EU Life algae

Algae in excess - harvesting for Life

Filamentous green algae are taking over shallow bays

Filamentous green algae like Cladophora *and* Enteromorpha *and some brown algae grow fast during the summer months, and form dense mats covering large parts of Europe's shallow coastal bays. Bays in the archipelagos in Bohuslän, on Sweden's West Coast and in the Åland Islands in the Baltic are particularly affected. The algal mats are decreasing the biological diversity and destroying the nurseries of several species of fish. The value of the bays in terms of outdoor life and tourism is decreasing. The rapid growth of algae is one of the results of the increasing amounts of nutrients in coastal waters and in bottom sediments. In a word, the bays have become eutrophicated.*

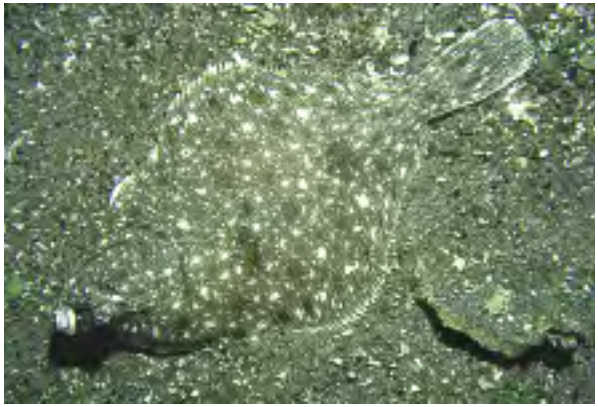
Fertilizing effects of phosphorus and nitrogen

With their shallow bays and inlets, the archipelagos of Bohuslän and the Åland Islands are nursery and feeding grounds for a number of important species of fish including cod, plaice and sea trout in Bohuslän, and flounder, perch and pike in the Åland Islands. From a biological point of view, the shallow waters are also very productive, both for fish, animals living on the bottom and birds.

Over the past century the archipelagos have been recipients for increasing amounts of nutrients, in the form of phosphorus and nitrogen, transported over long distances by air and sea currents and carried in run-offs and discharges from land. The presence of nutrients has led to eutrophicated coastal waters and bottoms. The waters of the archipelagos are particularly subject to eutrophication as they have limited water exchange. Additionally, the tidal range on Sweden's West Coast and in the Baltic is comparatively small. Here, wind and air pressure conditions can have as great importance as the tide, and sometimes greater, where water exchange is concerned.

Algal mats in bays

One effect of eutrophication observed during the 1990s is that short-lived filamentous algae such as *Cladophora* spp. and *Entermorpha* spp. have begun to cover the surface water in many shallow



bays, thus changing the environment for the flora and fauna that normally live there. During the summer months algae may cover as much as 30-50 per cent of the nursery areas of certain species of fish along the coast of Bohuslän. This has an adverse effect on the replenishment of stocks, damaging the prospects for sustainable commercial and recreational fishing and harming biological diversity.

Effect on outdoor life and tourism

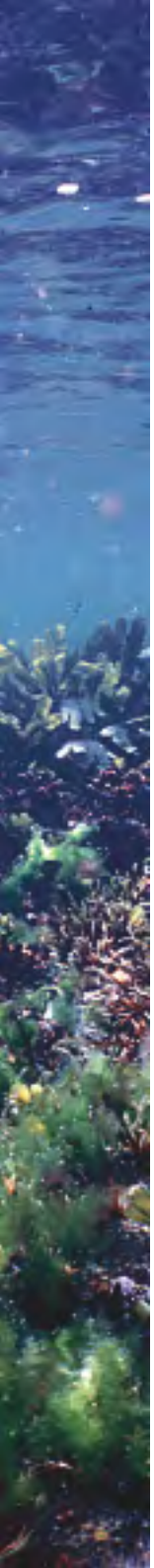
When algal mats die or are washed up along the shores, the algae decompose and give off an unpleasant smell, which spreads to the surroundings. This experience is a negative one so far as people in the area are concerned, not least among tourists during the summer months. There is also the risk that, if the algae are not removed from beaches, they will mix with the sand and lead to beaches becoming overgrown and, in the long term, have a negative impact on bathing facilities. Furthermore, the presence of algal mats in the water is a hindrance to the bathing, boating and other activities for which the archipelagos are noted and which makes them so attractive to tourists.

