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Technical Report

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WAGENINGEN UNIVERSITY & RESEARCH

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# Contents

# Summary

Typically monitoring of marine cultivation systems is done through labour intensive and intrusive field surveys. With the introduction of new sustainable marine production chains such as the cultivation of seaweeds, economically feasible solutions for production and monitoring should also be included in management processes. New technologies have led to a more indirect form of monitoring marine systems, which is more efficient. Remote sensing is such a new technology which was previously mainly used to find large aggregations of fish or underwater topography. This report investigates the use of sonar for a quantitative and effective means of monitoring seaweed cultivation. The sonar was able to detect seaweeds and distinguish between the cultivated and filamentous seaweeds growing on the lines. However difficulties where found due to the movement of both the boat due to waves, and the cultivation lines. Which made it difficult to analyse the sonar video on board. Later snapshots of the video were made which showed a clearer picture. The predicted length and amount of seaweed was compared with the actually harvested seaweed. The actual number of seaweeds was higher than the sonar could see due to the overlapping of the plants, this also increased the maximum length as predicted by sonar. Sonar showed the larger plants most clearly, however the advantage of hydro acoustics is that there are no turbulence interference as is often the case with optical monitoring techniques. Using sonar provides a good estimate of the maximum length of the cultivated plants and once validated could be a high potential monitoring system.

# 1 Introduction

The support and development of new and sustainable marine production chains, like the emerging seaweed cultivation in the western world, require innovative tools and techniques that are cost effective and reliable. In this manner, monitoring and mapping of seaweed cultivation is of great importance for an ecologically and economically sustainable management. Typically, monitoring methods and mapping of near-shore seaweed cultivations is achieved by direct observation or measurements by researchers and/or farmers. These direct methods are field surveys, including walking, diving, grabbing, and are not very efficient, due to time and labour investments. Indirect methods are quantitative more efficient and are categorized in two groups of remote sensing: (1) optical remote sensing, like video or satellite imagery, and (2) acoustic remote sensing, like sonar or echo-sounder imagery (Komatsu et al. 2002).

Originally, echo-sounders for acoustic remote sensing have been employed to detect distribution of fish schools and to measure underwater topography, besides its military background. They emit ultrasonic waves of a certain frequency in the water and measure their reflection from the sea-floor or an object in the sea. The reflection coefficient of the ultrasonic wave depends on the material of the objects, respectively sea-floor, and therefore a good image of the target is produced. In recent years, there has been significant progress in imagery techniques of the marine environment, including aerial and underwater surveys, by applying optical and multispectral imagery, as well as sonar and echo-sounder detection (e.g. Shono et al. 2004, Komatsu et al. 2012, Sagawa et al. 2012). For example, the remote detection by echo-sounder has been applied in several ecological studies on sea grass meadows with *Zostera marina* (Hatakeyama & Maniwa 1978) and seaweed beds of *Sargassum* species, which have air-filled vesicles that can be detected easily due to density differences of the media (Komatsu et al. 2002) and enables a good quantitative evaluation on their spatial distribution. However, different frequencies need to be installed to detect different target objects and wave lengths between 3.5 KHz and 200 KHz have been used to detect different sea grass beds (e.g. Colantoni et al. 1982, Hatakeyama & Maniwa 1978). The detection, respectively quantification of seaweeds without air-filled vesicles still remains difficult and mostly resembles unchartered territory.

Furthermore, different converting methods to refer from acoustic imagery to biomass have been proposed (e.g. Hatakeyama & Maniwa 1978, Tanaka & Tanaka 1985, Komatsu & Tatsukawa 1998). A simple index of the biomass may be calculated by the sum of the canopy heights times the unit sector (or cultivation rope) scanned by the echo-sounder. However, this index does not allow for a quantitative estimate of the biomass in comprehension to ecosystem services, respectively carrying capacity. Hence, a converting method from the shading grades of seaweeds and sea grasses on echograms was proposed. Tanaka & Tanaka (1985) classified *Sargassum* beds along defined transects into different groups based on the canopy height on echograms, which were related to sampled biomass along one transect. Finally, they estimated the total biomass from the surface area (SA) of each group.

