2] The inventory was made by Karvik & Larsson [*Karvik/Larssons Naturvårdsinventering 1972*], but is here reiterated from Stagen, 1994.

Fig. 2: Photo of part of the Östra Sannorna area, with its extensive zones of reed and (mostly) deciduous forest.

Because of the variation in topography, the area shows a mosaic of slightly different forest types, with mainly moisture loving species such as alder and willow, but with e.g. pine in drier areas (see Fig. 8 on page 14). Exactly how large a part of the area could be classified as "pure" wetland (wet) forest is hard to say. According to Bernes (1994) it is very rare with wet forests larger than ten ha, and they are commonly scattered across the landscape in just the kind of mosaic pattern displayed by Östra Sannorna. The combination of wetland and forest - and in this case also lakeshore and open water - produces many different conditions and niches, thus enabling a high biodiversity. It could be that the "mosaic" of many of these areas actually help to increase that biodiversity, even though the actual wet forest area might be small.

Östra Sannorna is appreciated by ornithologists and others for its biodiversity and the recreational and educational opportunities it offers. In 1994, Arne Stagen suggested that the area should be made into a nature reserve. Because of its attractive location on the lakeshore, it is also considered interesting from an exploitation perspective. The Physical Plan of 1991, discusses the possibility of lakeside living - homes with a view of the lake and/or easy access to the shores. In some areas (e.g. Villa Giacomina, at the western-most end of the city) such homes have been built during the nineties. In other areas no action has been taken yet, for example in Östra Sannorna.

The Plan of 1991 was the first Physical Plan to be determined for Lidköping Municipality and according to the "Planning and Building Act" (Plan och Bygglagen) it is to be regularly updated to ensure its accuracy. When the municipality revises the old Physical Plan, as they are about to do, it is in everybody's interest that the area of Östra Sannorna is treated with due respect.

EVALUATION OF PERTINENT ISSUES

To evaluate the possible value of Östra Sannorna, and the area's suitability for exploitation, one needs to look at the influence of the area upon its surroundings, as well as the surrounding's effects upon the area. Some matters will have a local significance, while others might have a regional significance, e.g. a species that might be common in the area, but uncommon elsewhere.

WETLAND FORESTS IN SWEDEN AND EUROPE

Before the 18th century there was approximately 65 000 km^2 of wet forests of different types in Sweden (Bernes, 1994). In the following centuries there was widespread draining of wetland areas, in order to acquire more farmland and to increase the production of forested areas. Of the original 65 000 km^2, about 16 000 have been irrevocably changed and another 27 000 have been significantly altered. Only about 22 000 km^2 remains relatively intact (*ibid.*). In the southernmost province of Sweden, Skåne, only 10% of the original wetlands remain (*ibid.*). The same development took place in for example Finland, where 2/3 of their original 70 000 km^2 wet forests have been drained and exploited (Bernes, 1993).

Up until 1994, 300 000 ha (3000 km^2) of wetland areas (including marshes and bogs as well as forests) had been protected; of this, only 10% was situated outside of the Swedish fjeld area[3] and those ten percent mainly consist of bogs and fens (Bernes, 1994). This means that wet forests are not very well protected in Sweden, while they are even less common in many other countries than they are here. Indeed, the Swedish wetland expert Michael Löfroth considers the three wet forest types "herb-rich wet forest", "deciduous wet forest" and "lake-shore wet forest" to be among the most endangered biotopes in Sweden (Löfroth, 1991).

Wetland areas are much more common in the Nordic countries as compared to the rest of Europe (Bernes, 1994). This means that species that have become rare (or even extinct) further south, may still be quite common here in Sweden. The Nordic wetland areas function as refugees for these species (*ibid.*). Thus, the Nordic countries could be considered as having an obligation to other European countries to help preserve what cannot be found elsewhere.

WETLANDS AND SWEDISH ENVIRONMENTAL PROTECTION LAWS

From the first of January, 1999, the new Environmental Code (*Miljöbalken, SFS 1998:808*) is Sweden's environmental protection law and it combines several earlier laws. According to this code all areas along lakes, seas and rivers are to be protected for two main reasons. The protection should ensure that the public have natural recreation areas and that plants and animals will find good living conditions, both on land and in the water. The protected area should be at least 100 meters wide and can be expanded to a maximum of 300 meters. If the area is not judged as valuable for either recreation or wildlife, or if it is included in e.g. a detailed physical plan, the protection might be cancelled. Several activities are forbidden in these protected areas, unless they are necessary for agriculture, fishing or forestry and unless "specific reasons" can be put forward to legitimise them (Miljöbalken, Chapter 7, 13-18 §§). There is no definition of what can and what cannot make up such reasons.

With regards to activities affecting water - by e.g. changing the depth or location of a water body or draining of wetlands - a permission obtained from the County Board is generally required. The activity should only be permitted if its advantages outweighs costs and disadvantages (*ibid.*, Chapter 11, 2-13§§). It is unclear who's interests are to be considered when defining the advantages and disadvantages. Among humans, short term economic gains are often preferred to long term ecological health. The law protects economic benefits not natural resources, without recognising that the economy is dependent upon the health of the environment. In earlier environmental laws, such as the Nature Conservation Law (*Naturvårdslagen, SFS 1964:822*) and the Environmental Protection Law (*Miljöskyddslagen, SFS 1969:387*) the same rules and the same exceptions applied. It seems the hoped for improvement of Swedish environmental legislation is still wanting.

[3] Most of Sweden's wetland areas, including wet forests, are located north of Mälardalen (Bernes, 1994).

Environmental Policy of the Municipality of Lidköping

As a complement to the environmental laws of the country, the municipality has developed an Environmental Policy that should also be considered when discussing the future land use and physical planning. The Environmental Policy's main function is to provide common guidelines for all committees etc. within the municipality.

- Economise with natural resources (close material cycles, reduce consumption).
- Promote good (human) health.
- Work for buildings that are "environment and health friendly" (closed cycles, renewable energy, waste is a resource).
- Preserve biodiversity.
- Protect the water resources (lake water and groundwater quality).
- Be a role model for environmental work.
- Everyone should participate (politicians, bosses, colleagues, inhabitants… Include environmental issues in all work).
- Inform and educate everyone (the politicians and employees of the municipality should be educated, inhabitants regularly informed).
- Demand environmental friendliness at all negotiation (products and services; at all stages - raw materials, production, disposal).
- Co-operate with inhabitants, companies, organisations and other municipalities.

In the case of this study, the preservation of biodiversity and the protection of water resources are the ones most relevant, since an exploitation, or a preservation, of Östra Sannorna would mainly have an effect on such factors.

NITROGEN LEVELS IN LAKE VÄNERN

Other aspects of importance to a decision on the future of Östra Sannorna are those that concern human and eco-system health. Ecologically, wetland forests are important as regulators of hydrochemical processes and especially in their capacity of nitrogen sinks (Gundersen, 1991). An excess of nitrogen in ground- or surface water becomes a problem mainly when the water reaches the sea where it causes eutrophication and algal blooms. The nitrogen surplus comes from atmospheric deposition and agricultural land runoff. Areas like Östra Sannorna serves to take care of part of the excess nitrogen. Still, in many places wetlands are disappearing in favour of farmland etc. In other areas the importance of wetlands is now being realised and wetlands are restored or artificially created. This is often done to reduce the nitrogen content in wastewater, but also for biodiversity reasons, as for example in *Kristianstads vattenrike* in Skåne. Studies in the United States show, however, that most attempts to create new (artificial) wetlands fail and that the results do not often resemble natural wetlands (Miller, 1998).

Treating wastewater in the Östra Sannorna area is probably not an issue here, the water treatment plant being situated almost at the other side of town. If there is a problem with high levels of nitrogen in Lake Vänern though, it may be important to keep these levels down. In Lidköping Municipality there is only one large contributor to the lake; the river *Lidan*. This river is also the largest contributor in the county and each year it delivers some 2700 tons of nitrogen to the lake (*Miljöförhållanden i Vänern i Skaraborgs län 1990*, 1991[4]). The nitrogen levels in the lake are classified as "high" (ranging from 0.75 to 1.5 mg/l). The lake outlet is the river *Göta Älv*, which delivers 50% of the "Swedish nitrogen" that ends up in the Atlantic Ocean each year (*ibid.*). Consequently a successful reduction of the nitrogen levels in Lake Vänern might have a significant effect upon the eutrophication and algal blooms at the west coast of Sweden.

The Östra Sannorna area is quite small in comparison to the size of the lake, and cannot be expected to solve the nitrogen-problem (if it could, there would be no problem), but if this wetland is "removed" the levels of nitrogen in Lake Vänern could possibly increase. To further address the nitrogen problems of the municipality, one might actually need to construct more wetlands. Other measures that could decrease the amount of nitrogen reaching the lake would be zones around watercourses where there was no cultivation of crops (but instead natural vegetation, to reduce the nitrogen leaking from the soil to the water), reduced fertilisation of the farmland and making sure there is a close to all-year-round vegetation cover (Lönngren, 1995). Another measure would be the construction of several small dams along the watercourse (*bid.*). This could be used both on the water's way to Lake Vänern, and on it's way from the lake to the sea. Studies on nitrogen retention measures in other countries imply that dams and wetlands are the most effective means of reducing nitrogen loads and Lönngren herself states that reducing the emissions of nitrogen could only reduce the loads by 25%. For the remaining 25% of the goal of reducing nitrogen loads by 50% (between 1985 and 1995; it had not been accomplished in 1995) it would be necessary to reconstruct wetlands (*ibid.*).