Project concept

The project concept is based on the hypothesis that eutrophication and its effects on shallow bays will decrease if the algal mats are removed by harvesting, and water circulation is improved by taking measures to increase water flow through road embankments. With the algae removed, the environment in which flora, fauna and human beings thrive will be restored. At the same time harvesting will have the effect of removing nutrients from the bays so that the problem of eutrophication gradually disappears.

Harvesting algae

The basic idea behind the project is that of recreating a satisfactory environment for flora, fish and other fauna once algal mats have been removed by harvesting. Harvesting will decrease sedimentation of dead algae and thus improve the environment on the bottom for the flora and fauna that live there. At the same time the amounts of phosphorus and nitrogen bound to the bottom will be decreased, which means in turn that the amounts of nutrients leaking from the bottom to coastal waters and



contributing to continued algal growth will also decrease. Algal mats both in the water and washed ashore will decrease, and so will the smell problem. Furthermore, nutrients bound to algae will be taken up.

Advantages of harvesting algae:

- limiting of the possibilities for algal growth
- restoration of conditions favourable to development of flora and fauna, and to enjoyment of outdoor life
- decrease in unpleasant smell
- reduction of the sink of nutrients in sediment
- increase in take-up of phosphorus and nitrogen from coastal waters
- decrease in the possibility for vegetation to establish on the sand beaches.

Improvement of water circulation

Water circulation is an important factor affecting the development of algal mats. In the archipelagos of Bohuslän and the Åland Islands, water exchange is often limited where shallow areas are concerned. Viewed in the long-term perspective it is also affected by land elevation. Increased growth of trees and vegetation on islands and mainland also has a negative effect on the influence of the wind on water flow.

In many cases road embankments and other manmade obstacles in narrow passages/inlets have impaired water circulation. Increasing flow through existing embankments and removing other hindrances are other means of combating algal growth.

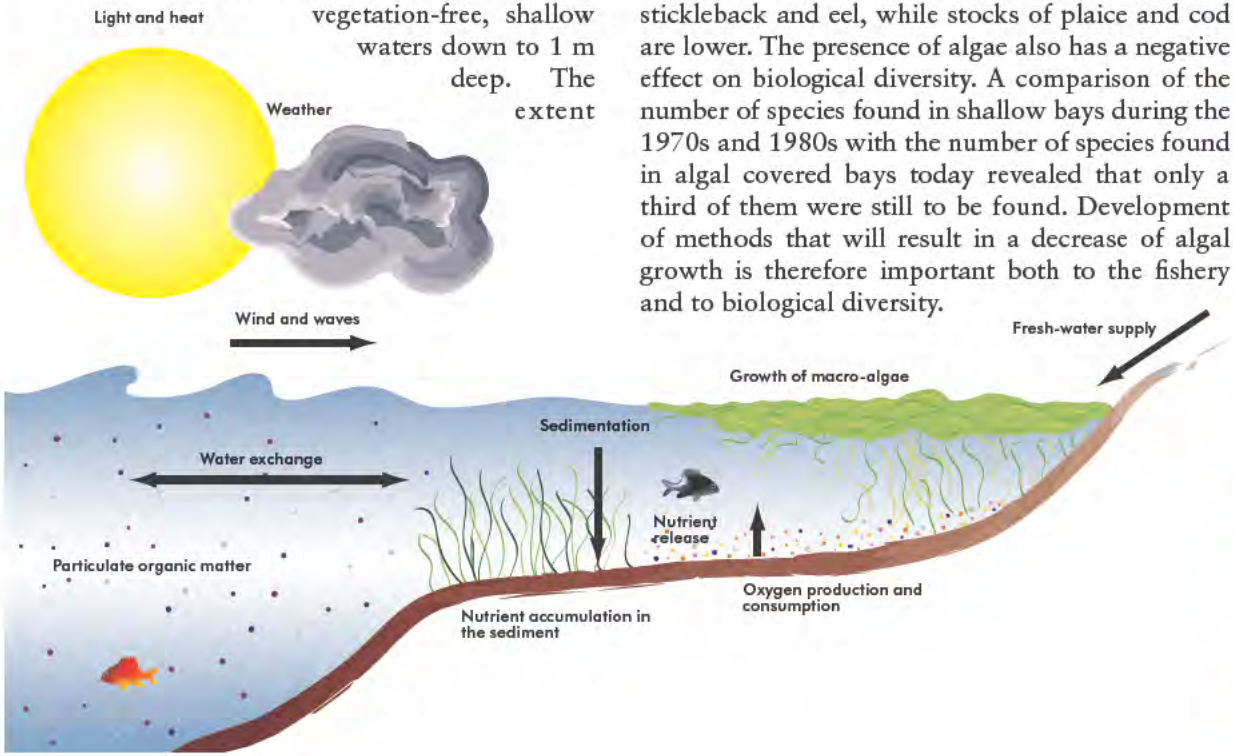
How does a bay work?

