P-11-10

Validation of the marine vegetation model in Forsmark

SFR-Site Forsmark

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April 2011

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Abstract

A regression model implemented in GIS of the marine vegetation in Forsmark were developed by SKB /Aquilonius 2010/ based on field investigations and video surveys /Fredriksson 2005/ and from correlations of field data and physical properties /Carlén et al. 2007/. The marine vegetation model describes distribution and biomasses of the marine vegetation and is used as input data in the dose modeling within the safety assessments performed by the SKB. In this study the predictive performance of the vegetation model in the less examined parts of the marine area in Forsmark is evaluated.

In general, the vegetation model works very well in predicting absence of biomass, except for Red algae. In total and for *Fucus sp*., the model also predicts the observed biomass fairly well. However, for phanerogams, *Chara sp*., filamentous algae and red algae the vegetation model works less well in predicting biomass.

Sammanfattning

En regressionsmodel, implementerad i GIS, som beskriver förekomsten av marin vegetation har tagits fram av SKB /Aquilonius 2010/. GIS-modellen är baserad på fältinventeringar och videoundersökningar av bottnar i Forsmark /Fredriksson 2005/ och på korrelationer mellan fältdata och fysikaliska parametrar /Carlén et al. 2007/. Den marina vegetationsmodellen beskriver förekomst, utbredning och biomassa av marin vegetation i området, och används som underlag för att ta fram parametrar till säkerhetsanalyser genomförda av SKB. I denna undersökning utvärderas den marina vegetationsmodellens prediktiva förmåga i de områden i Forsmark, där fältundersökningar inte genomförts tidigare.

Generellt fungerar vegetationsmodellen bra för samtliga vegetationsgrupper utom för röd alger, när det gäller att förutse om det finns vegetation eller inte på en plats. För den sammanlagda biomassan och för *Fucus sp.* separat, predikterar vegetationsmodellen den observerade biomassan relativt bra. Men för biomassa av fanerogamer, *Chara sp.*, fintrådiga alger och rödalger fungerar vegetationsmodellen mindre bra.

Contents

1 Introduction

SKB is conducting investigations prior to a future enlargement of the SFR repository for low- and medium level nuclear waste situated close to Forsmark nuclear power plant in the Östhammar community. These investigations are concentrated on specific issues of importance for the safety assessment for the enlargement of the SFR-repository. This study is part of a larger investigation program.

This document reports the performance and results from a validation of the marine vegetation map in the Forsmark area. The work was carried out in accordance with activity plan AP SFR-10-004. The controlling documents for performing this activity are listed in Table 1-1. Both activity plan and method documents are SKB's internal controlling documents.

A GIS-model of the marine vegetation in Forsmark were developed by SKB /Aquilonius 2010/, based on field investigations and video surveys /Fredriksson 2005/, and correlations of field data and physical properties in the area /Carlén et al. 2007/. The marine vegetation model describes distribution and biomasses of the marine vegetation and is used as input data in the dose modeling within the safety assessments performed by the SKB. This study aims to evaluate the predictive performance of the vegetation model in the marine areas of Forsmark, were former field investigations are absent. Hence, some parts of the marine area are very well studied in field investigations and the confidence in the vegetation model is larger in these areas, while other parts are less know, see Figure 1-1. In the less studied areas the vegetation model has been applied to predict the biomass and distribution based on the knowledge of the more frequently studied areas, i.e. correlations between observed vegetation and physical properties. This investigation comprises; a field investigation part with random sampling of the marine vegetation, and analyze part when the outcome of field sampling is used to validate the present vegetation model.

In the field investigation part, 29 randomly selected sites in previously unvisited areas were visited, and determination of benthic vegetation and bottom substrate were carried out.

Original data from the determination of benthic vegetation and bottom substrate and the estimations of dry weight were delivered to SKB's data base SICADA and is traceable by the activity plan number (AP SFR-10-004). The data presented in this report are regarded as copies of the original data.

The field investigation was performed in August 23–25, 2010.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Validering av den marina vegetationskartan i Forsmark	AP SFR-10-004	1.0

Table 1-2. Data references.

Sub-activity	Database
Fältdata ifrån dykinventeringar av den marina vegetationen i Forsmark	SICADA