HUMAN HEALTH CONCERNS - MICROBACTERIA

The water quality in Kinneviken Bay may not only affect the health of fish and algae - investigations have shown that microbacterial levels might be too high in the bay. Samples have been taken at 7 places in the bay during 9 years and tested for coliform 35, possible E. Coli and possible faecal streptococci. The water quality is divided into three groups which can be called Good, OK and Bad. Both Good and OK are acceptable, while a Bad water quality means that bathing is not to be encouraged due to the possible health risks. Constructing beaches in such areas would be inappropriate. Two of the sample sites are located at the beaches on either side of the Östra Sannorna area; Sandbäcken and Filsbäck. The data shows that the water quality in the area, and indeed in the entire bay, has decreased during the decade although the values fluctuates greatly (Figs. 3 and 4).

Comparing Östra Sannorna to the whole bay further shows that since 1996 the samples from the two sites of Östra Sannorna make up 71% of the bad water quality samples. Hence it seems that as the water quality has deteriorated the effect has been greatest in this particular area. It should be noted, however, that the data is not sufficient for a thorough analysis. Before making a decision on whether or not this area would be suitable for a large beach or not, the water quality should be further evaluated - and specifically one should try to find out why the quality has deteriorated in recent years and what can be done to reverse this. The area will not be suitable for beaches until the water quality has been improved. (Raw data supplied by the Municipality of Lidköping.)

[4] Although the data is from 1990, subsequent investigations have shown that the nitrogen levels have hardly changed during the past decade.

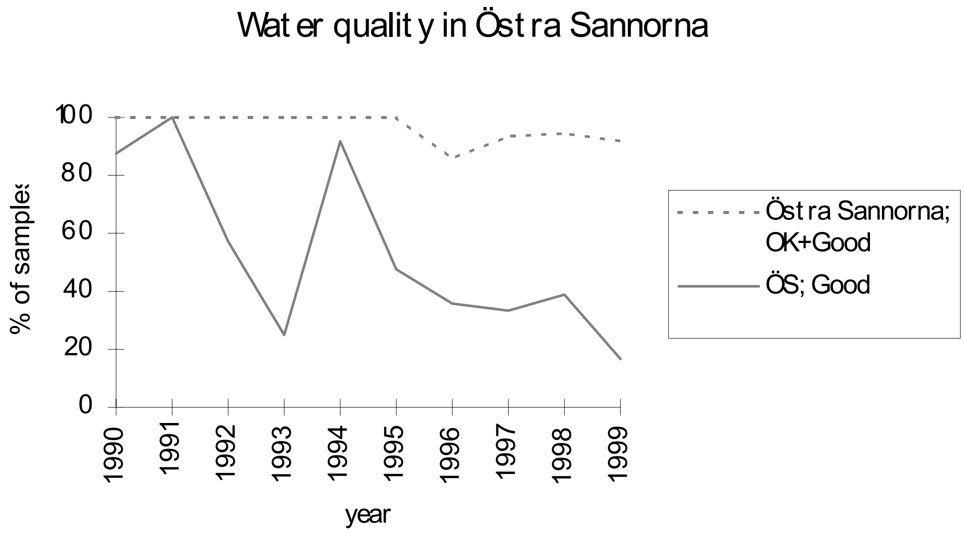


Fig. 3: The graph shows that the water quality in the Östra Sannorna area has decreased during the 90ies, and especially since 1995. The dark, upper line shows water classified as Good *and* OK, while the lower line shows only Good water quality samples.

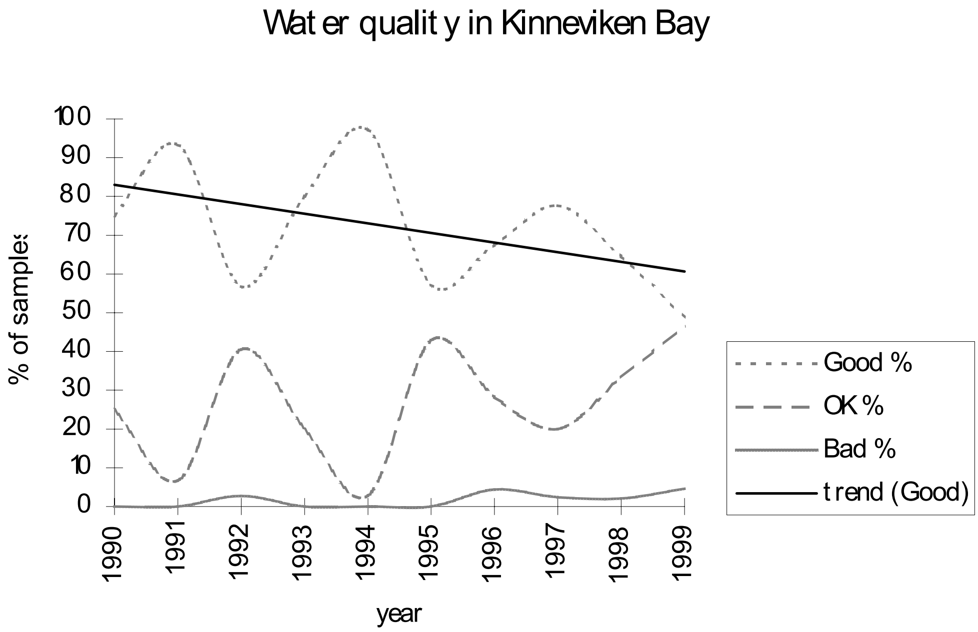


Fig. 4: This graph shows that water quality (content of microbacteria) of the water in Kinneviken Bay has fluctuated wildly during the decade but that there is an overall trend towards lower quality.

THE KARTÅSEN DUMP

Another health concern is related to the proximity of the Kartåsen dump. This dump has previously received various kinds of materials, from household garbage to industrial wastes (Hörnfeldt, 1999). It is still actively used, but with sorting and, when possible, recycling of materials. The leachate from the dump area contains high levels of salt, nitrates and iron plus an unknown amount of toxic chemicals (*ibid.*). If the leachates are not treated, these substances will eventually reach Lake Vänern through the groundwater. At present different possibilities of reducing these substances are under discussion but no measures have been decided upon. The water from the dump might have adverse effects upon both the Östra Sannorna area and the lake, but if the Östra Sannorna is completely or partly cleared of vegetation the negative effects on lake water quality might be even greater. This would result from the "cleaning capacity" of the vegetation being removed, and would probably mostly affect nitrogen content; since this nitrogen does not come from farmland but from the close-by dump, it could not be reduced by the measures discussed above.

EVALUATION OF EXPLOITATION ALTERNATIVES

A possible (further) exploitation of the Östra Sannorna area would depend on several factors, needs and money being the most important although natural values will certainly play a part in the decision as well. In the case at hand there is a need for housing (pers. communication, Kjell Holgersson, 1999) wherefore residential areas are considered, and the beach has been suggested because there is a wish to make the city and the municipality more attractive to its present and possible future inhabitants. The third exploitation alternative is a combination of these two, which would solve both the housing and the aesthetic needs of the municipality. For the evaluation of these different alternatives for land use in the Östra Sannorna area, models (a diagram and a computer model) have been developed that are based on the reasoning expressed below the following scenario descriptions. I hope that this assessment will provide some guidelines for the respective effects of the different alternatives, and supply a basis for making appropriate decisions.

SCENARIO DESCRIPTIONS

1) Residential

This scenario is, together with the beach scenario, based on a shared vision of the two neighbouring municipalities of Lidköping and Götene for an area along Lake Vänern that includes the Östra Sannorna area.[5] The measures discussed for Östra Sannorna is an addition to the settlement in Filsbäck at the easternmost end of the area (see Fig. 5) and cutting the forest in a couple of places, to provide a view of the lake from the road. At the same time, the large road (Riksväg 44) should be moved southwards (i.e. away from the Sannorna area) since the traffic is not wanted inside an expanded Filsbäck settlement. The maximum size of residential area would probably be about 40 ha (1/3 of the total area).

The immediate ecological consequences of this ought to be a locally drier soil, perhaps with risk of erosion of the sand-dunes, and in the easternmost part, where the residential buildings would be placed, a more extensive change of the conditions, with removal of vegetation, drying up of the ground through ditching and more people moving through the area. From an economic point of view, preparing this area for housing (providing plumbing and electricity) would entail some costs but the investments would most likely be returned when the land is sold. It might also bring increased revenue to the municipality through taxes from the people moving to the area. The "sight gates" through the forest, on the other hand, would have to be maintained regularly for some cost and the moving of the road is an investment in convenience and safety, that will not be paid back in money.

[5] Municipal document; *Gemensam vision för område vid Kinneviken i Lidköpings och Götene Kommuner*, 1996. The scenarios of this study are *not* the exact visions described in the document.

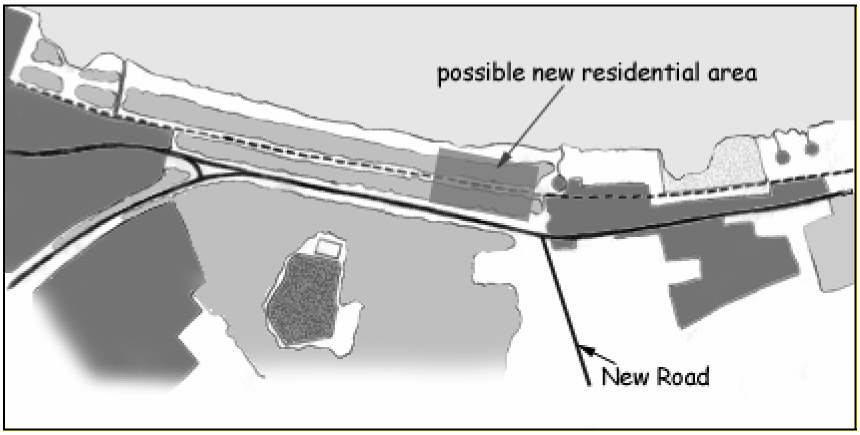


Fig. 5: A map showing how a new residential area with both physical and visual proximity to the lake could be planned, without fragmenting the remaining lakeshore forest. (For legend see Fig. 1.)