The project has developed two models that increase our understanding of the ecological role of shallow bays. One model describes how algal mats affect plaice recruitment. It also shows that the amount of juvenile plaice decreases significantly when the coverage of algal mats increases. The other model shows how the supply of nutrients and harvesting of algae limits the growth of algae.

Nurseries for plaice

Replenishment of stocks of plaice actually depends on the extent to which the waters of shallow bays are covered by filamentous algae. This is alarming news. Juvenile plaice recruit in vegetation-free, shallow waters down to 1 m deep. The extent to which waters are free of algal coverage is therefore crucial to the development of the population. The phenomenon has been established in a numeric model based on the results of experiments and field observations as to how plaice larvae choose their environment and the rate of their natural mortality during the first six months of life.

There is also a connection between the presence of algae and that of other organisms. Where algae are present in a bay in large quantities, the functional groups of organisms that dominate differ from those in a bay that is free of algae. For example, dominant fish species in algal covered bays are stickleback and eel, while stocks of plaice and cod are lower. The presence of algae also has a negative effect on biological diversity. A comparison of the number of species found in shallow bays during the 1970s and 1980s with the number of species found in algal covered bays today revealed that only a third of them were still to be found. Development of methods that will result in a decrease of algal growth is therefore important both to the fishery and to biological diversity.



Importance of nutrients in coastal waters

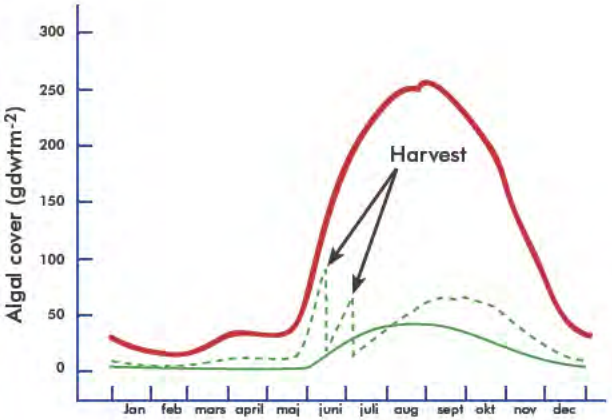
During the course of the project a model has also been developed for predicting the occurrence of filamentous algae on the Swedish West Coast. Important factors governing occurrence are environmental ones such as the topography of the bay in question, the extent to which wind and waves stir up the surface of the water, and the supply of nutrients (phosphorus and nitrogen). Results indicate that, to a large extent, algae are dependent on the sedimentation of small particles of organic matter that contain nutrients. This material is produced in surface water outside bays, and from there is transported into the shallow waters where it settles on the bottom, releasing nutrients as it decomposes. The concentration of nutrients in coastal waters is thus of the greatest importance to the occurrence of filamentous algae.

Local supply of nutrients is also important

However, results also indicated that nutrient supply from local drainage areas can be an important factor in certain cases, while in others the bays in question were less sensitive to this source of supply, depending on size of drainage area, use to which the land was put and dominant type of soil.

The figure below illustrates a simulation of algal growth in a bay. The conclusions to be drawn are that supplies of nutrients to coastal waters must be decreased generally, but that local measures can make valuable contributions in certain cases.