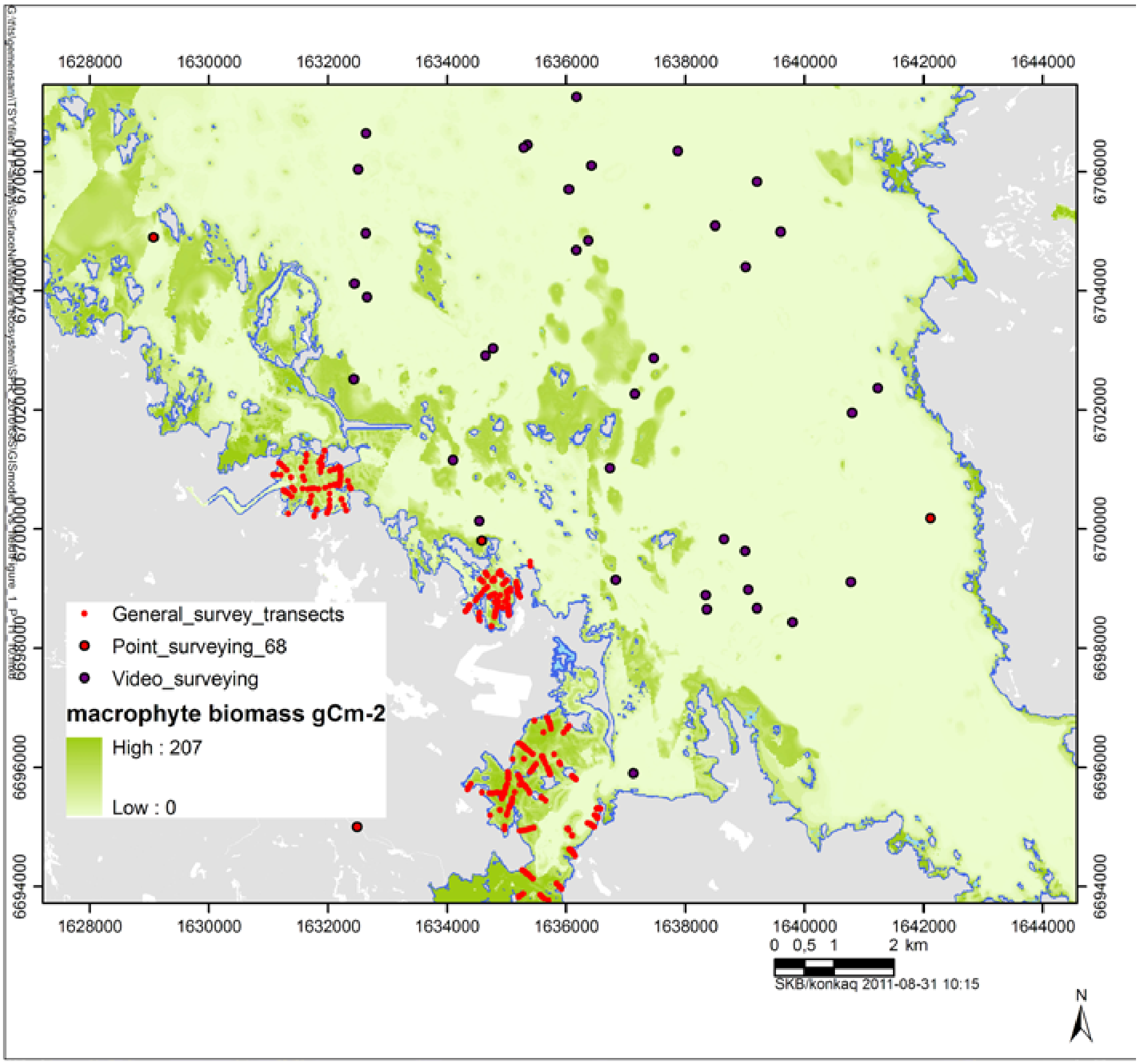


Figure 1-1. *The marine vegetation map, from the vegetation model for Forsmark, showing annual mean biomass of all macrophyte vegetation, in gC m*$^{-2}$*. Based on field investigations performed during SKB's site investigations (survey sites marked in map) and a regression model for vegetation implemented in GIS. Land is grey in the map and the shoreline blue.*

2 Equipment

The determination of vegetation and substrate was done using SCUBA-technique. Measuring tape, buoy, compass, GPS, plastic note board, dive computer and a boat was used in the vegetation survey.

3 Execution

3.1 Execution of field work

The field investigation part of this study was performed during the 23–25 of August 2010. The field investigation included determination of benthic vegetation and bottom substrate on 29 sites in the investigation area.

3.1.1 Sites

In order to evaluate the predictive power of the model in vegetated areas lacking earlier field observations, the field investigation sites were randomly selected in areas of the marine regional model area in Forsmark, fulfilling the following criteria:

1. Not included in previously performed field investigations of benthic vegetation.
2. No deeper than 15 m.

In addition, the randomly selected sites were evenly distributed between sub-areas of the investigation area in Forsmark. The sub-areas were divided according to depth and wave exposure in order to get a representative number of sites affected by these environmental factors. The investigation sub-areas were:

1. sheltered areas (bays) less than 7 m depth,
2. sheltered areas (bays) between 7–15 m depth,
3. open archipelago less than 7 m depth and
4. open archipelago between 7–15 m depth.

In these areas a total of 44 sites were randomly selected. The position of the investigated sites were determined using a randomized method (“random” function in MS Excel). Of the 44 selected sites 29 were finally visited in the field investigation (Figure 3-1).

3.1.2 Field methods

Vegetation survey

At each site an area of 60 m^2 of the seafloor was surveyed with regard to vegetation and substrate type. The employed method is based on the line transect method used in the national monitoring program of benthic vegetation communities on the Swedish east coast /Naturvårdsverket 2004/.

The predetermined position of the site was marked with a buoy by which the divers descended. Upon reaching the seafloor they attached a measuring tape to the buoy anchor and swam out 10 m parallel to the depth curves (see Figure 3-2). After 10 m the divers turned around and began the survey by noting the compass direction to the buoy on a plastic note board. The water depth was measured with a dive computer and distance on the measuring tape noted. The divers then determined the substrate type to rock, boulders, stones, gravel, sand or soft substrate (for example mud and clay). The coverage of the substrate types was determined according to a seven-degree scale: 1, 5, 10, 25, 50, 75% or 100%. The same scale was then used to determine the cover of the main vegetation species. Sediment cover was estimated using a four-degree scale where 1 is no or little sediment and 4 means that if the sediment cover is disturbed the visibility is reduced to zero.

The divers followed the measuring tape back toward the buoy. If a change in substrate or vegetation occurred a new estimation of all the parameters were made. The result is a detailed description of water depth, substrate type and vegetation cover along a six meter wide corridor of the seafloor (Figure 3-3).

The determination of vegetation was limited to main species or species groups and no extra effort was put into searching for rare species. Presence of the sessile animals hydrozoans and barnacles (*Balanus improvisus*) were noted.