2) Beach

In the beach scenario (Fig. 6) the Östra Sannorna area should be made into a kind of "Riviera" - a continuous beach from Lidköping to the smaller community Källby, in the neighbouring municipality. The reeds would have to be cut down and the ground closest to the lake "put in order". These measures would enable a use of the area for several recreational activities; walks, bathing, boating and camping. In this case the proximity to the Lidköping Golf course would be another attraction. If this scenario was implemented successfully and on a large scale, there is no doubt that the numbers of people using the area would increase (otherwise it would not be a success). This, together with the physical changes, would significantly alter the living conditions of especially the species dependant upon the present eco-system. Exploitation of the entire area, for this "Riviera", has been discussed, but the County Board has objected to the total removal of the marshy forest because of its ecological value (pers. communication, Gösta Nilsson, 1999). Thus, in this scenario it is estimated that a maximum of 80 ha would be exploited.

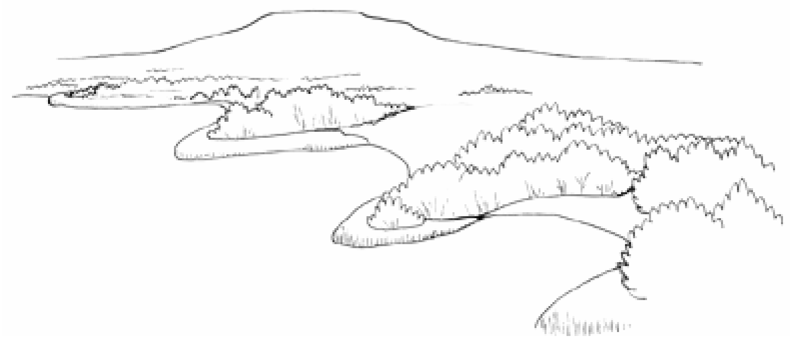


Fig. 6: A sketch of an Östra Sannorna with alternating beaches and untouched areas, and with sight gates between the beaches so that one may get a view of the lake from a distance, while the beaches are cut off from the road and view by a tree curtain.

3) Combination

The last case would be one of both residential and beach areas. In this scenario the beach and residential areas will occupy approximately the same amount of land (40 + 40 ha, for simplicity reasons in modelling) and the beach would most likely be located in close proximity to the houses. This could leave at least one third of the area intact and in one piece, for biodiversity and other wetland values to be preserved. Consequences would be expected to be the same as above but on a smaller or larger scale depending on the interaction of the effects of the different exploitation types.

IS THERE A NEED FOR THESE ALTERNATIVES?

If no beach was constructed in Östra Sannorna, what other alternatives for recreation and tourism are there to make up for this? As mentioned, there are beaches at both ends of the area. There is another beach, in close combination with an outdoor swimmingpool, at the other side of the city Lidköping. For both tourists and inhabitants there are plenty of places to go in the municipality, and the surrounding countryside. There is a golf course, harbours for small boats, walking tours, many historical sights and other places of interest, as well as museums of different kinds. In the summertime there are, furthermore, exhibitions in the baroque castle Läckö, situated about half an hour's drive from Lidköping. The nature around Läckö, as well as Mount Kinnekulle (half an hour's drive in the other direction, from the city) are considered very beautiful and are popular destinations of excursions. This shows that the municipality is not lacking attractive sights and recreation areas. The lack of houses for an increasing population constitutes a greater problem, but one may ask if all inhabitants need to live in Lidköping? The Physical Plan of 1991 states that the on-going depopulation of the countryside should be counter-acted, and if this was done successfully the pressure on the town area would most likely lessen.

INTERACTING FACTORS

A simplified map, of how different factors relating to economic, social and ecological consequences of an exploitation of the Östra Sannorna area affect each other, is presented in Figure 7. Several factors, here considered of lesser importance for the evaluation, have been omitted from this, so called, *causal loop diagram*, for example the reasons for exploitation. Others have been simplified into one mutual factor, such as "disturbances" for noise, erosion, pollution etc., caused by humans in the area.

Economic Factors

The economic factors included in the above figure, as well as the computer model, are those of direct costs of construction and direct incomes from the areas, plus the incomes from tourists visiting this area. The costs of moving the road Riksväg 44 are not included, and neither are maintenance costs. The figure shows that a residential area will yield income through taxes paid by the new inhabitants, while incomes from a beach would depend upon whether the tourists prefers the beach or the wetland. Since the area is quite inaccessible at present, incomes will most likely increase with either of the three exploitation alternatives. But, as mentioned, there are also costs involved, at least initially. The influence upon the municipality's decision regarding the area, that expected expenses and incomes would have, are not included, since the decision in itself is not included as a factor.

Social Factors

The number of people using the area mostly depends on what it is used for and how much it is liked. Beach (and the tourists the beach could attract to the area), residential buildings and the natural values (appreciated for recreation and education) would all increase the value of the area for humans (the anthropocentric value) and thus attract more people. The people visiting this area would, in return, have an impact upon the character of the area and therefore also upon its natural and anthropocentric values. The effect people have upon each other have here been omitted (people might, for instance, prefer to go someplace else if they find the new beach too crowded or want to live someplace else if their neighbours are disturbing them too much). The effects on wildlife have been summed up in “disturbances” and, as mentioned above, this includes noise, erosion, pollution etc. These will affect the wildlife in a negative way. It is possible that some species might benefit from the presence of humans, but to benefit a few species instead of a multitude is not a gain to the biodiversity of the area. That aspect is therefore not included. One could say it is the over-all effect that is considered here.

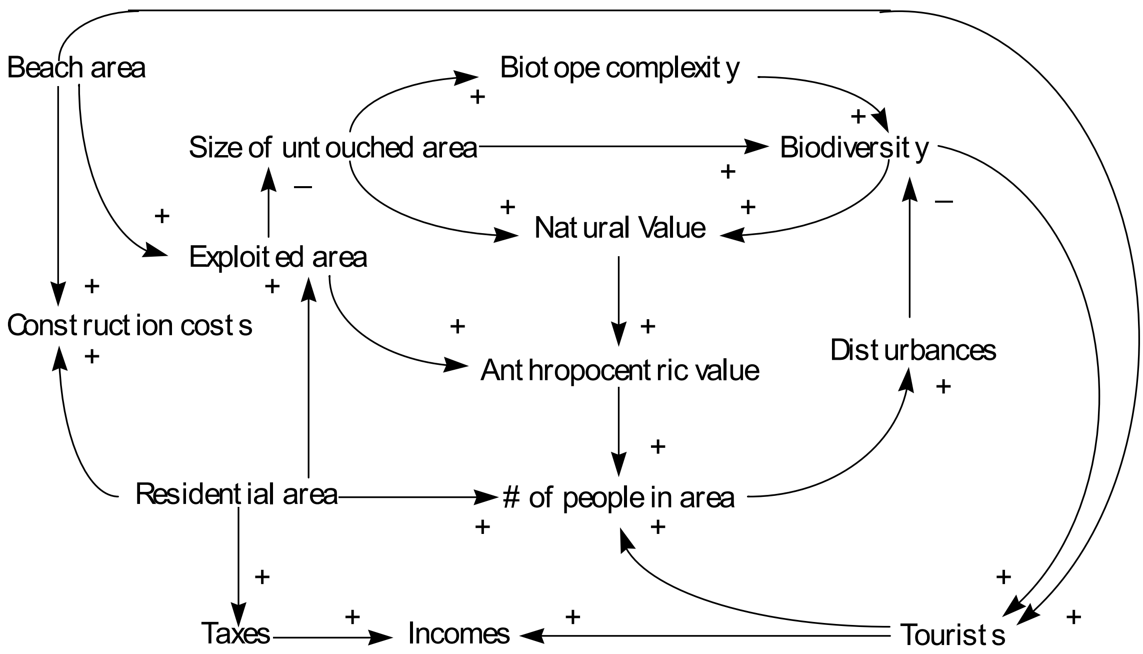


Fig. 7: A map of inter-relationships in the Östra Sannorna area. Arrows show how each factor influences the others. Plus and minus signs denote whether an increase in a certain factor will lead to an increase or a decrease in the next factor along the chain. For a further explanation see the text.

Ecological Factors

If we make part of the area into beach, or build houses upon it, the size of the unexploited area will decrease. This directly affects the “natural value”: the bigger the area the higher its value. The value would, however, not increase linearly with the size of the area. At a certain point the value stops increasing with size; this would be the case when the particular eco-system type is so widespread that it can be considered common. This natural value is also affected by the biodiversity of the area; most species will benefit from the presence of other species in some way or other. The natural value as used here, is distinct from the anthropocentric value, which is what we humans value in our environment (for a further discussion on these values, see page 14). However, it is impossible for a human being to be objective and not focus on anthropocentric values, even when looking at natural values. Therefore, the natural values mentioned in this study will mostly be values that are both natural and anthropocentric.

Wildlife and plant biodiversity can be defined in several ways, the most common probably being those of species diversity, genetic diversity and ecological (eco-system) diversity (Miller, 1998). The term biodiversity as used here, entails both species diversity (number of species in the area) and number of individuals within each species (in a sense, this is what is usually called genetic diversity, although here it is not the genetic variation but the "commonness" of the species, that is considered - note that this means that it is an anthropocentric way of valuing biodiversity).

The biodiversity depends to a great extent upon what I call *biotope complexity*. The term is here used to describe the variation within the Östra Sannorna eco-system. In Östra Sannorna there are grossly seven different "sub-systems" with varying vegetation and ground moisture characteristics (see Fig. 8 for a simplified map). Since there is a large variation within the area, this means that there exists a greater number of for example tree species in the total area, than there would if the vegetation had been more uniform. This also enables more animal species to survive here, and since both plants and animals are included in the biodiversity concept, it follows that a greater biotope complexity leads to a greater biodiversity.