All of the studies mentioned above were ecological mapping projects near coastlines, and data was analysed in corresponding cartographic dimensions. A precise estimation of biomass per meter cultivation line was not in focus, nor were stationary or automated acoustic monitoring systems discussed. These subjects still leave a lot of room for research and development, as seaweed cultivations are often located in remote and harsh environments, limiting access and the frequency of direct observations in regard to safety aspects and financial costs. For this purpose it is urgently required to develop and establish precise and reliable techniques to monitor seaweed cultivation sites in quantitative and efficient ways.

# 2 Objectives

The aim of this study was to test the applicability and feasibility to remotely estimate seaweed biomass by sonar. In this first attempt, the general concept was tested at a seaweed cultivation farm in the Schelphoek, the Netherlands, and limitations of this monitoring technique were evaluated. In addition, recommendations to eliminate bottlenecks to this technique for future (sonar) measurements are given.

# 3 Material and methods

## 3.1 Study site

All measurements were conducted at a seaweed test farm in the Schelphoek (51°41’30.1”N 3°48’31.3”E), Eastern Scheldt, the Netherlands (Fig. 1), operated by Seaweed Harvest Holland B.V and in kind collaboration with Noordzee Boerderij B.V. in June 2020. The day time of measurement matched the incoming high tide (3:56 pm) and average winds of 3.4 Bft from the south-west were reported (www.foreca.nl), causing small waves.

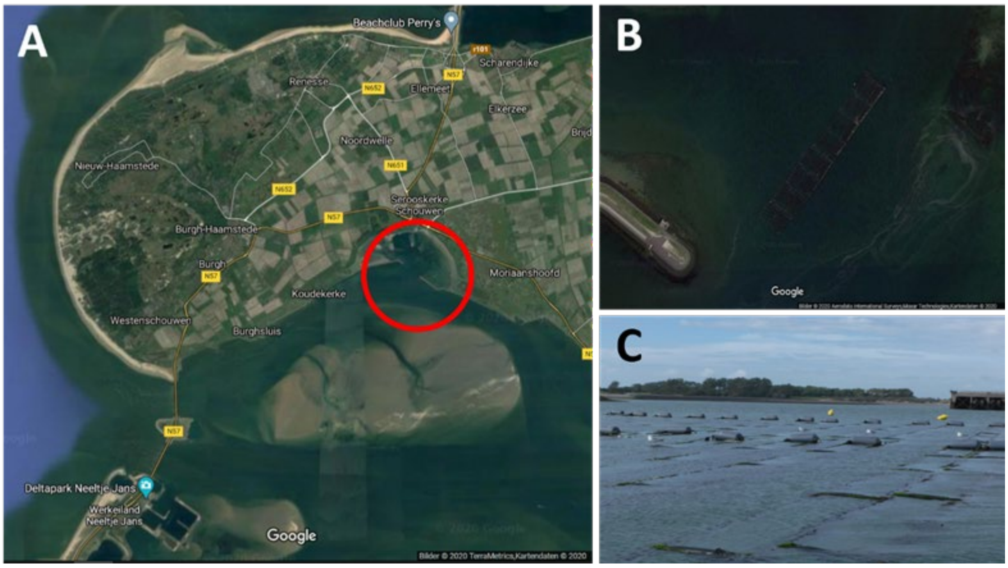


**Figure 1.** (A) Google™ satellite image of the study site in the Eastern Scheldt (Schelphoek; marked with red circle) (B) zoomed-in satellite image of the seaweed cultivation installation, and (C) photograph of the seaweed cultivation site.

## 3.2 Materials

### 3.2.1 Sonar

A sonar (DIDSON-sonar, Diver-held 100m; Sound Metrics Corp., Bellevue, WA, USA) was used to perform measurements (Fig. 2).