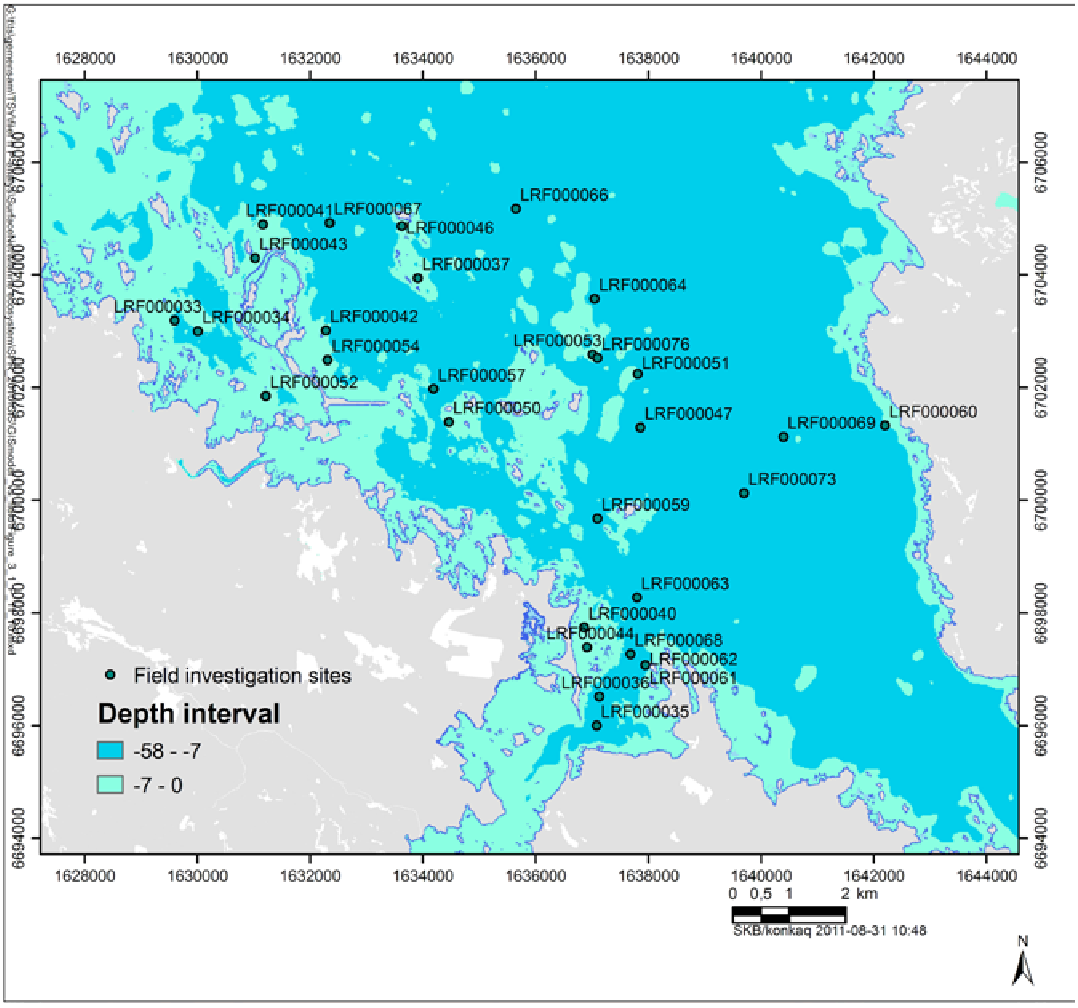
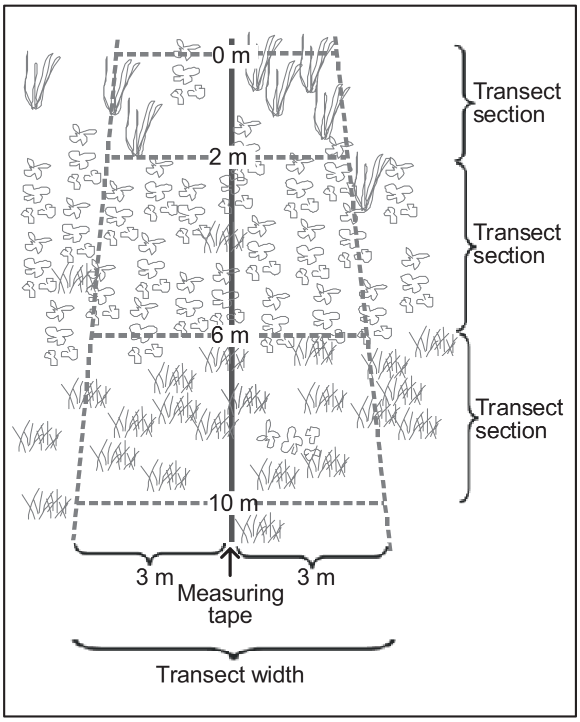


Figure 3-1. *The 29 investigated randomly selected sites, in the marine area in Forsmark, together with the two depth intervals 0–7 m and 7–15 m (and deeper).*

Figure 3-2. *Measuring tape at one of the investigated sites (LRF 000050) in the vegetation survey.*



Distance:Depth	Description of transect section
10:4.4	Soft substrate 100%, Sediment 3, plant A 50%, plant B 5%
6:4.3	Soft substrate 100%, Sediment 3, plant A 10%, plant B 75%
2:3.7	Soft substrate 75%, Rock 25%. Sediment 3, plant B 25%, plant
0:3.7	End of transect

Figure 3-3. *Schematic picture of the field method and example of the diver's notes.*

3.2 Validation of vegetation model

The predictive power of the vegetation model was examined by comparing biomass estimates predicted by the model with observations at the selected sites. The biomass estimates extracted from the vegetation model for the sites was annual means of gC m^{-2}. To make the comparison, the field data were converted the same way as applied in the vegetation model; from observations of covering degree to biomass in dw, by using the relationship described in /Fredriksson 2005/ and from biomass dw to gC m^{-2} by using the relationship presented in /Kautsky 1995/, for all functional groups except for *Fucus sp*. *Fucus sp*. was converted using the relationship between dry weight and carbon content from /Engdahl et al. 2006/. The vegetation model is given a brief description and conversion factors used is presented in Appendix 2.

The predicted model values of vegetation biomass, was then compared with observed, for the total macrophyte community at the sites, and for the functional groups; *Chara sp*., phanerogams (vascular plants), filamentous algae, *Fucus sp*., red algae and *Vaucheria sp*., separately. Descriptive statistics was generated for predicted and observed biomass values, and the Bray-Curtis dissimilarities test and the Wilcoxon signed rank test were carried out. The Bray-Curtis dissimilarity was used to characterize how similar the observed value was from the predicted value, ignoring observations were no biomass was observed or predicted. The Wilcoxon signed rank test was used to test whether the model predictions were systematically lower or higher than the observed values. The root-mean-square error (RMSE) was also calculated. RMSE is an absolute measure of fit and is in the same units as the response variable. In addition the predictive power of the model was tested by calculating the variation in observed data explained by the model ($r^2_{model)}$. This was done by dividing the sum of squares explained by the model (i.e. corrected sum of squares – residual sum of squares) with the corrected sum of squares (i.e. the variance of the observed data), and a ratio of explanation degree for the model was achieved. When the observed values deviated more from the predicted values than from their mean value, r^2_{model} was set to 0.