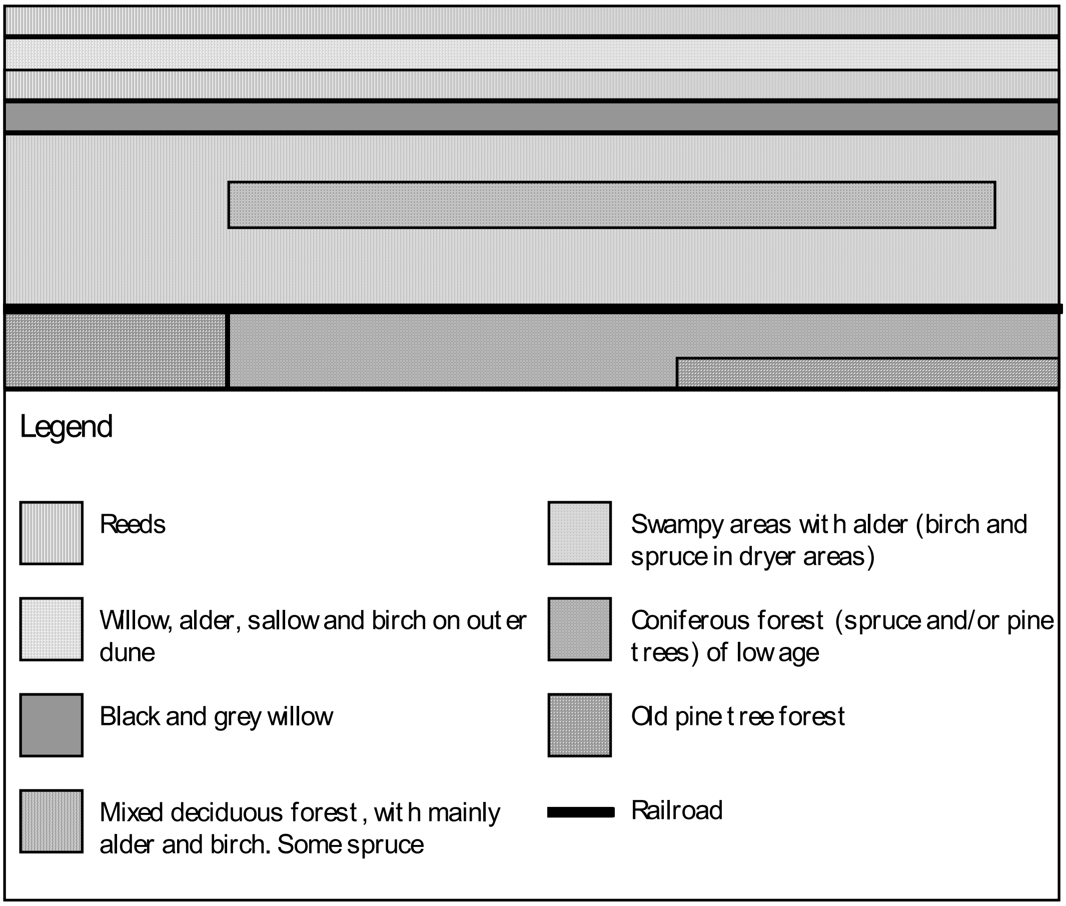


Fig. 8: A schematic simplification of the Östra Sannorna vegetation as described by Arne Stagen in 1994.

From this reasoning follows that whatever is done with the area of Östra Sannorna, it will not only affect its value of nature but also its value for inhabitants and tourists in the Municipality. This change is not necessarily all for the worse or all for the better, and the result depends very much on how the above discussed factors interact.

NATURAL VALUES AND ANTHROPOCENTRIC VALUES

The view held throughout this paper is that an "untouched natural area" (or reasonably untouched, where most people would not even see the impact of human actions) has an intrinsic value (equal to the "natural value" in the diagram of Fig. 7) that decreases as the area is exploited for human purposes. As exploitation proceeds humans also create new, anthropocentric values. These values can carry considerable importance for people although they are rarely significant for other species. Examples are farmland that gives us food but creates a monotonous eco-system, or certain buildings that become valuable to us only after they have existed for many years, perhaps centuries. Occasionally an anthropogenically induced small change in the environment leads to increased natural values. Changes are inherent in nature and changes as such do not alter the total natural values of an area. Oscillating conditions such as fluctuations in predator-prey populations are necessary for a long-term survival of an eco-system (whatever their short-term effects) and a "steady state" will, in any natural system, always be interrupted by social, biological or physical processes (Clements, 1995). A change in climate, for example, might prove fatal for one species but on the other hand it would probably also benefit another species. Thus, it is mainly when an already exploited area is changed in a way that increases multiple use values and improves the living conditions for other species, not only humans, that a natural value can increase. This is attempted more and more in society, since the Rio Conference in 1992 and the development of Agenda 21.

One could argue that someone has to set the value, be it natural or anthropocentric. This, however, is based on the assumption that all values are known. My opinion is that things might have great values to us although we have no knowledge of them. Before vitamins were known they were still vital for our well-being. Thus, values exist regardless of our awareness of them. This also means that values exist not only for humans but for animals, plants and entire eco-systems. Natural values would thus be all values that are created and maintained independently of human actions, whereas anthropocentric values would be all values that affect humans. Consequently, natural and anthropocentric values often overlap. Still, as mentioned previously, the intrinsic values that we *see* are usually also anthropocentric values, since we cannot but view nature through our human eyes. These two kinds of values, *Natural values* and *Anthropocentric values* (or *Value for people*, which it will also be called here) are interconnected in many ways and link together the natural environment - of which humans are but a part - and the human environment which in a sense exists more in the minds of people than in the physical world[6].

Values for people are, as explained previously, measures of an area's preciousness for humans, due to both anthropogenic structures and uses. Even if the area is not used for e.g. forestry, farming or industry it may have values for us, because of its beauty and recreational values of importance for human health, the value as a biogeochemical stabiliser for e.g. nitrogen fluxes, the research possibilities it offers etc. Thus, a high natural value usually increases the value for people.

The above discussion on values is closely related to the world view held by the *Deep Ecologists*. According to Deep Ecology, all life on earth is interrelated and interdependent to such a degree that "nature and the self are one" (Capra, 1996, p. 12). The belief that all life possess an intrinsic value regardless of it's usefulness to humans, is central in this movement (Miller, 1998). As in any world view there are variations within the whole. Thus, not all Deep

[6] That is to say, that our feelings, moral judgements, political or religious convictions etc. are without physical form, but they will still affect the perceptions and actions that shape our individual environment.

Ecologists would argue, as is done here, that even eco-systems (i.e. non-living things) have intrinsic values. Likewise, I would not go so far as to say that the self is the same as nature. As Miller (1998) puts it: "We need the earth, but the earth does not need us".[7]

There are many other views on nature than the above discussed. In the western world we have traditionally (at least since the 16th century) had a very anthropocentric view of nature (Smith, 1998). It is there for our use - for us to conquer. Nature is seen as a raw material without beauty and utility until we shape it after our own liking. Figure 9 shows three ways in which we view and value nature.

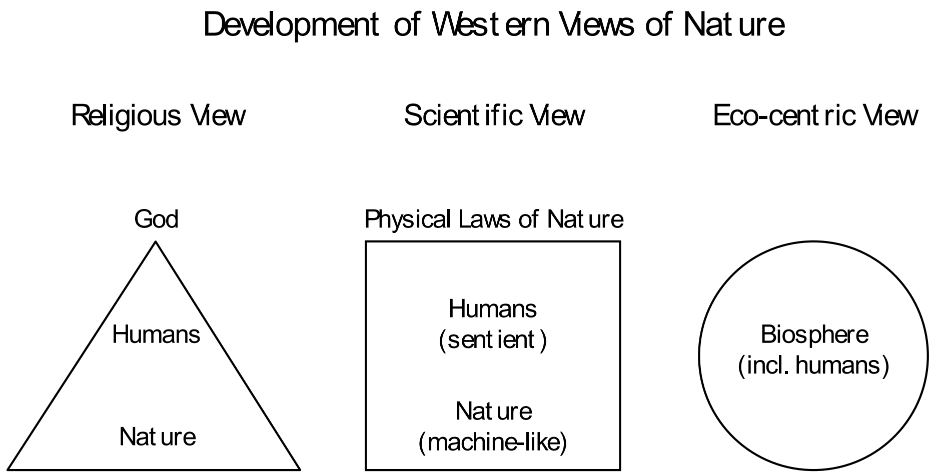


Fig. 9: Natural values - the way in which we have, and still do, value nature in relation to ourselves, in the western world. (Inspired by Smith 1998.)

The religious view is based upon the story of creation, as written in the Bible; man was created after God's own image and set to rule over the world and all that was in it. This view is often blamed for the exploitation of the world around us. Since the world, in this case, belongs to us - is our property - we have the right to do whatever we please, to it. But having a dog and having the right to kick it is rarely considered the same thing. Likewise, the passage from the Bible can be interpreted as God making men and women into guardians of the planet, rather than its despots. According to this view, God gave us the *responsibility* for the well-being of the planet (*ibid.*). And that people did not always consider man as "closer to God" (or more worth) than animals is shown by the trials that took place during the 13th to 18th centuries (at least some ten trials in France) where the accused animals - the animals never raised any charges against humans - had their own defenders and often won the cases with the argument that God created both man and beast and therefore both have the same right to life and livelihood (Ferry, 1997).

A more scientific worldview might place man in the tree of evolution, but most commonly he is then also crowned King and declared the perfect species. Humans are still considered distinct from other animals because of their intelligence and ability to feel emotion. They are better than animals, who are considered to function merely like machines (Smith, 1998). Instincts have a lesser value than logical thought. The perspective is still anthropocentric and

[7] Miller uses this phrase (on page 751) to explain the beliefs of the *Earth Wisdom Worldview*, of which Deep Ecology is a part.

still places nature at our disposal. But science has also shown that "man and beast" are not as different as we once thought, and perhaps this has led the way towards the more eco-centric view where, at long last, humans are placed alongside their fellow-beings instead of above them. This last view is, as previously stated, the view held in this study; that humans are - although very influential - but one part of nature, not the owners of the world.