**Figure 2.** Image of the DIDSON-sonar Diver-held 100m (©www.soundmetrics.com)

The sonar device was attached to the end of a 3 m long stainless steel pole (Ø = 40 mm) in a 90° angle and submerged, while the other end of the pole served as a handle. Any cables (data, energy) connected to the sonar were attached and aligned around the pole, eventually going to the energy supply and laptop provided on the boat.
A safety cord between sonar and boat was also installed to prevent loss of the device, as the steel pole was held in hands to be able to manoeuvre between the cultivation lines, prevent entanglement, and easy retrieval. Specifications of the sonar were (set) as follows in Table 1.

**Table 1**. Information on specification of the sonar. Specifications were tested in the field, or based on expert judgement.

| Parameter | Value and UNIT |
|---|---|
| Identification frequency | 1.8 MHz |
| Detection frequency | 1.1 MHz |
| Sound speed | 1457 m/s |
| Beams | 96 |
| Sample rate | 37.3 KHz |
| Rcv Gain | 40 dB |
| A2D-Ps | 37-32 C |

Analysis of the sonar recordings was conducted with the DIDSON-Sonar Control and Display Software Version 5.26. Snapshots of sonar images were analysed with the open source software ImageJ (ImageJ, U. S. National Institutes of Health, Maryland, USA) for relative coverage in regard to biomass (2-D surface area (SA) and length of seaweed individuals (after Tanaka & Tanaka 1985)). For that, the sonar image was converted into grayscale (type 8-bit) and further processed into a binary image before SA could be analyzed. A reference to refer to the relative length of the seaweeds was given on each site of the sonar image by default.
The calculated results from the sonar measurements were compared to data retrieved after the harvest of the cultivation ropes on the very same day. This data was kindly provided by Noordzee Boerderij B.V..

### 3.2.2 Seaweed

The estimation of biomass by sonar measurements is targeted at the brown seaweed *Saccharina latissima* (sugar kelp or sea belt) cultivated on horizontal lines in a depth of approximately 1.5 meters (Fig. 3). Each of the cultivation ropes has a length of 50 meters.

The perennial seaweed *Saccharina latissima* dominantly grows during the winter months. In cultivation, small sporophytes are typically deployed in November, while harvest takes place in spring and early summer.

**Figure 3.** The brown seaweed *Saccharina latissima* on a cultivation rope in the Schelphoek just harvest.

## 3.3 Methodology

From a boat (length 4.5 m), the sonar was held in the same depth as the cultivation ropes, pointing towards the ropes. While one person manoeuvred the pole with the attached sonar, while watching the laptop monitor with the live echogram, two persons slowly pulled the boat parallel to the cultivation ropes by grabbing to the structural ropes. The use of paddles was not possible due to lack of moving space, neither was the usage of a motor to prevent air bubbles in the water column, which hamper precise sonar measurements.

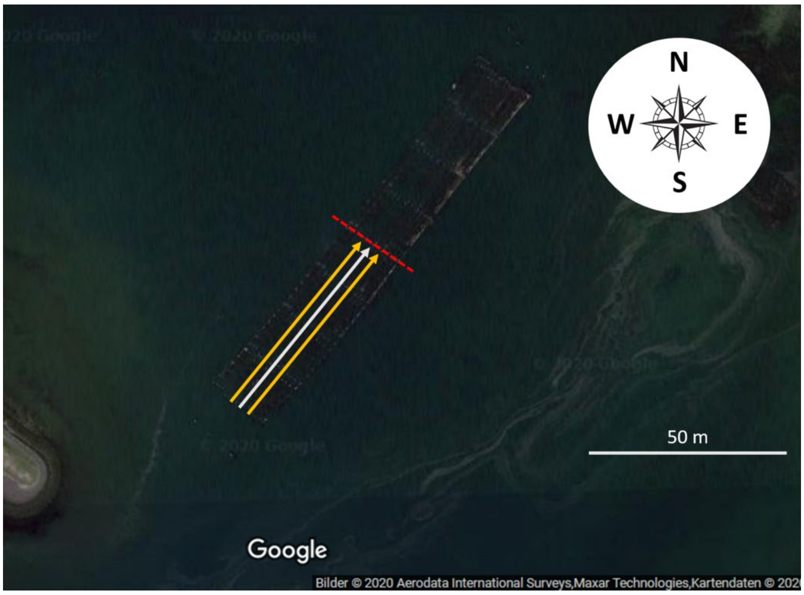


**Figure 4**. Route of the sonar measurements along the centre ropes of the seaweed test farm: the centre line was focussed on from both sites (white), the 2 outer lines were measured from one side only (yellow). Measurements stopped in the centre of the farm after 50 m (red), due to structural design and access.