4 Noncomformities

Nonconformities have not been reported during the performance of this activity.

5 Results

5.1 Results field investigation

The investigation area is situated in a naturally low saline area in the northern Åland Sea within the Baltic Sea. The salinity in the area is around 4.5 psu which gives a benthic vegetation communities consisting of both marine and limnic species. The marine species are mainly macroalgae whereas the limnic species are represented mainly by vascular plants (phanerogams). Vascular plants grow mainly on shallow, soft or sandy substrate in relatively wave sheltered sites whereas macroalgae prefer hard substrate and more wave exposed sites.

In this survey of the main vegetation on 29 sites, a total of 21 vegetation taxa were observed (Table 5-1). These included red, brown and green macroalgae as well as charophytes, moss and vascular plants. The vegetation cover on the sites varied between 100% coverage and no vegetation (0%). The maximum depth surveyed was 15 m and the minimum depth 0.9 m. All types of substrates were represented although the most common types on the sites were rock, boulders and sand.

Table 5-1. List of observed taxa on the 29 investigated sites. Both *Fucus vesiculosus* and *Fucus radicans* were observed but as these two species are hard to distinguish morphologically they were not separated but determined only to *Fucus sp.*

Group	Latin name	Swedish name
Red algae		
	Ceramium tenuicorne	Ullsläke
	Furcellaria lumbricalis	Kräkel
	Hildenbrandia rubra	Havsstenhinna
	Polysiphonia fibrillosa	Violettslick
	Polysiphonia fucoides	Fjäderslick
Brown algae		
	Chorda filum	Sudare
	Ectocarpus/Pylaiella	Moln-/Trådslick
	Fucus spp	Blåstång/Smaltång
	Sphacelaria arctica	Ishavstofs
Green algae		
	Cladophora glomerata	Grönslick
	Cladophora rupestris	Bergborsting
	Enteromorpha spp	Tarmalger
Charophytes		
	Chara aspera	Borststräfse
	Tolypella nidifica	Havsrufse
Mosses		
	Fontinalis sp	Näckmossa
Vascular plants		
	Callitriche hermaphroditica	Höstlånke
	Myriophyllum spicatum	Axslinga
	Potamogeton pectinatus	Borstnate
	Potamogeton perfoliatus	Ålnate
	Zannichellia palustris	Hårsärv
Fungus		
	Ephydatia fluviatilis	Sötvattenssvamp
Invertebrates		
	Balanus improvisus	Havstulpan
	Hydrozoa	Nässeldjur

5.1.1 Overview description of the vegetation

The investigated marine area in Forsmark was divided in four sub-areas with somewhat different physical environment, Figures 5-1 and 3-1. Area a, in average deeper and wave exposed, Area b, included wave exposed but in average more shallow sites, and area c and d are representative of less exposed bays.

Area a, deeper wave exposed sites

In the wave exposed part of the investigation area, among the small islands and skerries toward the middle of the sound (area **a** in Figure 5-1), the sea floor consisted mainly of hard substrates such as rock, boulders and stones. The sedimentation was generally low, estimated at 1–2 on the four graded scale, occasionally 3.

Vegetation occurred from the maximum investigated depth, 15 m. The deepest growing vegetation was the filamentous brown alga *Spacelaria arctica*. The perennial *S. arctica* was dominating in the vegetation communities up to ca 12 m depth where the filamentous red alga *Polysiphonia fucoides* took over. The vegetation cover between 12–15 m varied between 1–75% depending on depth and availability of hard substrates.

The red alga *P. fucoides* covered 25–100% of the hard substrates between 8 and 12 m depth. The vegetation was otherwise comprised of the red algae *Ceramium tenuicorne* and *Furcellaria lumbricalis*, the brown algae *S. arctica* and the moss *Fontinalis sp*. In Figure 5-2 an example of red algae vegetation from site LRF000041 is presented.