The model has also been constructed in such a way as to make it possible to predict the effects of algal harvesting. The simulations made during the course of the project indicate that strategic harvesting carried out twice a season during growth phase can lead to lower algal covering later during the season (broken green line). This is explained by the fact that harvesting reduces the supply of nutrients in a bay, with the result that algal growth is postponed to a period when rate of growth is also slowed by other limiting factors.

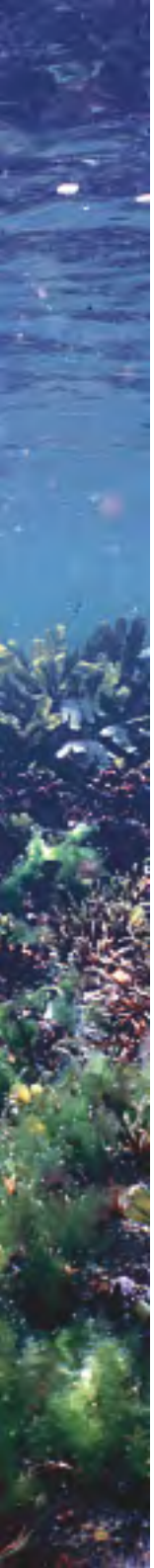


Filamentous algal cover in a shallow bay. The model results were obtained using coastal nutrient concentrations observed in coastal waters today (red solid line), and "preindustrial" conditions assuming a 50 per cent lower concentrations (green solid line). The broken green line indicates model results for the same bay if 80 per cent of the algae harvested twice a season in mid June, and early July.

In some cases there is also a tendency of lowered algal growth the years following harvest. This is explained by the fact that algae that otherwise are stored in the sediment instead are removed from the bay. The conclusion is an important one, since it suggests that harvesting could affect recurrent massive algal blooms.

The Åland Islands

Just as on the Swedish West Coast, on the Åland Islands algae are to be found that form mats in protected bays. But here algae are also to be found in more exposed habitats where the bottom is hard. They stay attached to the bottom during the summer months, and do not detach until later in the season, when they may drift for considerable distances into other bays, in which they then form mats covering the bottom and suffocating life beneath them. Here too, in addition to filamentous green algae, red and brown algae are to be found within the algal mats. The mixture of different types of algae floats into bays and may be washed up on the beaches, where sand and algae combine to create favourable conditions for land-growing plants. Unless something is done about this, the Åland Islands risk losing their fine beaches.



Harvesting algae and increasing water circulation

During the time the EU Life algae project has been running, a technique for harvesting algae has been developed and tested. The result is a prototype algae harvester that can take up floating algae in bays where water is more than 30 cm deep. Model calculations of water flow through road embankments in shallow archipelago waters show that simple measures can increase flow.

The harvesting technique

There is one basic criterion that the algae harvester must meet: it must be able to harvest floating algae in water deeper than 30 cm without disturbing the bottom or plant and animal life to any considerable extent. The prototype that has been built has three main components: a hydraulic engine that drives the other two components; a platform; and three transport belts that pull up, de-water and buffer-store the algae. The algae are subsequently loaded onto a barge for transportation to dry land.

Experience derived from the project

The latest prototype functions well in water deeper than 30 cm, and the de-watering process is efficient. Where algae have drifted in towards very shallow water along the shoreline, however, they have had to be hauled out to the harvester using a beach seine. Thus algae covering large areas of water less than 30 cm deep cannot be harvested efficiently using this prototype, and an amphibious harvester may need to be developed to deal with them.

The model studies predicted that harvesting algae during the growth phase can inhibit their continued growth considerably. However, field studies carried out in the Åland Islands showed that harvesting can also result in increased growth, probably due to the decreased competition for nutrients and light. Additional studies are therefore needed to evaluate how and when harvesting should be conducted to render it efficient.