Economic Values

However important the intrinsic values of nature are to many people today, the economic factors often have had sovereign rule over the other factors, in past years. Although environmental issues are now gaining in importance there is still a risk that it is mainly the economic factors of cost and gain that are considered. This is, I think, one main reason for many marshy areas disappearing - they are considered useless and un-economic if left as they are.

One way to avoid overexploitation of a natural resource for short term economic gain is to assign an economic value to the resource, e.g. based on the services it can be said to provide society with. In a wetlands area such as Östra Sannorna this could be the services of:

- denitrification, reducing the amount of nitrogen entering the water of Lake Vänern and thus reducing subsequent problems due to high nitrogen loads in lake and sea waters;
- recreation, reducing the costs of healthcare and increasing people's productivity;
- biodiversity and tourism - for example the birds in the area would attract ornithologists who will pay for food and housing during their stay, increasing the revenues of the Municipality.

Although the practise of pricing natural resources in this way is a positive development leading to less overexploitation and destruction of the resources, one should keep in mind that they are not exact. Often, the economic values of "standing natural capital" are underestimations - simply because we do not know enough to define and evaluate all services provided and because there are values which cannot be measured in dollars or SEK.

Construction of the Model

To evaluate what changes might occur, in the present conditions of Östra Sannorna, if the area is exploited according to one of the three scenarios discussed above, a computer model was developed, based on the causal loop diagram in Fig. 7 (page 12). The model and the exact equations used can be found in appendices I and II respectively. The model was built in five sectors, or parts, to facilitate the correct transformations between differing units (Areas/ha, Economy/SEK, People/#, Biodiversity/indexes and Values/indexes). The evaluation focuses, however, on the same three main spheres as the causal loop diagram; social, economic and ecological consequences.

The Economy Sector

As the relationships in the Area Sector are very straight-forward (unexploited area = total area - exploited area; unit ha) I will not explain that reasoning further, but move directly onwards to the Economy Sector. As in Fig. 7, the effects of possible and actual incomes and expenses are not included. The incomes are the sum of sales (of land for residential use, scenarios 1 and 3, at the approximate price SEK 100.000/750 m^2 [estimated by employees at the Municipality Office in Lidköping.]), taxes from the people living in the residential area and incomes from tourism in the area. The tax income is based upon the assumption that, on average, half the inhabitants pay taxes (e.g. the two parents in a family of four) and that their income is some 20 000 SEK/person and month. (The municipal tax is approximately 20% of the salary.) The incomes from tourism are based upon the numbers of tourists to the municipality - about 600 000 a year[8] - and the yearly net income to the municipality from tourism - nine million SEK (pers. communication, Torbjörn Ziegler, 2000; figures from 1997). This gives a net income per tourist, of SEK 15.

The expenses only include construction costs; maintenance costs have, as already mentioned, been omitted. The construction costs of beach have been estimated at 25 SEK/m^2 or 250 000 SEK/ha (by employees at the Municipality Office). The costs for constructing a residential area have been estimated as reasonably close to the sales prices. This means that what the municipality spends on the residential alternative, they would probably get back - with a minor delay (which has been made into one year, in the model).

The People Sector

Measuring the number of people in the area constitutes a certain difficulty. For one thing, there is no knowledge of how many people visit the area today. For another, there is a difference between the kind of visits made to a beach and to a residential area. In scenario 1, people would live there and spend much of their time there. Each inhabitant is in the model counted once. In scenario 2, people would come to the beach on days with sunny, warm weather. Each *visit* is counted, not each individual. This means that the measures are in reality different and that they could perhaps not be compared. However, this has been found to be the least complicated solution and it is my belief that the estimates of people in the area have been made so as to minimise this problem. Each person/visit will also cause some disturbance to the wildlife of the area, decreasing the biodiversity index somewhat.

The total number of people/visits is made up of inhabitants from scenarios 1 and 3, people living in the municipality who visits the beach of scenarios 2 and 3, or visits the area for other reasons (included in visits due to anthropocentric value) and tourists. The inhabitants, in case of a residential area in Östra Sannorna, are estimated to be some 50/ha. This is the approximate main density when comparing between the population of the city Lidköping (divided by the city area) and the population of the entire municipality (divided by area).

The tourists are attracted both by beach and biodiversity. Since the most popular vacation targets (according to Torbjörn Ziegler, pers. communication, 2000) in the municipality are historical sites (Castle Läckö, the porcelain factory Rörstrand, museums and churches) and "nature sites" (especially Mount Kinnekulle in the neighbouring municipality) I have given the biodiversity of the Östra Sannorna area a somewhat greater "attraction power" than the beaches. The beaches would no doubt be visited if they were there, but they would hardly serve to attract more tourists to the municipality.

The Biodiversity Sector

The biodiversity index is influenced by area size, biotope complexity and the amount of disturbance caused by visiting people; it should be interpreted as an index of possibilities for

[8] This is actually not 600 000 individuals, but 600 000 "day-visits" but since tourists are here measured in the same way, the net income per tourist will remain the same.

the wildlife to be healthy and diverse rather than an indication of number of species. The relationship between these factors is somewhat complicated:

Biodiversity Index = biotope complexity (effects) • area size (effects) - disturbances (effects)

The biotope complexity of Östra Sannorna is, as mentioned earlier, considered to be “7” (compare Fig. 8), i.e. there are seven subsystems in this area. To use this in the model it has been estimated that each 20 ha of the area enables the existence of one such subsystem, thus the biotope complexity of the model equals unexploited area divided by 20. The area size will itself affect the biodiversity; even if there had been only one subsystem there is a greater possibility to find more species in a greater area than in a smaller one. Here, the relationship *area•10 = biodiversity•2* is used and made into a graph (Bernes, 1994). Multiplying this with the biotope complexity’s influence on biodiversity, means that a larger area with high complexity will hold more species than a smaller area with the same complexity.

The Values Sector

Finally, the model simulates the development of the two formerly discussed values - natural values and anthropocentric values. The natural value is here simplified (as humans can never achieve an objective measure of all - or any - natural values) to be influenced by biodiversity index and unexploited area size, only. The natural value in turn, influences the anthropocentric value, together with the value of *exploited area* - not the unexploited - since the value for people will also be influenced by human structures and uses (as mentioned earlier). This means that the anthropocentric value may increase although natural value decreases, or vice versa, depending on circumstances.

Remarks

Since changes are considered natural to any system, it is not attempted here to simulate effects of further reed growth etc. This means that if the model is run for an “as-is” scenario, it will show no changes at all. Further, since some of the data to be simulated is based upon assumptions (especially the people visiting), the results should be interpreted qualitatively rather than quantitatively.

RESULTS

The three scenarios have been compared to one another, in terms of costs and incomes, anthropocentric value, natural value, biodiversity index and total people (or visits) in the area. The model have also been used to investigate the effects of the different exploitation types on different scales, i.e. from 0 to 130 ha. This test showed that the three scenarios only differ greatly in the amount of visitors they would bring to the area, if the same area size was exploited. (Compare Figs. 10 and 11.) The results from that comparison also show that the effects upon the environment generally becomes greater, when more than 40 ha of the area are exploited.

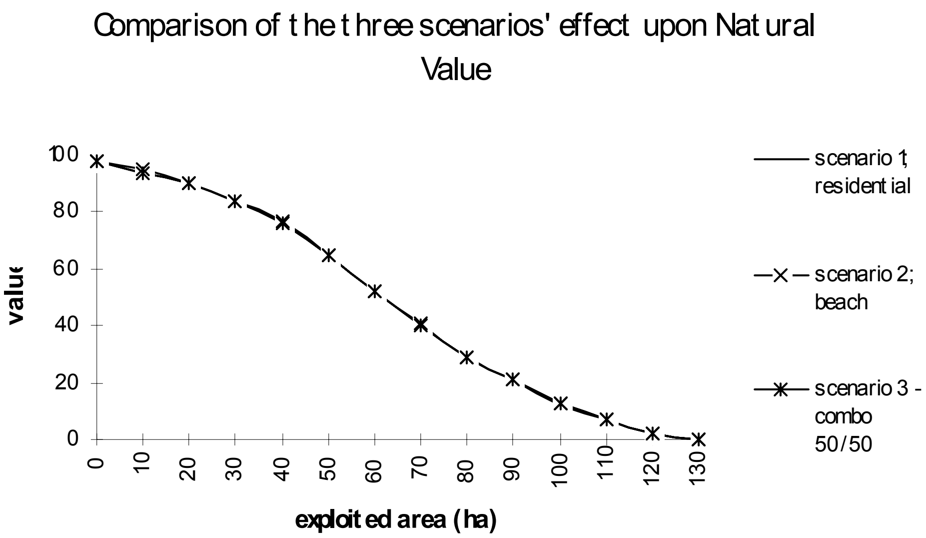


Fig. 10: Showing the similarity in the decrease of natural value with exploitation between the three scenarios. The changes in anthropocentric value and biodiversity index show the same similarity.

