Techniques for collecting floating algae in shallow areas of Trelleborg Municipality.

Beach section of algae washed ashore off Trelleborg, June -08 (Photo: Lars Olsson).

Problem orientation

For centuries, man has recovered bladder wrack (fucus vesiculosus) to fertilize crops. But due to the increased nutrient levels in the coastal zone in recent decades the kelp has competition from other species, such as filamentous red and brown algae. These are not permanent, like kelp, but annual algae which grow in such large quantities that they become detached and accumulate in compost like belts along the coast. When the algae dies, the creation of oxygen free decay is to the detriment of all life in the coastal zone: plants, benthic invertebrates, fish, birds and humans.

Mission

To develop a technology (hardware) that enables the collection of floating algae masses in the riparian zone of Trelleborg Municipality.

Background

The eutrophication of the Baltic and North Sea has resulted in an overproduction of filamentous macro algae. These annual algae has taken the multi-annual algal spot along the coast. The algae invade the beaches each year, resulting in oxygen depletion and odor (during decomposition). This report looks at these macro-algae, in terms of what problems they cause, in the shallow coastal waters, and how to tackle them.

Environmental impact of decaying algae in the riparian marine zone

The eutrophication of the sea has been occurring for at least half a century. Already in the late 1960s, there were accumulations of filamentous macro algae not only in shallow areas, but also further out in deeper water (8-15 m). Today large areas of sea bed are covered, more or less frequently, by "algae mats", often with oxygen deficiency and a “dead bottom” as a result.

Emissions from agricultural, forest and municipal sewage treatment plants are the largest single sources of nitrogen and phosphorus. During the last 10-15 years most of the major coastal sewage treatment plants in southern and central Sweden were designed for advanced nitrogen removal. Today, more than 75% of the wastewater nitrogen content is removed and converted to atmospheric nitrogen. However the results of these efforts is currently insufficient as the diffuse emissions of phosphorus and nitrogen, particularly from agricultural and forestry, have not decreased to the same extent. Although in recent years it has been possible to discern emission reductions from agriculture. Each spring, summer or autumn the western and southern coasts of Skåne are invaded by loose and floating filamentous macro algae, mainly various species of red and brown algae. The algae are packed together by the action of waves and wind to form compact seaweed composts, ranging from and distributed out to one or a few meters. In shallow sandy beaches it can include an algal belt from the shoreline to 25-50 meters out in the water. After a week the bottom algae start to die, mainly because of the lack of light. Decomposition depletes oxygen in the water and exposes the environment to anaerobic conditions. When the fragmented algae die it results in disadvantages in the form of bacteria, an unpleasant smell and masses of rotting seaweed.

Example of shoreline seaweed and algae from Laholmsbukten 2008 (foto: Lars Ohlsson).

The shallow productive sandy beaches are a unique phenomenon in Sweden, as less than 5% of the Swedish coast consists of sandy beaches. Each beach is unique in that from the North Sea to the Gulf of Bothnia there is a continuous gradient of decreasing salinity, in which varieties of plants and animals have adapted genetically in order to cope with living conditions in their particular habitat. Many areas are endemic and have a great conservation value. The top ten deci-meters in the ocean may produce more biomass per year than any other ecosystem that we know of. These marine landscapes are important spawning, nursery and larder sites for many important species of fish, birds and other animals. It is of great importance to preserve and protect these shallow seabeds for future generations, and so that they maintain a large genetic variation in order to better withstand competition from alien species.

Even now, many new species have established themselves along the coast and have started to compete with the native flora and fauna. According to the Environmental Protection Agency there are currently 70 new species that have

become established in the marine ecosystem.
Tourism, outdoor activities and local people are affected by eutrophication. When the algae die, or are washed up on beaches, they rot and create an unbearable odor that spreads into the surroundings. Even at greater distances from shore, the stench can be unpleasant.

Fundamental reasons for collecting the algae
If the shallow sandy sea bed is freed from the excess seaweed, through collection, conditions improve allowing the existing flora and fauna to survive. In addition, if the amount of oxygen consuming algae biomass can be reduced, then the outlying deeper sea bed, which might otherwise be secondarily affected when the algae is washed back into the sea, will also benefit. The removal of biomass also means that some of the phosphorus and nitrogen bound into the algae is removed from the oceans biological cycle. If the beaches are freed from potentially decaying algae, some of the odor and bathing water quality problems that exist today will disappear. In addition, the collected biomass can be used as a resource, for example, to be digested into biogas, used as fertilizer or, in some cases, to be used for completely different products.

Technical problems with collecting the algae
The biggest challenge has been to find a method that allows the collection of floating algae biomass in high volumes from the land. Volume weight, of the wet seaweed and algae collected from the water, is calculated to be between 0,7-0,9 ton/m3. Dewatered algae, collected from the beach, has a volume equivalent weight of about 0.3-0.4 ton/m3.
The key to this technical solution is to take up a fraction of the biomass at a time, but at high speed so that the absorption capacity, per second, is cost effective.
The technique is based on the algae mass being collected from the surface by steel tines, then being moved up along a conveyor. The algae is dewatered further, falls onto another conveyor and then into a collection container.
In order not to damage the existing ground environment requires that the bottom substrate be affected as little as possible as the machine moves over it. The focus has been on testing the technology on beaches with a substrate of little stones.

Technical specifications of tested machines

Prototype I
Tested in 2008 and redesigned as a so-called “side-rake”.
In the past this was an ordinary piece of farm machinery, used to rotate or gather hay. The prototype weighs about 150 kg and can be mounted to the power take off of a conventional tractor. Price of new unit is currently about 12 000 kronor.