For the first test, the sonar was deployed on the southern site of the farm site, between the centre lines, facing south-east. In a second run, the sonar was facing to the north-west. Three cultivation ropes were measured all together: one cultivation rope was focussed on from each side (east, west), while two ropes were measured from one side only (Fig. 4). Due to the (structural) design of the cultivation site, the boat was only able to go half the length of the site and could not smoothly pass the anchoring centre.

# 4 Results

## 4.1 Sonar images

Sonar was able to detect (cultivated) seaweed, as well as structural components of the underwater farm (Fig. 5).

The specifications and settings of the sonar allowed for a clear detection signal and images of the underwater scenery (see Fig. 5). Cultivated seaweed biomass (*S. latissima*) was clearly recognizable on the cultivation lines and distinguishable from filamentous seaweeds, like *Enteromorpha* species, mostly growing on the structural ropes of the installation near the water surface.

However, the presented images are snapshots of a video by the continuously measuring sonar. The snapshots represent momentary positions, which can be analysed, while the video itself cannot be analysed accordingly, due to movement of the seaweed and cultivation ropes in the current, and the movement of the boat in the (small) waves. These dynamics caused massive differences in the position of the sonar and angles towards the cultivation ropes, which made it impossible to maintain a focus point. Consequently, only a few snapshots allowed an analysis and estimation of biomass, while most recordings were unclear and turbulent.

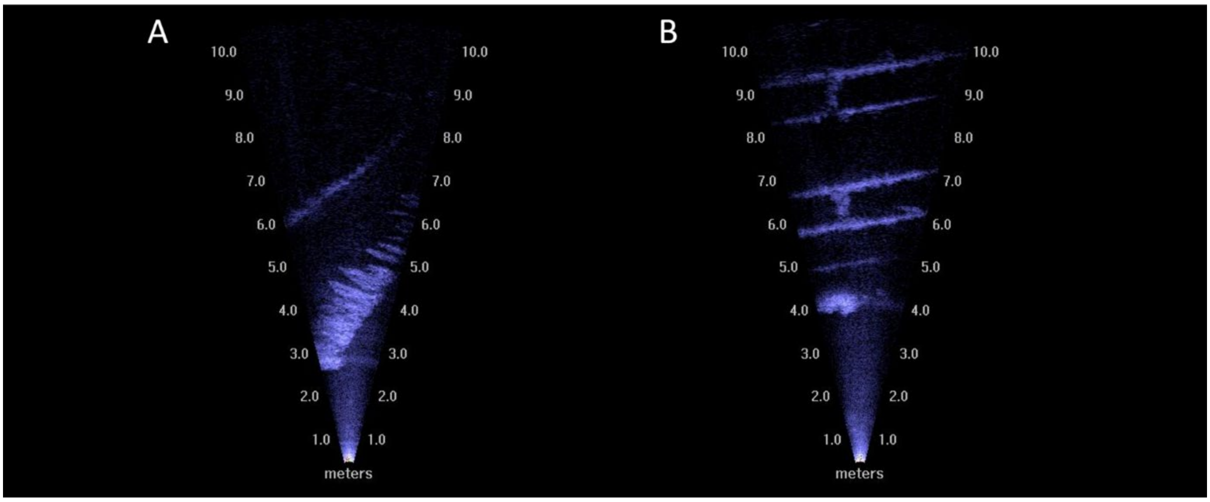


**Figure 5**. Example images from sonar observations in a seaweed test farm in the Schelphoek, the Netherlands. (A) Sonar images of the cultivated seaweed *Saccharina latissima* (depth: ~1.5 m), and (B) sonar images of the structural ropes of the installation, overgrown by filamentous macroalgae (close to surface waters).