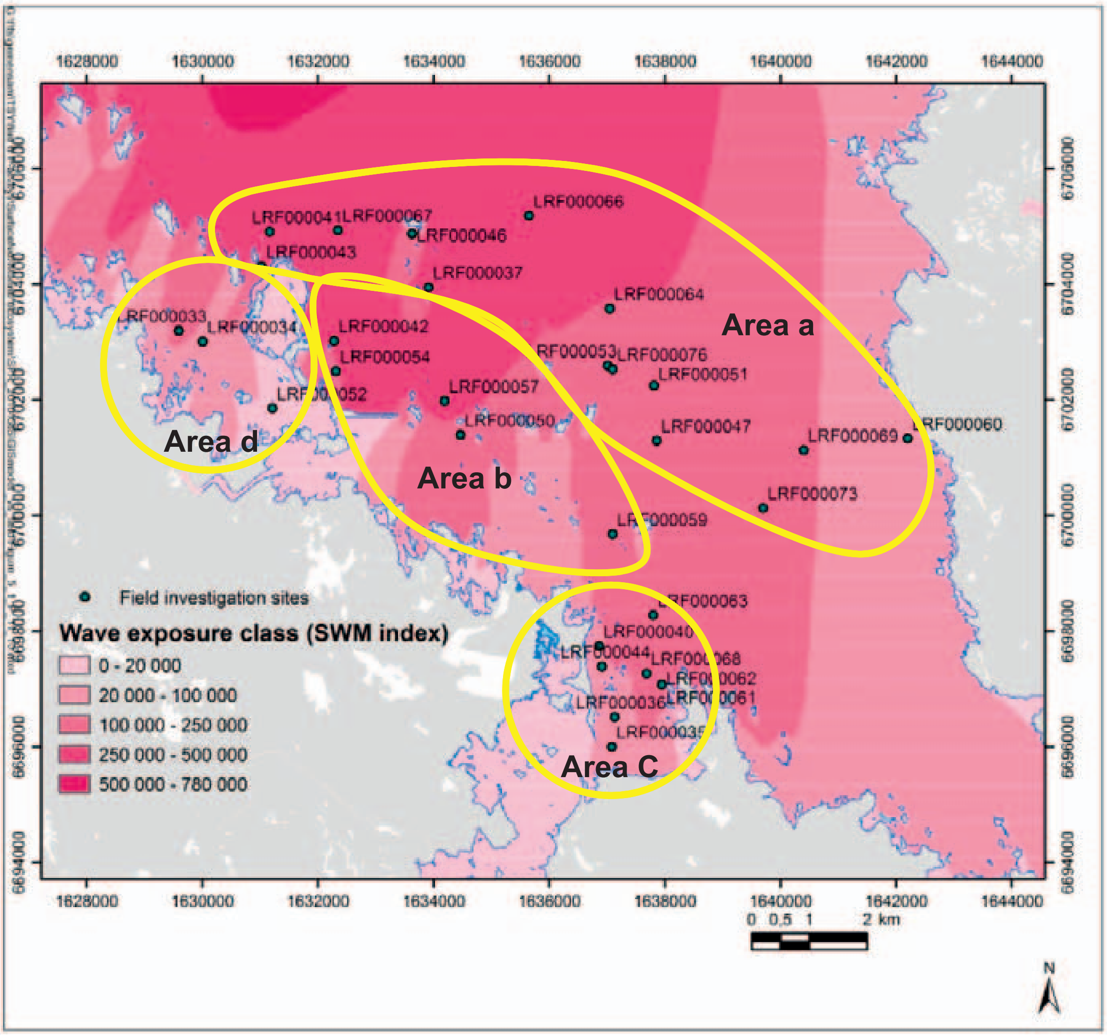


Figure 5-1. *The four marine sub-areas in Forsmark, the visited sites and the wave exposure index.*

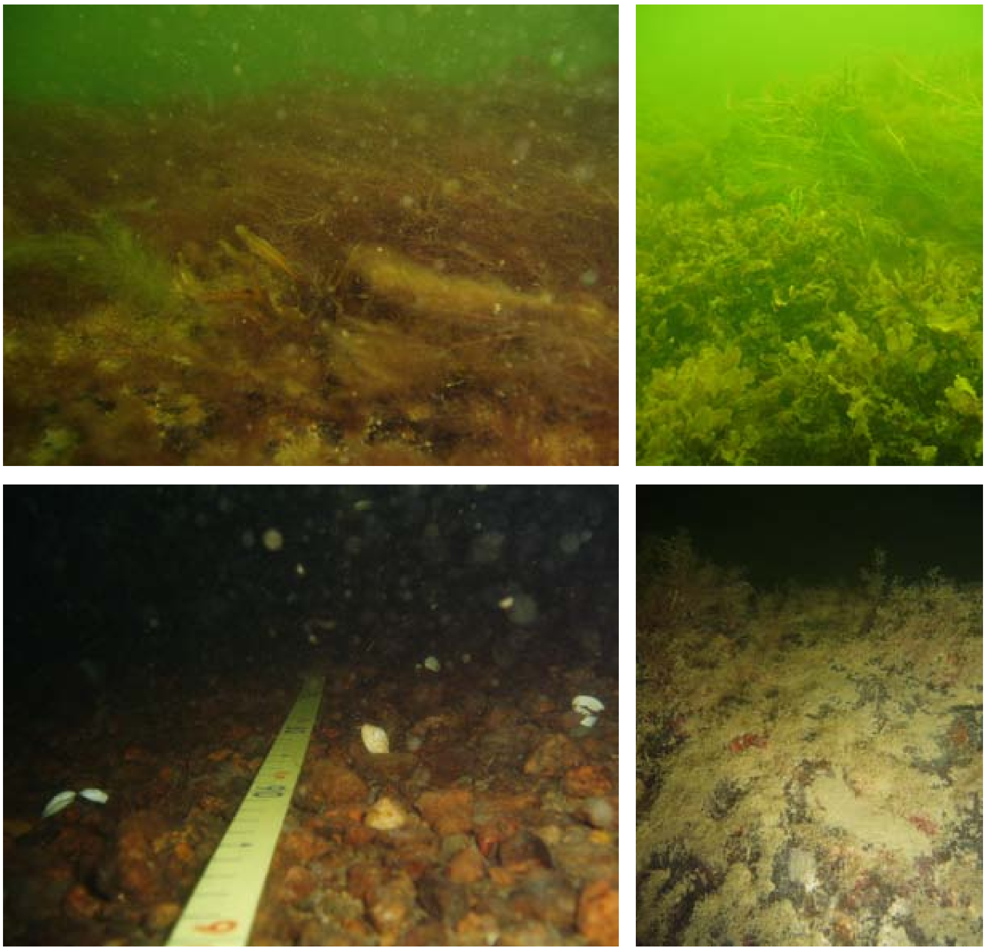


Figure 5-2. *Vegetation at site LRF000041 (area a), mainly consisting of red algae (upper left photo), Fucus sp. at LRF000054 (upper right photo, area b), bottom at LRF000036 (lower left photo, area d) and filamentous algae on a boulder at LRF000052 (lower right photo, area c).*

The depth interval 3–6 m (the minimum investigated depth in area a) included the *Fucus*-belt (> 25% coverage), but the red alga *P. fucoides* was still common covering up to 100%. The *Fucus*-belt was more developed in slightly more sheltered locations whereas *P. fucoides* dominated on more wave exposed surfaces. The *Fucus*-belt included both *Fucus vesiculosus* and *Fucus radicans*.

Sand and gravel areas generally had little or no vegetation deeper than 3 m. Although, at 3 m depth the vegetation could be dense including vascular plant species and *Chara sp*.

Area b, more shallow wave exposed sites

In the wave exposed but generally more shallow area (area **b** in Figure 5-1) with larger islands and closer to the mainland sandy substrate was more common. The deeper seafloor at 13–14 m depth often consisted of soft substrate or clay with a dense sediment cover (4). The sandy substrates dominating in the depth interval 6–12 m and the gravel, stone and boulder bottoms around 4 m depth had less sediment (1–2).