When algae are harvested, many other organisms are harvested with them, and this has a negative effect on fauna. By choosing the right time for harvesting, these unwanted secondary catches can probably be minimized. When harvesting is carried out on a large scale there are also other important bio-

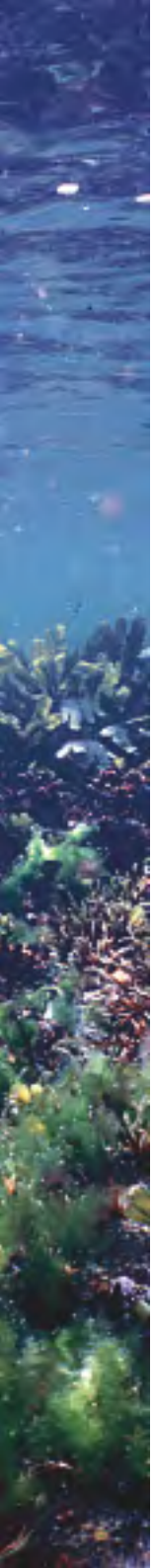
logical factors to be taken into consideration, including the time for recruitment of plaice and nesting of birds.

Setting a price on the environment ...
There are a number of positive effects that favour algae harvesting. If correctly performed, harvesting can probably halt algal growth in a bay and thus favour the return of its earlier plant life, fish stocks and fauna. However, supplementary studies are needed to verify that the effects of harvesting will be those intended. Harvesting filamentous algae covering the waters of bays may appear to be the only means of restoring the desired ecosystems until such time as other measures eliminate eutrophication problems in coastal waters and drainage areas.

Supplies of nutrients (phosphorus and nitrogen) in coastal waters could be decreased if algae were to be harvested on a large scale, since nutrients are bound to the algae. An estimate of the costs of nitrogen uptake as a result of algae harvesting, compared with other measures such as sewage treatment or the establishment of wetlands, reveals that costs are relatively high, at about 600 SEK per kg of nitrogen.

If harvesting algae significantly improve the recruitment of plaice it is without a doubt a cost-efficient measure. Assuming that the shallow bays in Bohuslän are responsible for one forth of the recruitment of plaice to the Skagerrak, and that the increased occurrence of algal mats decreases the recruitment with fifty per cent, the potential catch of adult plaice will be reduced with 1 250 tonnes. This corresponds to a sale loss of ca 60 million SEK!

Increasing water circulation
Model calculations of water flow through road embankments and inlets have already led to a number of measures being taken to increase flow. In the Bohuslän archipelago, for example, a road embankment previously built over an inlet with rapidly flowing water has been fitted with cylinders that will restore flow to the original rate. The results to date have been positive: the quantity of algae has decreased dramatically.



Can the algae be used in a meaningful way?

If we shall harvest algae on a large scale as a way of restoring bays and other shallow areas, we must also find an environmental friendly way of taking care of the algae. Therefore, the project has investigated different areas of use for algae. For example, as fertilizers, as raw material for the manufacture of paper, and production of biogas.

Fertilizers

In former days, coastal farmers, both on Åland and on the Swedish west coast, used algae as fertilizers. Therefore we have tested how the algae can be used in agriculture. The experiments show disappointing results when used as fertilizers for autumn wheat. However, algae can be used as soil improving matter in public parks and for certain salt tolerant crops such as white cabbage, beetroots and celery. But because of their relatively low content of phosphorus and nitrogen, algae cannot completely replace these substances but can be used in combination with other fertilizers. If very large amounts of algae are used, the algae's content of cadmium, nickel, chromium and lead may become a problem.

Other areas of use

The project has also tested other areas of use, like production of biogas, paper and egg cartons. The possibility of using the algae as raw material for extraction of microcrystalline cellulose, which is used for production of tablets in the pharmaceutical industry, has also been discussed.

The biogas experiments show that algae do not suite this kind of process. However, other studies have shown that in combination with other raw materials better results can be achieved, but more studies are needed. Paper production works very well, and there are good possibilities of using algae as a component in paper even on an industrial scale. However, problems in relation to storage e.g. unpleasant smell and leakage of nutrients need to be solved.