Field tests
Full-scale test at Åhus Strand (video available) showed that the prototype was easy to use and effective in removing small amounts of seaweed from the water and the sandy beach. For larger quantities, it was found that the wet drive belts skid. This should be remedied by switching to a chain drive.
Capacity was at best around 300 kg of wet algae per minute.

Assessment
A very simple, cheap and easy to use machine that is suitable for capturing easily accessible algal mats of filamentous green algae. It is therefore possible to prevent fresh water from becoming overgrown by Cladophora. As the machine is small it is best suited to areas with less water, such as landscaped lakes, ponds or wetlands, where heavier and larger machines are unsuitable.
The prototype could significantly reduce the amount of surface covering green algae in nutrient-rich aquatic environments, such as golf courses and wetland ponds, in which odors often arise due to the lack of oxygen during decomposition.

“Side Rake” has proven to be effective along beaches where there are limited quantities of floating seaweed in the water, 1-2 meters out from land.

Prototype II

A narrower side rake of the same principle as above, but with a fixed collection basket. Prototype II can operate through the arm of an excavator.
Thanks to the excavator arm the basket can maneuver at speed, this allows the collection container to be emptied very quickly and easily in a separate container.
The cost of production amounts to about 15-20 000 SEK.

Field tests

Full-scale test at ÅhusStrand (video available) showed that the capacity represented approximately the same as prototype I.
In contrast, both the collection basket and excavator are smaller and easier to operate efficiently. It should be suitable for remote water surfaces, including around large rocks or boats in harbours.

Assessment

Prototype II is a useful tool to "precisely" collect floating algae in harbours, especially around boats and bridges. The long arm of the machine allows precision collection, so that material can be collected safely in an area with recreational boats. Excavator size, as well as tracked or wheeled type, can be selected as required.

Testing of prototype II on a beach in Åhus, Winter 2008 (Photo: Lars Olsson).

Prototype III

In principle, a wider side rake with a catch-and slip-sheet for grating, shorter and stronger steel tines and heavy chains operated by gears from a hydraulic motor. Speed (capacity) can be adapted to circumstances. The entire unit is hydraulically suspended and may be gyro stabilized in order to comply with conditions.
The material is caught and pulled up by the front grille, made of steel tines, and on to the sliding plate and before falling down on to a conveyor. The collected material is sent to a high tip container at the rear of the machine (in this version).
The algae is dewatered throughout the process and in the collection container.
A future model should probably have a transverse narrow side conveyor, for a continuous off-loading of algae mass to tractors with trailers.
The prototype is hydraulically based on a remastered pea combine harvester. A 150 hp diesel engine drives a hydraulic pump, which in turn drives the 4 wheels and other hydraulic motors.
Cost (based on a second-hand pea combine harvester) is approximately 100 000 SEK.

Technical data:
Total Weight: approximately 7 to 9 tons (empty / full container (estimated weight))
Length: 8.7 m **Width:** 2.80 m, **Height:** 3.60 m
Front Wheel Size: 150 cm/60 cm; **Rear Wheel Size:** 60 cm/40 cm
Front Contact Area: 7 200 cm2. **Rear Contact Area:** 3 200 cm2.
Total Contact Area: 10 400 cm2
Wheel Load: 7-9 kg/cm2
Fuel: MK1 (Environmental Diesel, Class 1)
Fuel consumption during harvesting: 3.5 - 4.0 l per hour
Max speed on public roads: 30 km / h.
Capacity: approximately 500 kg wet weight per minute

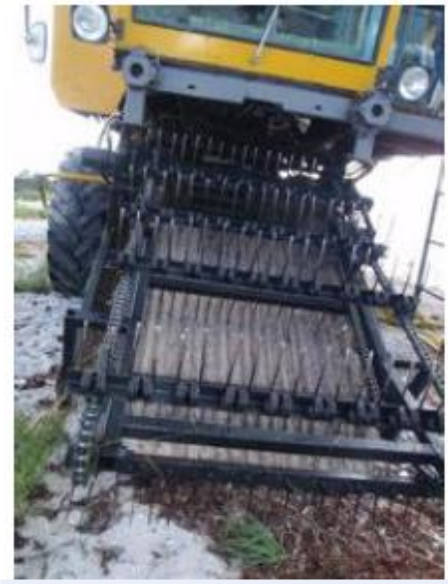
In the tests carried out, the composition of seaweed and algae were as follows:
40% Polysiphonia fucoides,
20% Furcellaria lumbricalis
15% Ceramium spp
15% Fucus vesiculosus
5% Eelgrass, Zostera marina
5% other species

Field tests
During field trials in Skåre, November 2009 (video available), capacity was approximately 500 kg per minute. The unit could be adapted to be driven, for example, by an ordinary tractor with a boom.


Detail of spring tines and drainage plate (photo: Sven Bertil Johnson).

Assessment
A simple method that is designed to be manufactured at a low price. Prototype III has a much stronger design than the above sides rakes and more than double the capacity.
Through the robust design prototype III can also process the land "occidentalis". These so-called occidentalis, is the name of the small undulations in the water, which consists of a mixture of seaweed, sand and sometimes stone and gravel. By separating the seaweed from the sand and sea the machine is capable of quickly restoring the shoreline.


Test run on the beach outside Trelleborg (photo: Sven Bertil Johnson).


Detail of the collecting device (photo: Sven Bertil Johnson).

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