The vegetation in this area occurred from ca 12 m depth in the form of sparse growth of *S. arctica* and *P. fucoides* on occasional boulders. In the depth interval 3–4 m where hard substrates dominated the vegetation covered 75–100% consisting mainly of the macroalga *P. fucoides*. *Fucus sp*. was beltforming on one site (LRF00054) at 2–4 m depth, see Figure 5-2.

The communities on gravel or sandy substrates consisted of vascular plants and charophytes (*Chara sp*.). The depth distribution of these communities only reached down to ~ 4 m, despite availability of suitable substrate.

Area C, southern bay

In the southern part of the investigation area (area **c** in Figure 5-1), the seafloor sheltered within the bay Kallriga consisted mainly of sand, stone and clay with scattered boulders, see Figure 5-2. The vegetation in the investigated depth interval 5–10 m was sparse comprised of a few macroalgae growing on the scarce boulders and stones. The sediment layer on the seafloor was thicker (3–4) than in the more wave exposed areas.

Area d, somewhat more sheltered bay

In the very sheltered area (area **d** in Figure 5-1), behind the peninsula formed by Lake Biotestsjön the investigated depth interval 5–8 m had a seafloor consisting of mainly boulders and clay with regions of sand and stones. The sediment layer was estimated as 3–4 on the four graded scale. The vegetation was generally sparse and comprised mainly of the macroalgal species *P. fucoides* and *S. arctica* and some vascular plant species, see Figure 5-2. Macroalgae was observed down to ca 7 m depth and vascular plants down to ca 5 m depth.

Detailed description of the sites is presented in Appendix 1. In addition data of the benthic vegetation and the bottom substrate are stored in SKB's database SICADA.

5.2 Results model validation

Biomass data for the investigated sites were extracted from the vegetation layers in the GIS model for Forsmark /Aquilonius 2010/. The predicted biomass data from the model was in annual means of gC m^{-2}, and the mean value represents the 60 m^2 rectangle of the investigated site. The observed field values of covering degree was converted to annual means in gC m^{-2} , representative for the whole 60 m^2 rectangle, in order to be able to make a comparison. A summary table of predicted and observed biomass values for the investigated sites is presented for the total macrophyte biomass and for the separate functional groups; *Chara sp*., Phanerogams, filamentous algae, *Fucus sp*., red algae and *Vaucheria sp*. in Table A3-1 in Appendix 3. Descriptive statistics and plots are presented below.

The predicted annual mean values of biomass for all investigated sites are presented together with observed annual mean biomass values, in Figure 5-3.

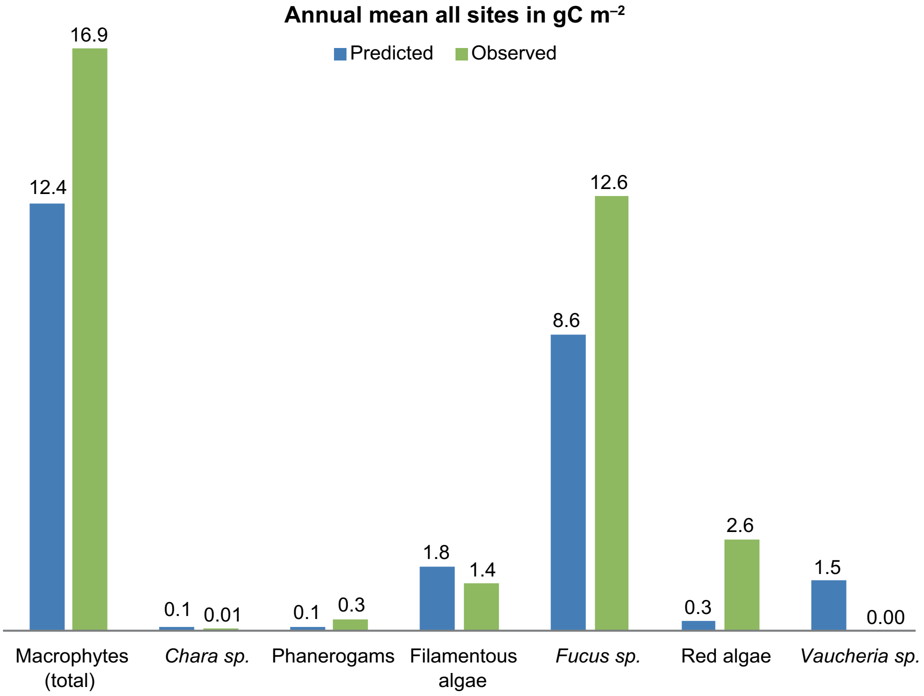


Figure 5-3. *The predicted and observed annual mean biomass (in gC m^{-2}) of macrophytes in all investigated sites. Note the logarithmic values.*

5.2.1 *Chara sp.*

Chara sp. was only observed in one of the investigated sites. The vegetation model succeeded in predicting this absence of biomass in 22 of the sites. The RMSE, takes zero values into account and therefore indicates a good predictability of the model. Hence, there is only one observation of *Chara sp.* at the investigated sites, which makes statistical tests on sites with biomass irrelevant. However, it seems as the model overestimates the occurrence of *Chara sp.* in the investigated area (Figure 5-4).

5.2.2 Phanerogams

Phanerogams (vascular plants) were only observed in 3 of the investigated sites. The model succeeds in predicting absence of phanerogams in 22 of the sites. However, in the sites with vegetation the predicted biomass are in general too high or too low, Figure 5-5. RMSE is large in comparison to predicted values, and r^2_{model} is 0 (i.e. the model does not explain any of the variation in the observed data). The sites with observed biomass are all in the shallow depth interval (0–7 m), which is in accordance with the depth limitation for phanerogam distribution applied in the model (Appendix 2). The Bray-Curtis dissimilarity shows that there are no common features between the predicted and observed values (on sites with biomass). In addition to the visual picture in Figure 5-5 the Wilcoxon signed rank test shows that there is no specific over- or underestimation by the model.