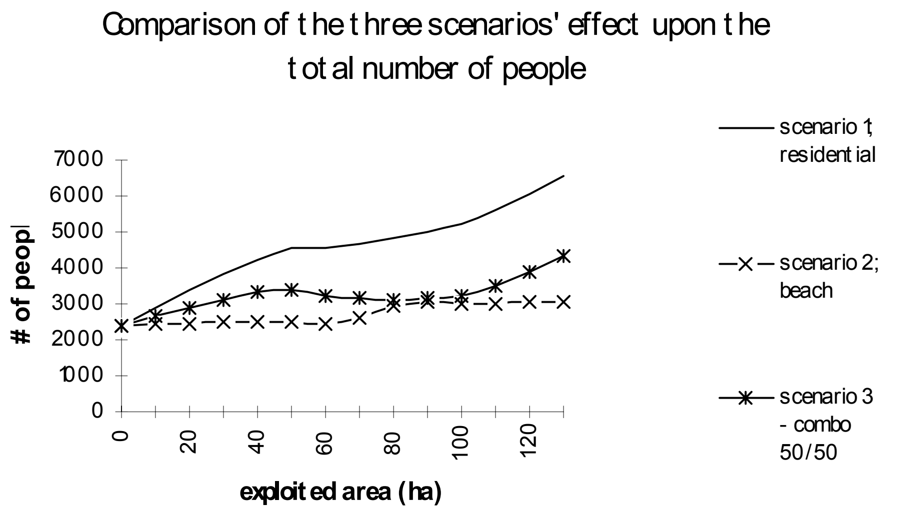


Fig. 11: This figure shows that the different scenarios will attract differing numbers of people to the area, residential clearly attracting the most.

Economic, Social and Ecological Consequences of Exploitation

When comparing the three described scenarios, with their differing sizes, the results are more diverse. A comparison of the costs and incomes for the alternatives show that although the residential alternative is more expensive than the beach, the costs will be repaid, when the land is sold. The beach on the other hand, will not be able to repay the cost of construction since the incomes generated are too small. The model even shows that incomes from the area might decrease, if the beach alone is constructed. (See Table 1.) The combination scenario shows approximately the same results as the residential; it is slightly more expensive, but the residential incomes will repay all the costs involved.

Table 1: A list of the construction costs for the three scenarios, the time it will (according to the model) take before the incomes from the area will cover the costs of exploitation and yearly incomes before and after exploitation.

Scenario	Construction costs (SEK)	Years to repay	Yearly income before expl.	Yearly income after expl.
1 - Residential	53,2 million	"1"*	30 000	48 million
2 - Beach	20 million	>50	30 000	23 000
3 - Combination	63,2 million	>1**	30 000	48 million

*) The costs will be paid back at the time of sale - in the model this happens after one year.
**) In the combination scenario it will take slightly longer since the cost is greater, otherwise as above.

The social factors, anthropocentric value and number of people moving through the area, both show an increase for the residential alternative. The beach and combination scenarios show a similar effect on these two factors, because of their similarity in size; the anthropocentric value goes down (affected by the loss in natural value) but the number of people in the area increases. The increase is, however, not as large as that for residential. (See Fig. 12 for anthropocentric value and Fig. 13 for the number of people in the area.)

Both the natural value and the biodiversity index are simplified as concepts, in the model, and are strongly influenced by the remaining unexploited area. Both values will therefore decrease with exploitation and, as above, the second and third scenarios cause the greatest drop. Looking at the change in natural value with scenario (Fig. 14) one finds that the decrease in natural value for the two larger exploitation alternatives is not simply twice as great as that of the residential scenario (which is half the size of the other scenarios). In the case of biodiversity, the drop is nearly twice as large for scenarios 2 and 3 (Fig. 15).

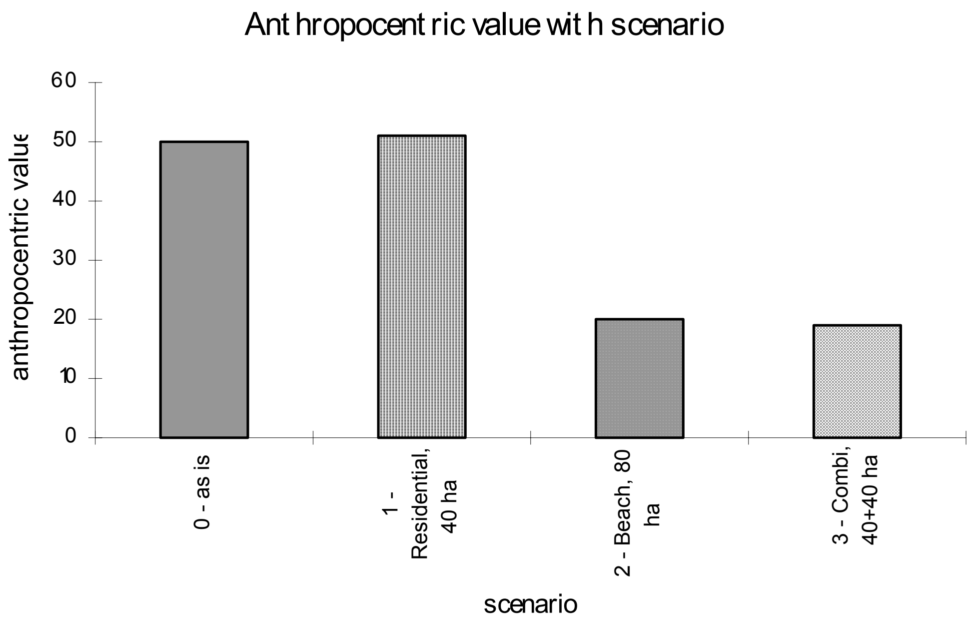


Fig. 12: A comparison of the anthropocentric value as it is affected by the three exploitation alternatives. The "as-is scenario" is shown to make the comparison clearer.

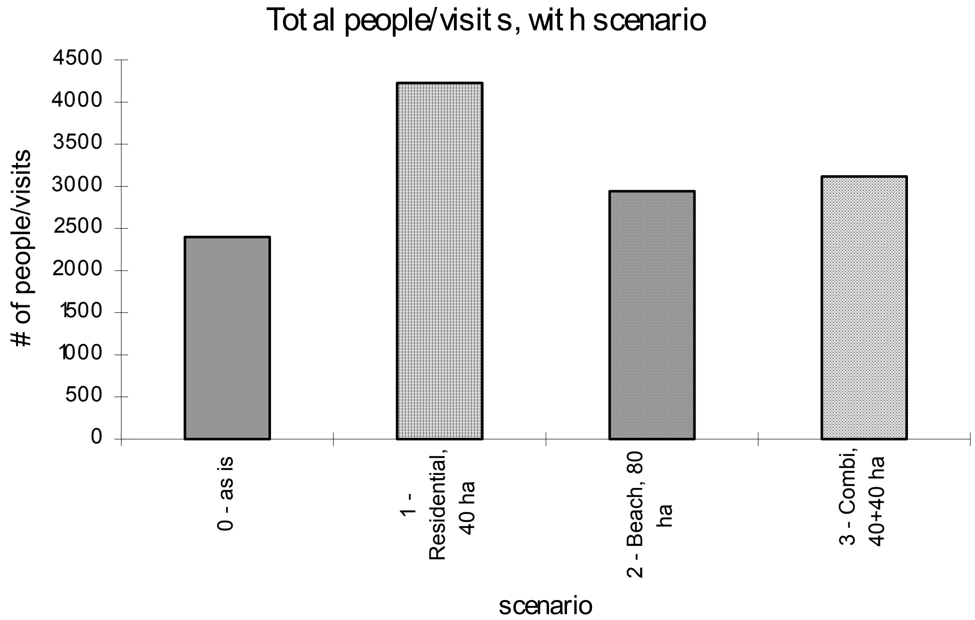


Fig. 13: This diagram shows that the residential scenario clearly will bring more people to the area than the other scenarios, but that all scenarios will increase "traffic". Note that the third scenario is not a simple addition of the two earlier scenarios; the large exploitation means that other people will visit the area *less* than they do now.

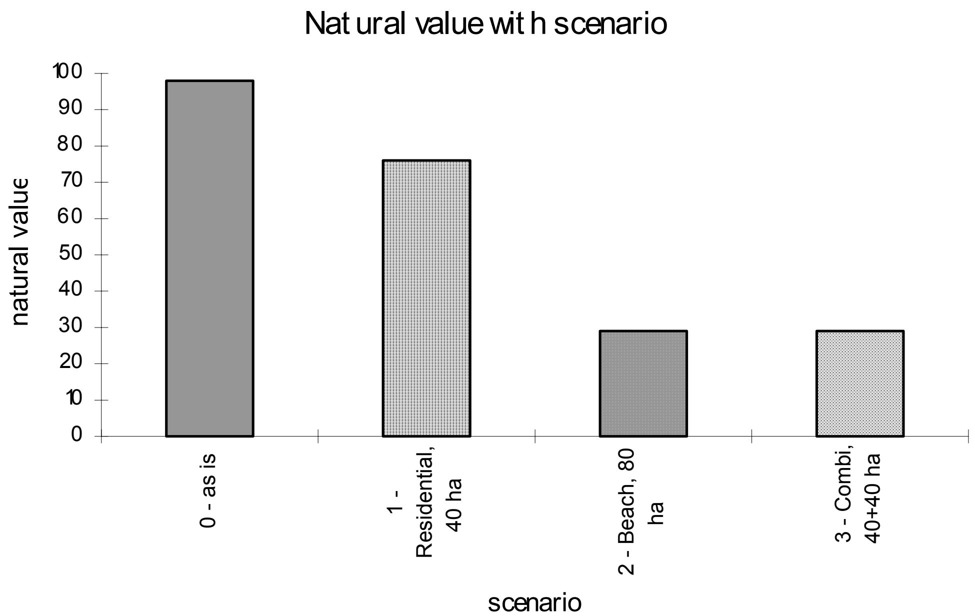


Fig. 14: The effect on natural value depends greatly upon exploitation area; all scenarios will cause a decrease, but the two larger ones (both on 80 ha) will cause the greatest drop in value.

