Name of indicator	2.10 *Cladophora glomerata* growth rate
Type of Indicator	State indicator
Author(s)	Ari Ruuskanen
Description of the indicator	The indicator describes the abundance of *Cladophora glomerata* in an assessment unit. The abundance of the *C. glomerata* vegetation is expressed as growth rate, derived from information on frond length and the length of the growth period. The filamentous summertime green algae *C. glomerata* is the most common algae occupying shorelines along the Finnish coast line. Its seasonal occurrence and abundance is mainly determined by nutrient availability in the water column, as well as water temperature. Sources of natural variation in abundance are geographical location, wave exposure, and sea bottom structure. If the sources of natural variation are known, it is possible to assess responses of *C. glomerata* to anthropogenic pressure. In the present work, the pressure is nutrients and the response is expressed as *C. glomerata* growth rate. By excluding sources of natural variation, and comparing with the observed growth rates of *C. glomerata* when grown in laboratory conditions in different nutrient concentrations, we can, based on measurements of *C. glomerata* populations in the field, estimate the overall summertime nutrient status in the studied sea area. In traditional water quality monitoring, sampling takes place once a week or even less frequently. Nutrient concentrations fluctuate on a daily basis and by taking samples once a week or month this variation will not be observed (Figure 1). However, *C. glomerata* takes up available (fluctuating) nutrients from the water column continuously as it grows and this can be measured as an increase in frond length. Thus, frond length represents the total amount of nutrients present in water column during a given time period. This indicator species describes short term (1-4 months) direct human-based impacts of sea-use activities. The frond length of *C. glomerata* is a cost-efficient way to measure approximate nutrient concentrations in large areas where traditional sampling procedures or the use of measurement devices are not applicable. The indicator does not replace traditional nutrient sampling, but indicates the direction how nutrient levels are developing. The indicator was developed and tested for the coastal area of south-western Finland (MARMONI 3FIN) study area (MARMONI 3FIN).
Relationship of the indicator to marine biodiversity	The length of the frond of the indicator species is related to the nutrient concentrations in the water and reflects the state of the sea in the area. By excessive growth due to increased nutrient concentrations *C. glomerata* forms mass occurrences which in turn inhibit colonization success and later occurrence of perennial key species such as *Fucus vesiculosus* and associated fauna, decreasing total biodiversity.
Relevance of the indicator to different policy instruments	Through collaboration between MARMONI and the HELCOM CORESET project, the *Cladophora glomerata* length segment of the indicator has been agreed as a Candidate Indicator in the HELCOM CORESET of Biodiversity indicators (HELCOM 2012). Marine Strategy Framework Directive (MSFD) descriptor 1, criterion 1.2 Population size, 1.2.1 Population abundance and/or biomass MSFD descriptor 5, criterion 5.1 Direct effects of nutrient enrichment MSFD descriptor 6, criterion 6.1 Kind and size of relevant biogenic substrata HELCOM Baltic Sea Action Plan (BSAP): Ecological objectives "Natural distribution and occurrence of plants and animals" (Eutrophication) and "Thriving communities of plants and animals" (Nature conservation).
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass
Method(s) for obtaining indicator values	The growth of *C. glomerata* is approximated through measuring fronds of *C. glomerata* at a known time of its seasonal succession. Basically, sampling can take place at any time during the growth period of *C. glomerata* (May-August), but late summer is recommended. To exclude sources of natural variation in abundance, frond length or growth rate samples are collected from chosen sea marks located along ship routes (Figure 2). The sea marks are identical in terms of the microhabitat of the growth surface, construction material, etc. and their maintenance history is known. An important feature of sea marks is that the buoyancy effect of sea marks keeps C. glomerata canopy at steady depth all the growth season. From