## 4.2 Sonar image analysis

Prior an estimation of biomass, all usable sonar images were analysed for number of individuals, length of individuals, average length and size of canopy formed by the individual fronds (Fig. 6).

The average count of individuals was 55 per meter of line, while the average length of seaweed individuals, respectively length of the seaweed canopy, was calculated to be 97 cm with an average surface area of 16,680 $cm^2$ (1.7 $m^2$) per meter line (Tab. 2).

**Table 2**. Summary of analysis of the sonar images (n) for average number of seaweed individuals (*Saccharina latissima*), mean length (in cm), respectively canopy length, and its calculated surface area (SA; in $cm^2$) per meter cultivation line.

| Cultivation rope | n | Ø number | Ø length (cm) | Ø SA ($cm^2$) |
|---|---|---|---|---|
| Northern | 1 | 64 | 99 | 15518 |
| Centre | 4 | 46 | 92 | 18780 |
| Southern | 2 | 54 | 101 | 15742 |

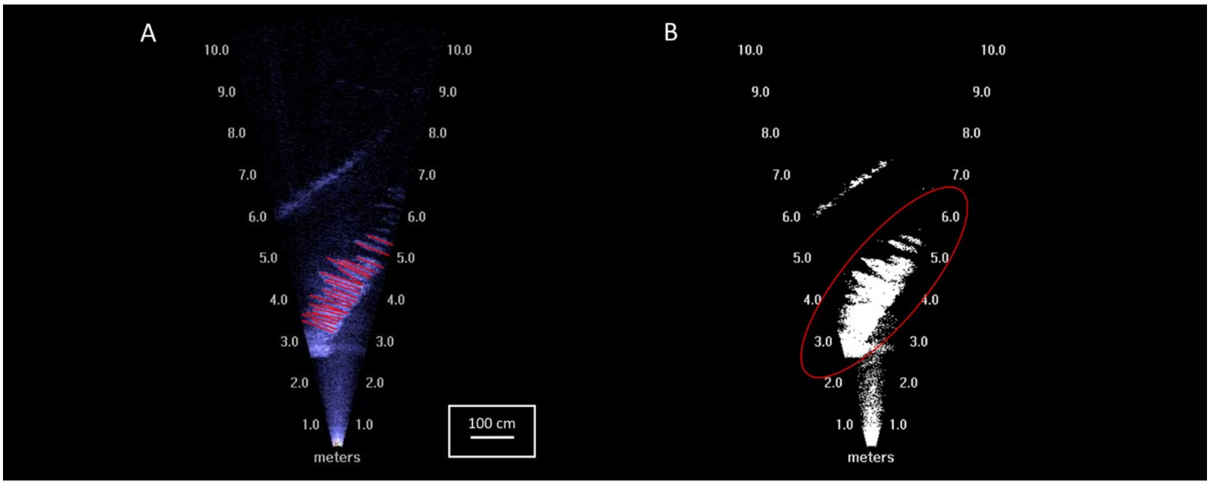


**Figure 6**. Example of analysis of a sonar image (A) for number of individuals, length of individuals (red lines), and (B) average canopy size by transferring the sonar image into a binary image for automated surface area analysis (red circle).

## 4.3 Comparison to biomass

Harvest and haptic analysis of 2 cultivation lines by Noordzeeboerderij B.V. showed a mean of 215 seaweed individuals per meter. The average length of these individuals was 43.25 cm. The mean wet fresh weight was 2.98 kg/m. A comparison in the findings of the sonar and the harvested biomass can be found in table 3. As there are no conversion factors available to calculate biomass from surface area for *S. latissima*, it is difficult to estimate the biomass of crops from sonar images. In addition, the sonar detected seaweed individuals in front, while individuals growing behind the front-line were not detected, as resembled by the differences in average count of seaweed individuals. The analysis of different shading grades, as proposed by Tanaka & Tanaka (1985) was not possible from the sonar imagery in ImageJ-software. Respectively, it did not add to the analysis for biomass evaluation. However, the sonar images gave a good estimation of the maximum length of the individuals, as well as a valuable estimation of the average surface area of the detected canopy. In the sonar images the larger seaweed individuals are clearly seen. However, the smaller individuals could not be clearly detected. Leading to a higher average length than what was found in the in harvested biomass. From this index, an experienced farmer could make decisions on harvest times. Nevertheless, this index does not allow for a quantitative estimate of the biomass in comprehension to ecosystem services, respectively carrying capacity.