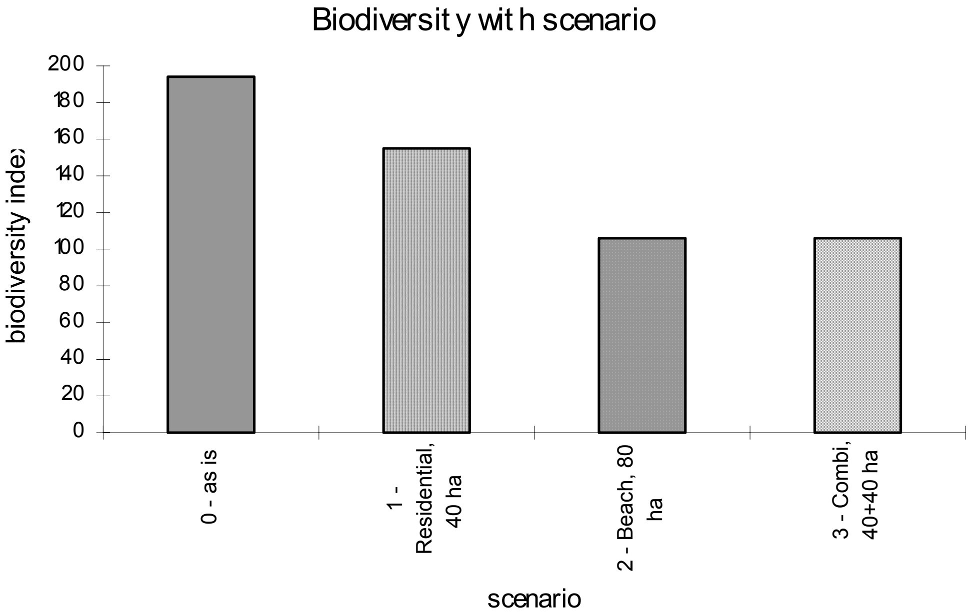


Fig. 15: Like the natural value, in the figure above, the consequences on biodiversity are linked to the remaining size of untouched eco-system. Again, the residential scenario of 40 ha, causes a smaller decrease than the other two.

DISCUSSION

It seems clear, from the above results, that a large-scale exploitation of the Östra Sannorna area would not be sustainable neither socially nor ecologically. The beach scenario is not even economically sustainable, but then the idea of making the area a beach, was perhaps not meant to be economically profitable. According to the model results, it seems that an expanded settlement at Filsbäck is the least degrading alternative. (One could, perhaps, choose to make a smaller beach in the area, than what scenario 2 implied.)

One should keep in mind that a computer model is only capable of supporting, never replacing, human judgement. Several issues which the computer model excludes have been addressed in this paper. They include the possible unsuitability of the area for beaches because of the lake water quality (both due to leachates from the Kartåsen dump, and microbacterial content), the importance of areas such as Östra Sannorna for nitrogen reduction and the actual problem of high nitrogen loads in the lake, as well as the current distribution and legal protection of wetlands in Sweden.

As a recapitulation, wetlands are not as rare in Scandinavia as they are in many other European countries, but they are not well protected. Wet forests especially, are threatened, in spite of their value as for example refuges for many species. Further, I feel that the Swedish environmental protection law is too weak and that it prioritises economic interests. It would only allow protection of a 300 meters wide area along the lake, whereas the area concerned is 500 meters wide. This means that, if the municipality wants this area to be protected, they need to make it into a nature reserve. Considering that the nitrogen problems in Lake Vänern and at the west coast might make the production of artificial wetlands necessary, it seems unwise to remove what wetlands there already are. Besides the computer model results, the proximity to the Kartåsen dump, and the problem with bacteria in the lake water add further reasons for not constructing a beach in the area. These problems would need to be addressed before any decision upon beach construction was made.

All the mentioned factors point towards the conclusion that although a small-scale exploitation might be acceptable, protecting and preserving the area as it is would be preferable. Therefore I think it is important that the municipality of Lidköping follows its own policy of biodiversity protection, water quality protection and the aim to be a role model in environmental work, by making Östra Sannorna into a nature reserve.

CONCLUSIONS

- The Östra Sannorna area could possibly be classified as unique. This means that it is a valuable resource that the municipality and its inhabitants should appreciate and treasure.
- I recommend not exploiting the Östra Sannorna area and, if possible, ensuring protection of the area by making it into a nature reserve, like Arne Stagen suggested in 1994.
- If the municipality does decide to exploit the area, the part affected should not exceed 40 ha and the remaining area should definitely be protected from future exploitation.
- No exploitation, or decision of exploitation, should take place without a prior inventory of species (plants, animals, fungi etc.) in the area.

ACKNOWLEDGEMENTS

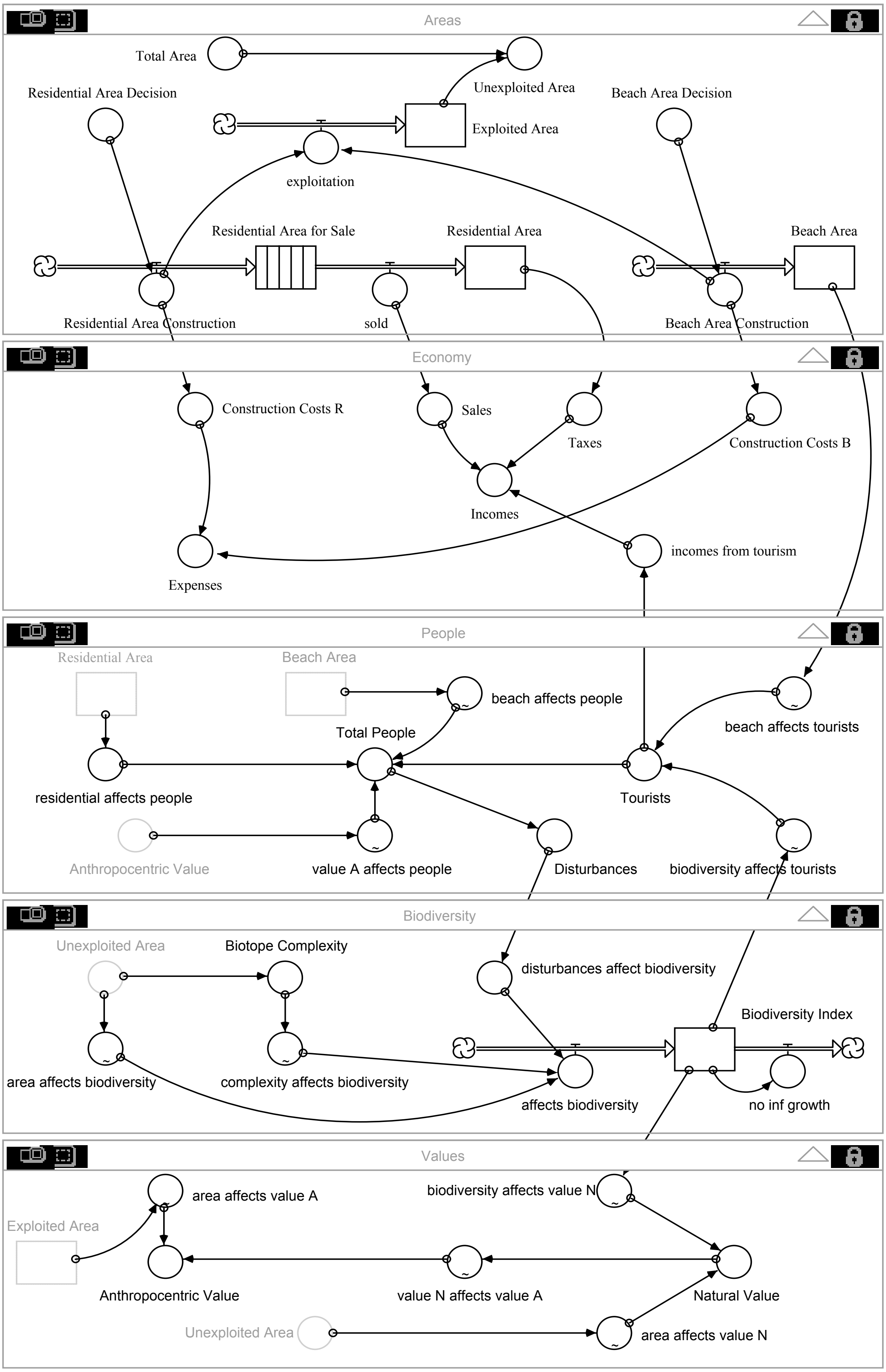
Many thanks to everyone who has helped me with information. Special thanks to Yvonne Träff and Kjell Holgersson at the Municipality of Lidköping, and to Bengt Nihlgård and Christer Kalén at Lund University for valuable and much appreciated comments.