Constraints and possibilities

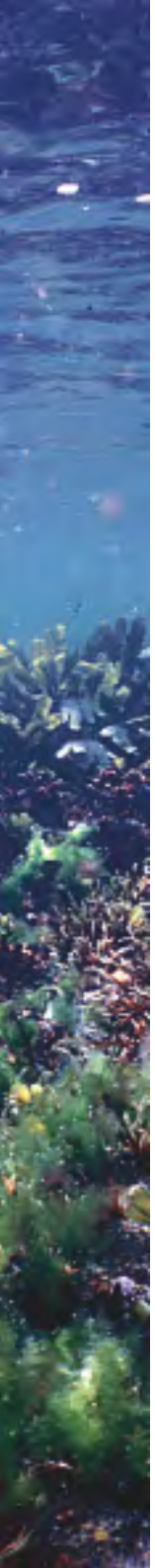
There are many statutes and regulations affecting the possibilities of harvesting algae and increasing the flow of water through road embankments, even though such measures are designed to help preserve and reconstitute natural environments that are very important to biological diversity, fishing and outdoor recreation. The following indicates the ways it works in Sweden.

Owners of property and water rights must be requested to grant their permission for algae harvesting to be carried out in their waters. According to Swedish law on the environment, Miljöbalken, permission is also normally required from the relevant supervisory authorities, which may take the form of exemption from protective regulations or announcement of consultations with them. Subsequent treatment of the algae harvested is also regulated in this way. If harvesting of algae is likely to be necessary for a long time to come, it might be as well to revise legislation in order to facilitate it.

Under Swedish law, an embankment in or adjacent to water is a water installation. Building an embankment or taking other steps in connection with one is a water operation in terms of Swedish law on the environment.

Which regulations apply in a particular case will depend on whether there are water rights attaching to the embankment under the terms of an existing permission. Where this is the case, the terms of the existing permission must be observed. If a diversion is necessary for the purposes of improving the flow of water, new permission must be applied for.

Legislation relating to roads and constructions may also be applicable, depending on whether the road in question is a public or private right of way. In the case of an embankment, it is the infilling that has the greatest influence, since flow of water is impaired, and the owner of the water rights and the owner of the embankment are the ones to take measures. Basically, the Åland Islands have the same legal conditions as Sweden.



Algae in excess – harvesting for Life

If we are to preserve and, in some cases, restore the ecosystems of the shallow bays around our coasts, and ensure the future presence in them of stocks of valuable fish, what is needed is cooperation far beyond the norm. The EU Life algae project demonstrates a number of new methods and tools that can be put to use in designing measures well thought-out.

The effects of eutrophication in coastal areas are threatening to knock out whole ecosystems, and with them the reproduction of commercially important species of fish. During the course of the project, new measures have been developed and tested with a view to countering the negative effects of eutrophication on shallow coastal bays. Consequently there are no simple solutions to the problem. It is highly likely that a combination of a number of measures will be needed, both on shore and off shore if optimum results are to be achieved. And, in selecting the measures to be taken, we must also take the particular conditions in each case into account. For example, we may want to retain the sandy shore in one spot for bathing and outdoor recreation, while in another priority must be given to protecting the nurseries of commercially important species of fish.

Working together – more knowledge

Measures designed to protect and restore the very rich ecosystems in these shallow coastal waters need to be based on documented knowledge of topmost quality. Thanks to successful cooperation between researchers and the relevant authorities it has proved possible to develop a model that provides a simplified description of the way in which a bay works. We would like to see it developed further, to become a valuable tool for forecasting purposes when we decide on future measures to be taken. What we need to know is this: Will we need to harvest algae for just two years, or for two hundred?

There are still a number of important bits of the puzzle missing; bits that would explain in greater detail how a bay works. We would also like to see more research being done on the replenishment of fish stocks, the dynamics of ecosystems and the

composition of flora and fauna. If we are to take a further step in the task of preserving and restoring these ecosystems, we must also be prepared to set a price on their proper function and on the value of biological diversity.

International cooperation – cleaner seas
Eutrophication in seawater is supplying the archipelagos of Bohuslän and the Åland Islands with an excess of nutrients. Reducing and, in the long term, eliminating this massive eutrophication requires international cooperation on agreements as to water quality and emission limits for operations both ashore and at sea. Institutions and commissions capable of providing this international cooperation are already in place. The EU's Framework Directive on Water will be implemented in the course of the next few years, and will attach additional importance to issues of water management and control.