**Table 3**. Summary of analysis of the sonar images (n) for average number of seaweed individuals (*Saccharina latissima*), mean length (in cm), respectively canopy length, and the harvested biomass of the seaweed on the same day. Data is calculated per meter cultivation line.

| Cultivation rope | n | Ø number Sonar | Ø length (cm) Sonar | Ø number harvested | Ø length (cm) harvested |
|---|---|---|---|---|---|
| Northern | 1 | 64 | 99 | X | X |
| Centre | 4 | 46 | 92 | 233 | 45.5 |
| Southern | 2 | 54 | 101 | 204 | 42.5 |

# 5 Conclusions and recommendations

## 5.1 Feasibility

Hydro-acoustic techniques, such as echo-sounder or sonar measurements hold the advantage to have no limitations to turbidity, which dramatically impairs optical methods. The sonar technique applied in this study was practical to evaluate vertical density, respectively canopy length of the cultivated seaweeds. However, exact numbers of seaweed individuals due to overlapping and clusters of seaweeds could not be analysed from the gained data, despite a good sonar imagery. Difficulties were mainly caused by unsynchronised and chaotic movement of boat, cultivation rope, and especially seaweeds, which is difficult/impossible to avoid in elongated or canopy forming specimen, like *S. latissima* ("sea belt").

Adjustments to the structural design of the operation and/or position of the sonar device(s) are needed to get a more balanced imagery. While the seaweed on ropes cannot be stabilized in currents, the sonar device(s) can. For example, one way to stabilise the sonar device may be the installation on the seafloor, pointing upwards into the farm. Another way to stabilise the sonar could be achieved by installing the device on a fixed rail from one side of the farm to the other to be able to move the sonar along the rail. Similarly a hydrodynamic casing that allows for towing the sonar device by boat may be employed. Depth and distance of the rail, respectively path of the sonar, in relative position to the cultivation lines must be determined accordingly.

In conclusion, an echo-sounder, respectively sonar, resembles a practical tool to remotely monitor seaweed farms and allows to analyse changes in spatial and temporal distribution, respectively growth of seaweed crops.

## 5.2 Applicability

However, it is difficult for this method to measure densities and heights of plants along the cultivation ropes. Main disadvantages are (1) the high acquisition cost of sonar equipment, (2) difficult treatment of the system on a small boat, and (3) difficult processing of recorded imagery due to movement and position of boat, cultivation rope, and seaweeds in the current, respectively waves. Nevertheless, sonar resembles a practical method to remotely monitor seaweed biomass.

It may be possible to gain comparable information with a low-budget sonar that is commonly used on boats for sea floor profiling (e.g. side scan sonar) or for fishing (Echolote). A side scan sonar installed underneath a seaweed farm may be able to appropriately map broad horizontal distribution (Kool and Bernard in prep).

Ultimately, the coupling of several (indirect) monitoring techniques is more useful than using only one method. A reliable, validated and standardized design for an echo-sounder/sonar system will open new opportunities in remote monitoring to support marine resource management in an ecologically and economically responsible fashion.

# 6 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

# 7 Acknowledgements

We thank Noordzee Boerderij B.V. for their kind collaboration on the project and providing access to their seaweed cultivation, facilitated by Seaweed Harvest Holland B.V. (SHH). Furthermore, our gratitude goes to SHH for their permission, access, and assistance at their seaweed test farm site in the Schelphoek. Special thanks are dedicated to John N. from SHH and Jasper Veen from Noordzee Boerderij. Alexander Lubsch is responsible for the experimental design, performance and reporting. Romy Lansberg provided a secondary review on the report.

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# Justification

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Project Number: 4318300156

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: M. Poelman MSc
Researcher Aquaculture

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Date: 09-12-2020

Approved: Drs. Jakob Asjes
MT member Integration

Signature: 

Date: 16-12-2020

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