REFERENCES

- Bernes, Claes, 1993: Nordisk miljö - tillstånd, utveckling och hot. [State of, development of and threats to the Nordic environment] 211 pages. *Monitor 13*, Naturvårdsverket Informerar.
- Bernes, Claes (ed.), 1994: Biologisk mångfald i Sverige - En landsstudie. [On biodiversity in Sweden. Also published in English.] 280 pages. *Monitor 14*, Naturvårdsverket.
- Capra, F., 1996: *The Web of Life*. 347 pages. Doubleday.
- Clements, C. D., 1995: Stasis: The Unnatural Value. *In* Elliot, R., (ed.) 1995: *Environmental Ethics*, pages 215-225. (Reprinted from *Ethics, 86*, pages 136-143.)
- Eriksson, Kjell, Skogsstyrelsen. Tel. no. 070 - 379 61 95. Email: kjell.eriksson@svsvg.svo.se
- Ferry, Luc, 1997: *Den nya ekologiska ordningen.* [original title: *Le nouvel ordre écologique. L'arbre, l'animal et l'homme*; "The new ecological order"] 187 pages. Daidalos AB, Göteborg.
- *Gemensam vision för område vid Kinneviken i Lidköpings och Götene kommuner*, 1996 [Joint vision of an area at Kinneviken Bay in the municipalities of Lidköping and Götene] Lidköpings kommun & Götene kommun.
- Gundersen, P. 1991: Nitrogen Deposition and the Forest Nitrogen Cycle: Role of Denitrification. *Forest Ecol. Manage., 44*, pages 15-28.
- Holgersson, Kjell, Planarkitekt, Lidköpings kommun. Tel. no. 0510 - 77 02 23. Email: kjell.holgersson@lidkoping.se
- Hörnfeldt, Mats, 1999: *Lakvattenplan - en studie över lakvattenproblematiken vid Kartåsens avfallsanläggning*. [A study of the problems concerning leaching from the Kartåsen dump] Gatukontoret, Lidköpings kommun.
- Lönngren, Gabriella, 1995: *Våtmark - renare vatten och rikare livsmiljö*. [about wetlands for cleaning water] 68 pages. Naturskyddsföreningen & MOVIUM.
- *Miljöbalken* [The Environmental Code]. Retrieved from the World Wide Web, July 3, 1999: http://rixlex.riksdagen.se/ (SFS no. 1998:808)
- *Miljöförhållanden i Vänern i Skaraborgs län 1990*, 1991. [The environmental situation in Lake Vänern, County of Skaraborg, 1990] Länsstyrelsen i Skaraborgs län.
- *Miljöskyddslagen* [the former environmental protection law]. Retrieved from the World Wide Web, May 5, 2000: http://www.riksdagen.se/debatt/index.asp (SFS no. 1969:387)
- Miller, G. T. Jr., 1998: *Living in the Environment* (10^{th} ed.). 761 pages. Wadsworth Publishing Company.
- *Naturvårdslagen* [the former nature conservation law]. Retrieved from the World Wide Web, May 5, 2000: http://www.riksdagen.se/debatt/index.asp (SFS no. 1964:822)
- Nilsson, Gösta, Park och fritidskontoret, Lidköpings kommun. Tel. no. 0510 - 77 02 94. Email: gosta.nilsson@lidkoping.se
- Smith, Mark J., 1998: *Ecologism - Towards Ecological Citizenship*. 107 pages. Open University Press.
- Stagen, Arne, 1994: *Östra Sannorna*. Park och Fritidskontoret, Lidköpings kommun.
- Ziegler, Torbjörn, Head of Lidköping's Tourist Agency. Tel. no. 0510 - 77 05 50.
- *Översiktsplan*, 1991. [Physical Plan] Lidköpings kommun.

APPENDICES

APPENDIX I


Areas
Total Area
Unexploited Area
Residential Area Decision
Exploited Area
Beach Area Decision
exploitation
Residential Area for Sale
Residential Area
Beach Area
Residential Area Construction
sold
Beach Area Construction
Economy
Construction Costs R
Sales
Taxes
Construction Costs B
Incomes
incomes from tourism
Expenses
People
Residential Area
Beach Area
beach affects people
Total People
beach affects tourists
residential affects people
Tourists
Anthropocentric Value
value A affects people
Disturbances
biodiversity affects tourists
Biodiversity
Unexploited Area
Biotope Complexity
disturbances affect biodiversity
Biodiversity Index
area affects biodiversity
complexity affects biodiversity
affects biodiversity
no inf growth
Values
area affects value A
biodiversity affects value N
Exploited Area
Anthropocentric Value
value N affects value A
Natural Value
Unexploited Area
area affects value N

APPENDIX II

The values and equations of the Stella® model, at steady state (no exploitation).

Sector – Areas:
Beach_Area(t) = Beach_Area(t - dt) + (Beach_Area_Construction) * dt
INIT Beach_Area = 0 { ha }
INFLOWS: Beach_Area_Construction = Beach_Area_Decision

Exploited_Area(t) = Exploited_Area(t - dt) + (exploitation) * dt
INIT Exploited_Area = 0 { ha }
INFLOWS:exploitation = Beach_Area_Construction+Residential_Area_Construction

Residential_Area(t) = Residential_Area(t - dt) + (sold) * dt
INIT Residential_Area = 0 { ha }
INFLOWS: sold = CONVEYOR OUTFLOW

Residential_Area_for_Sale(t) = Residential_Area_for_Sale(t - dt) + (Residential_Area_Construction - sold) * dt
INIT Residential_Area_for_Sale = 0 { ha }
TRANSIT TIME = 1
INFLOW LIMIT = INF
CAPACITY = INF
INFLOWS: Residential_Area_Construction = Residential_Area_Decision
OUTFLOWS: sold = CONVEYOR OUTFLOW

Beach_Area_Decision = PULSE (0,8,1000)
{x ha beach area are constructed in 2008 (starting year 2000 + 8) and the pulse interval is set to 1000 to avoid any more construction phases during this model's runtime}

Residential_Area_Decision = PULSE (0,8,1000)
{x ha residential area are constructed in 2008 (starting year 2000 + 8) and the pulse interval is set to 1000 to avoid any more construction phases during this model's runtime}

Total_Area = 130 {ha}

Unexploited_Area = Total_Area-Exploited_Area

Sector – Biodiversity:
Biodiversity_Index(t) = Biodiversity_Index(t - dt) + (affects_biodiversity - no_inf_growth) * dt
INIT Biodiversity_Index = 194.78 {the value the model starts at}
INFLOWS: affects_biodiversity = area_affects_biodiversity*complexity_affects_biodiversity - disturbances_affect_biodiversity
OUTFLOWS: no_inf_growth = Biodiversity_Index

Biotope_Complexity = Unexploited_Area/20
{assuming each 20 ha allows one kind of biotope in this particular area}

disturbances_affect_biodiversity = Disturbances*0.001
{"one thousand people/disturbance units will cause a decrease by 1 in the biodiversity index"}

area_affects_biodiversity = GRAPH(Unexploited_Area)

(0.00, 0.45), (13.3, 0.522), (26.7, 0.594), (40.0, 0.666), (53.3, 0.729), (66.7, 0.783), (80.0, 0.846), (93.3, 0.891), (107, 0.945), (120, 0.99), (133, 1.04), (147, 1.07), (160, 1.11)

complexity_affects_biodiversity = GRAPH(Biotope_Complexity)
(0.00, 20.0), (1.00, 91.0), (2.00, 140), (3.00, 165), (4.00, 178), (5.00, 185), (6.00, 190), (7.00, 193), (8.00, 195), (9.00, 198), (10.0, 200)

Sector – Economy:
Construction_Costs_B = Beach_Area_Construction*250000
{constructing beach costs approximately SEK 25/m2 = SEK 250000/ha}

Construction_Costs_R = Residential_Area_Construction*1.33e6
{the construction costs approximately SEK 100.000/750 m2 = SEK 1.33e6/ha}

Expenses = Construction_Costs_B+Construction_Costs_R

Incomes = Sales+Taxes+incomes_from_tourism

incomes_from_tourism = Tourists*15
{Lidköping municipality recieves about 600 000 tourists each year, who bring a net income to the municipality of 9 million SEK}

Sales = sold*1.33e6
{the land is sold at approximately the price SEK 100.000/750 m2 = SEK 1.33e6/ha}

Taxes = Residential_Area*48000*25
{assuming there are on average 25 tax payers per ha and each pays SEK 48.000/year}

Sector – People:
Disturbances = Total_People
{each person causing 1 "unit" of disturbance, such as pollution, erosion, noise, etc...}

residential_affects_people = Residential_Area*50
{Assuming that, on average there will be 50 inhabitants/ha}

Total_People = residential_affects_people+beach_affects_people+value_A_affects_people+Tourists

Tourists = beach_affects_tourists+biodiversity_affects_tourists

beach_affects_people = GRAPH(Beach_Area)
(0.00, 0.00), (13.0, 15.0), (26.0, 50.0), (39.0, 123), (52.0, 248), (65.0, 530), (78.0, 1340), (91.0, 1690), (104, 1890), (117, 1980), (130, 2000)

beach_affects_tourists = GRAPH(Beach_Area)
(0.00, 0.00), (13.0, 15.0), (26.0, 50.0), (39.0, 123), (52.0, 248), (65.0, 455), (78.0, 665), (91.0, 840), (104, 940), (117, 985), (130, 1000)

biodiversity_affects_tourists = GRAPH(Biodiversity_Index)
(0.00, 0.00), (20.0, 15.0), (40.0, 50.0), (60.0, 140), (80.0, 340), (100, 690), (120, 1130), (140, 1590), (160, 1860), (180, 1960), (200, 2000)

value_A_affects_people = GRAPH(Anthropocentric_Value)

(0.00, 0.00), (7.50, 5.00), (15.0, 20.0), (22.5, 50.0), (30.0, 120), (37.5, 245), (45.0, 365), (52.5, 440), (60.0, 475), (67.5, 490), (75.0, 498)

Sector – Values:
Anthropocentric_Value = area_affects_value_A+value_N_affects_value_A

Natural_Value = area_affects_value_N+biodiversity_affects_value_N

area_affects_value_A = GRAPH(Exploited_Area)
(0.00, 0.00), (13.0, 2.50), (26.0, 5.00), (39.0, 7.50), (52.0, 10.0), (65.0, 12.5), (78.0, 15.0), (91.0, 17.5), (104, 20.0), (117, 22.5), (130, 25.0)

area_affects_value_N = GRAPH(Unexploited_Area)
(0.00, 0.00), (13.0, 0.75), (26.0, 2.00), (39.0, 4.25), (52.0, 9.00), (65.0, 18.3), (78.0, 29.8), (91.0, 40.5), (104, 45.8), (117, 48.8), (130, 50.0)

biodiversity_affects_value_N = GRAPH(Biodiversity_Index)
(0.00, 0.00), (20.0, 1.00), (40.0, 4.00), (60.0, 8.25), (80.0, 13.8), (100, 19.5), (120, 25.3), (140, 31.5), (160, 37.8), (180, 43.8), (200, 50.0)

value_N_affects_value_A = GRAPH(Natural_Value)
(0.00, 0.00), (10.0, 0.75), (20.0, 2.00), (30.0, 4.25), (40.0, 9.00), (50.0, 18.3), (60.0, 29.8), (70.0, 40.5), (80.0, 45.8), (90.0, 48.8), (100, 50.0)