A regional and local responsibility
Water management under the terms of the EU's Framework Directive and the overall plans of local authorities help to create forums in which measures for dealing with eutrophication of shallow bays can be formulated to meet specific local needs.

An excess of unwanted algae
Mats of filamentous algae are threatening biological diversity, fishing, bathing and boating, in fact, all the qualities for which our archipelagos are loved. If the answer is to harvest them with a view to protecting and, in some cases, restoring the ecosystems in the bays, and harvest them every year until the excess of nutrients in the water has been sufficiently reduced, who is to be responsible for the harvesting?

A vision for us all to share
Our vision of the future is one in which the waters along our coasts, our archipelagos and inlets are once again clean, and once again rich in flora and fauna. It is one in which we see our grandchildren rowing out on a late summer evening, to take a swim or fish for plaice. This vision can be realized if we look after our unique natural surroundings with utmost care, so that everyone can benefit from and enjoy them. The vision has not yet been realized. We therefore urge every member of the public to cooperate in continuing with the task of reducing eutrophication and creating sustainable life in the shallow bays and archipelagos along our coasts.

What can you do?
- Reduce, separate and treat your waste water
- when yachting, leave your garbage and waste water at collection stations in the harbours
- use alkylate petrol and degradable oils for your boat engine
- collect filamentous algae and use them in your garden.

About the EU Life algae project

The EU Life algae project is a cooperation between government authorities and research institutes in Sweden, Finland and on the Åland Islands.

The project is owned by Länsstyrelsen Västra Götaland, County Administration.

The project has a budget of SEK 13 million, 50 per cent of which has been financed by the EU Life environmental fund (Allocation LIFE96ENV/S/380).

The project commenced in the 30 of November 1996 and finished the 31 of May 2001.

The figure below illustrates the way in which the project has been organized and the subprojects.

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Project reports and other publications

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1997

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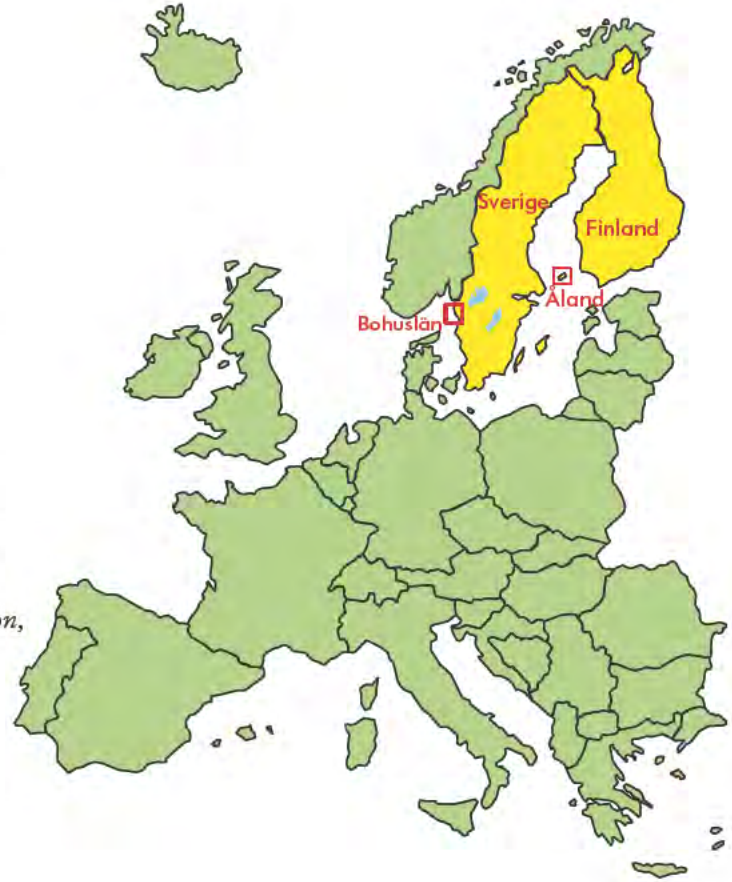

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