	each sea mark at least eight fronds are collected, but a number of 20 - 30 fronds is recommended, and measured with the accuracy of one millimetre; thereafter their mean length is determined. At least eight sea marks should be included. It is recommended that the same sea marks are sampled each time (year). After the mean length or growth rate of *C. glomerata* has been determined from all sea marks at the given water site, the acquired values are compared to a reference growth rate value, which is also the GES border.
Documentation of relationship between indicator and pressure	The length and growth rate of *C. glomerata* fronds has been shown to be determined mainly by nutrient availability. We assume that the growth limiting nutrient in Finnish coastal waters is nitrogen (NO_3). In the present work, the relationship between *C. glomerata* frond length (growth rate) and pressure (nutrients) was tested in controlled laboratory experiments. *C. glomerata* fronds were cultivated in manipulated natural sea water by the water flow-thru method in different nutrient (NO_3) concentrations for approximately eight weeks (Figure 3). The change in frond length was measured and growth rates at different nutrient concentrations were determined. As a result we found that the average daily growth rate at 0,02 mg NO_3/L was 1,8 mm per day, and at a concentration of 0,05 mg/L the growth rate was 2,3 mm per day. The growth season starts when sea surface temperature reaches 5 ºC.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The indicator reference value, i.e. the daily growth rate at pristine conditions, was determined as follows: first, we determined the overall growth rate of *C. glomerata* frond at manipulated nutrient conditions (see section "Documentation of relationship between indicator and pressure" above). The growth rate was linear in the beginning of the laboratory growth experiment period, but started to decrease at the end of the period, perhaps for natural reasons. By using pooled growth rates acquired from the laboratory experiment we concluded that a mean daily growth rate was 2,05 mm at 0.035 mg NO_3/ L. Second, we determined the reference level of NO_3 by field studies and expert judgment. This value is needed to estimate growth rate of *C. glomerata* frond in pristine conditions. In the field, the range of NO_3 levels was studied *in situ* with a high-frequency measurement device in 2010 and 2011. The monitoring was carried out for the duration of approximately 6 weeks during the growth season and the measurement frequency was 10 minutes. As a result we found that NO_3 ranged between 0,005 and 0,08 mg NO_3/L (see figure 1 for year 2010). We use the lower quarter of the data set as the reference nutrient conditions. The lower quarter was 0,01 mg/L. To conclude: when the mean growth rate was 2,05 mm at 0,035 mg NO_3/ L, then the estimated daily growth rate in pristine conditions (NO_3 0,01 mg per L) is 0,58 mm per day.
Method for determining GES	GES will be determined quantitatively through the target (i.e. reference condition value). Two examples of determining indicator status, both from the Hanko peninsula, Finland (MARMONI 3FIN study area): Example 1: In 2011, the growth season was 154 days and the observed mean length of *C. glomerata* was132 mm, yielding a growth rate of (132 mm / 154 days) 0,86 mm/day. To meet GES, the growth rate of *C. glomerata* may not exceed 0,58mm/day in the area; this mean that GES was not reached. Example 2: In 2012, the growth season was 91 days and the observed mean length of *C. glomerata* was182 mm, yielding a growth rate of (182 mm / 91 days) 2,0 mm/day. To meet GES, the growth rate of *C. glomerata* may not exceed 0,58 mm/day in the area; this mean that GES was not reached.
References	HELCOM 2012. Development of a set of core indicators: Interim report of the HELCOM CORESET project PART B: Descriptions of the indicators. HELCOM Baltic Sea Environment Proceedings 129B: 1-219. Auer, M.T. & Canale, R.P. 1982: Ecological Studies and Mathematical Modeling of *Cladophora* in Lake Huron: 3. The Dependence of Growth Rates on Internal Phosphorous Pool Size. – Journal of Great Lakes Research 8: 93-99. Auer, M. 2004: Modeling *Cladophora* Growth: A Review of the Aure-Canale Framework. – Cladophora Research and Management in the Great Lakes. Proceedings of a workshop Held at the Great Lakes WATER Institute, University of Wisconsin-Milwaukee, December 8, 2004. Berger, R., Henriksson, E., Kautsky, L. & Malm, T. 2003: Effects of filamentous algae and

deposited matter on the survival of *Fucus vesiculosus* L. germlings in the Baltic Sea. - Aquatic Ecology 37: 1-11.

Bergey, E.A., Boettiger, C.A. & Resh, V.H. 1995: Effects of water velocity on the architecture and epiphytes of *Cladophora glomerata* (*Chlorophyta*). – J. Phycol. 31 (2) 264–271.

Eklund, M. 1998: The influence of eutrophication and metal contamination on the seaweeds *Cladophora glomerata* and *Ceramium tenuicorne*. – Vatten 1: 7-16.

Gubelit, Y. & Berezina, N.A. 2010: The causes and consequences of algal blooms: the *Cladophora glomerata* and the Neva Estuary (eastern Baltic Sea). – Mar. Poll. Bull. 61: 4-6.

Herbst, R.P. 1969: Ecological Factors and the Distribution of *Cladophora glomerata* in the Great Lakes. – American Midland Naturalist 82: 90-98.

Lohman, K. & Priscu, J.C. 1992: Physiological indicators of nutrient deficiency in *Cladophora* (*Chlorophyta*) in the Clark Fork of the Columbia River, Montana. – J. Phycol. 28: 443-448.

Lorenz, R.C. & Herdendorf, C.E. 1981: Growth Dynamics of *Cladophora glomerata* in Western lake Erie in Relation to Some Environmental Factors. – Clear Technical Report No. 224. The Ohio State University Center for Lake Erie Area Research Columbus, Ohio.

Robinson, P.K. & Hawkes, H.A. 1986: Studies on Growth of *Cladophora glomerata* in Laboratory continuous-flow Culture. – Br. Phycol. J. 21: 437-444.