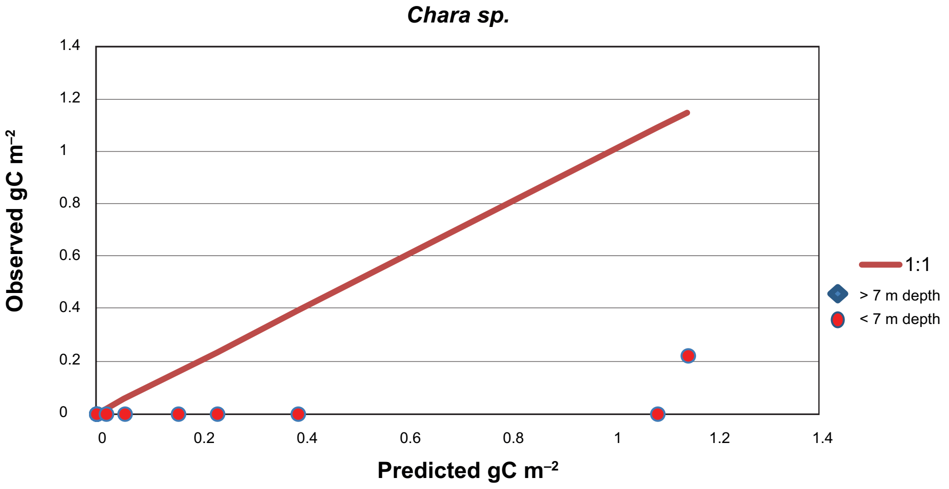


Figure 5-4. *Predicted biomass of Chara sp. vegetation in annual mean of gC m^{-2} plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.*

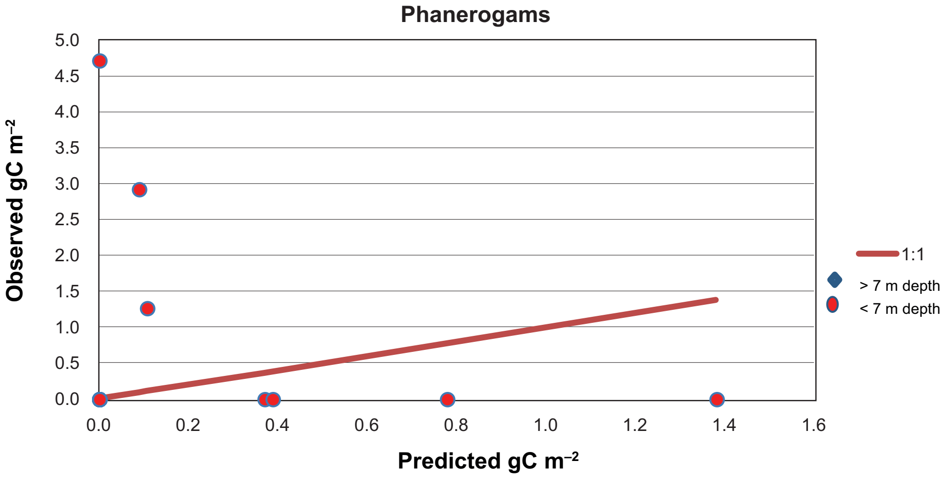


Figure 5-5. *Predicted biomass of phanerogams vegetation, in annual mean of gC m^{-2}, plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.*

5.2.3 Filamentous algae

The vegetation model predicts no filamentous algae in 5 out of 6 observed sites with filamentous algae missing. The predicted to observed, correlation is insignificant and the model generally seems to overestimate the biomass of filamentous algae, especially in the shallow depth interval (0–7 m) in the investigated sites. The vegetation model fails to explain any of the variation in the observed values. The RMSE is quite high and the statistical tests indicate that there is a difference between the predicted and observed biomass.

5.2.4 *Fucus sp.*

The vegetation model predicts 20 of the 22 sites were no *Fucus sp.* is observed. The predicted biomass correlates fairly well to the observed, especially in sites with lower biomass. The variation in the observed values is explained to 45% by the vegetation model. The variation in biomass is higher in sites with high biomass in the shallow depth interval (0–7 m), causing a quite high RSME value. The statistical tests indicate that the predicted biomass values are relatively similar to the observed.

Table 5-2. Summary statistics and results from tests of Bray-Curtis dissimilarities and Wilcoxon signed rank test for filamentous algae biomass.

	Predicted	Observed	Divergence
Mean	1.85	1.36	
Std av	2.12	2.43	
Median	0.90	0.81	
N≠0	21	26	
r^2_{model}			0%
Root Mean Square Error (RMSE)			3.06
Bray-Curtis dissimilarity			0.60
Wilcoxon signed rank test (n=7, 95% significance)			Difference exists

* Bray-Curtis dissimilarity is bound between 0 and 1, where 0 means that the two populations are the same, and 1 means the two populations do not share any features.

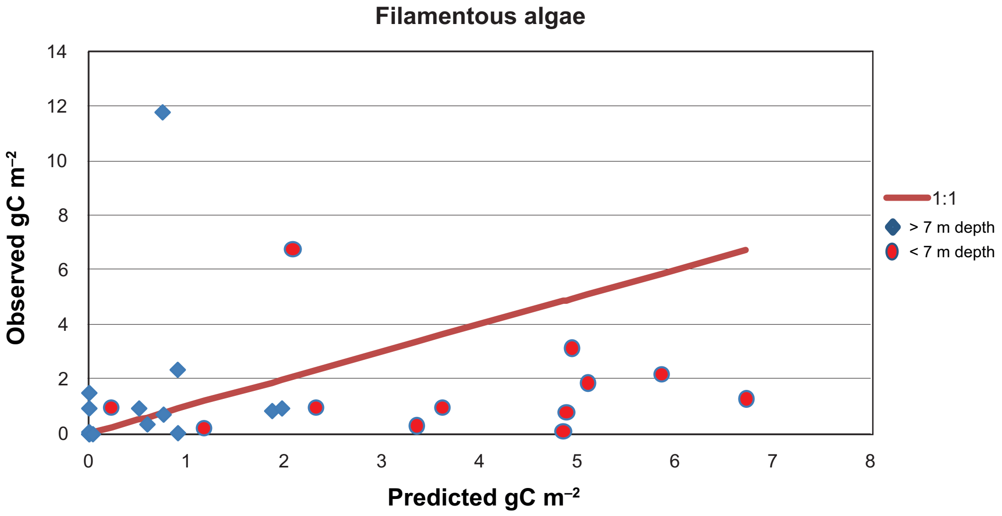


Figure 5-6. Predicted biomass of filamentous algae vegetation in annual mean of gC m^{-2} plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.