Rosemarin, A. 1982: Phosphorus Nutrition of Two Potentially Competing Filamentous Algae, *Cladophora glomerata (L.)* Kütz. and *Stigeoclonium tenue* (Agardh) Kütz. from Lake Ontario. - Journal of Great Lakes Research 8: 66-72.

Tamminen, T. & Seppälä, J. 1999: Nutrient pools, transformations, ratios and limitation in the Gulf of Riga, the Baltic Sea, during four successional stages. – J. Mar. Syst. 23: 83-106.

Tamminen, T. 1990: Eutrophication and the Baltic Sea: Studies on phytoplankton, bacterioplankton, and pelagic nutrient cycles. PhD thesis. University of Helsinki.

Wallentinus, I. 1984: Comparisons of nutrient uptake rates for Baltic macroalgae with different thallus morphologies. – Mar.Biol. 80: 215-225.

Illustrative material for indicator documentation

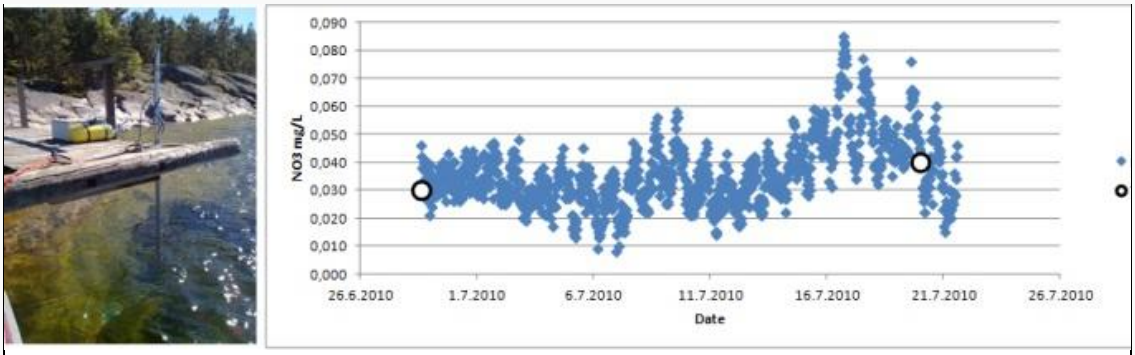

Figure 1. Left: a nutrient measurement device in action. Right: Daily fluctuations in NO_3 measured at 10 minutes intervals (diamonds) and by traditional sampling protocol data obtained from the database of the Finnish Environment Institute SYKE (open circles) in Finnish coastal waters in the summer of 2010. Photo by A. Ruuskanen.

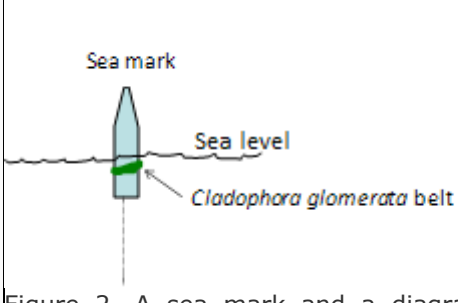

Figure 2. A sea mark and a diagrammatic illustration of the annual filamentous green algae *Cladophora glomerata* growing on it.

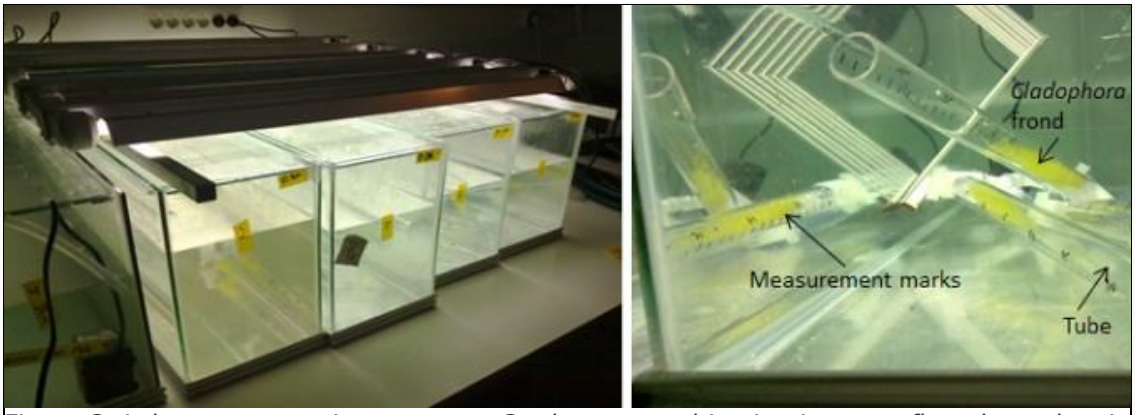

Figure 3. Laboratory experiment setup: *C. glomerata* cultivation in water flow-thru tubes in different nutrient concentrations. Changes in frond length were observed by measurement marks on the tube. Photos by A. Ruuskanen.