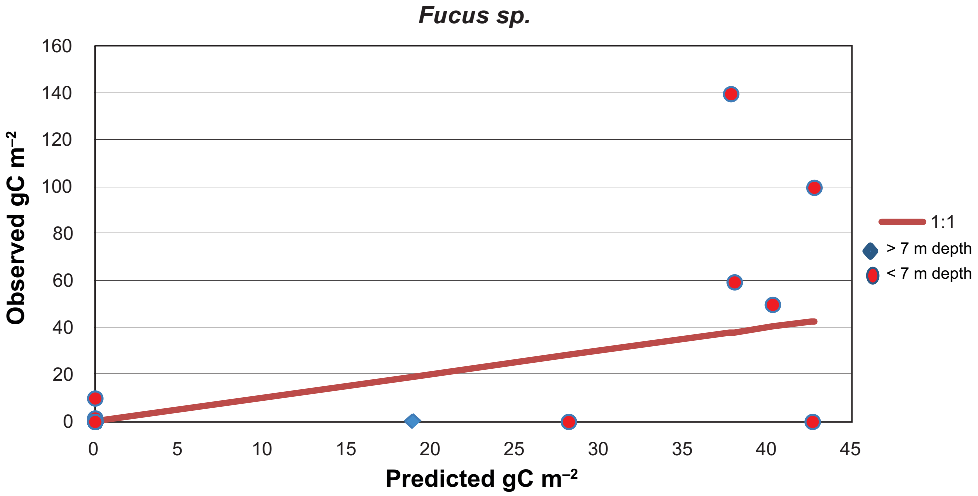


Figure 5-7. *Predicted biomass of Fucus sp. vegetation in annual mean of gC m^{-2} plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.*

Table 5-3. Summary statistics and results from tests of Bray-Curtis dissimilarities and Wilcoxon signed rank test for *Fucus sp*. biomass.

	Predicted	Observed	Divergence
Mean	8.58	12.6	
Std av	16.0	33.6	
Median	0.00	0.00	
N≠0	7	6	
r^2_{model}			45%
Root Mean Square Error (RMSE)			24.5
Bray-Curtis dissimilarity			0.48
Wilcoxon signed rank test (n=7, 95% significance)			No difference

* Bray-Curtis dissimilarity is bound between 0 and 1, where 0 means that the two populations are the same, and 1 means the two populations do not share any features.

5.2.5 Red algae

The model predicts 8 sites to be free of red algae and at all those sites red algae were observed. On 8 other sites no red algae were observed, hence the model predicted occurrence of red algae. The model could not explain any of the variation in the observed values. The correlation between predicted and observed biomass is negative RMSE is quite high and statistical tests show a difference between predicted and observed biomass. In general the vegetation model seems to work poorly in predicting biomass of red algae in these areas.

5.2.6 *Vaucheria sp.*

Vaucheria sp. were only predicted to occur on one of the investigated sites, however, it was not found at any of the visited sites. *Vaucheria sp.* is sensitive to wave exposure and is only found in very sheltered areas with soft bottom, and in the marine vegetation model a limit in wave exposure was set to capture the presence of *Vaucheria sp.* in the area (see also Appendix 2). Hence, this limit in wave exposure applied in the model seems to work fairly good, the model predicts no *Vaucheria sp.* in 28 out of 29 empty sites. However, this investigation does not give any information of how well the model predicts the biomass at sites were *Vaucheria sp.* is present.

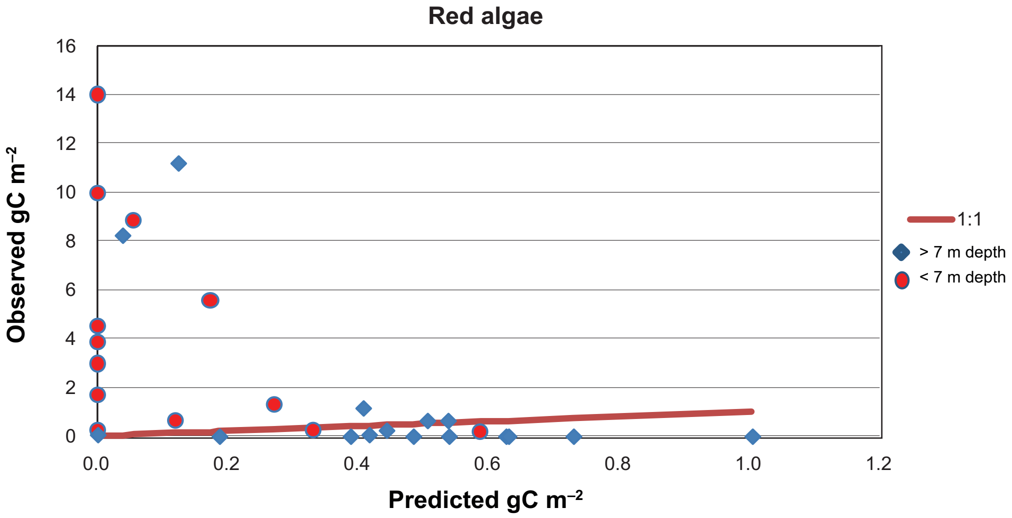


Figure 5-8. Predicted biomass of red algae vegetation in annual mean of gC m^{-2} plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.

Table 5-4. Summary statistics and results from tests of Bray-Curtis dissimilarities and Wilcoxon signed rank test for red algal biomass.

	Predicted	Observed	Divergence
Mean	0.30	2.63	
Std av	0.28	4.0	
Median	0.27	0.64	
N≠0	21	21	
r^2_{model}			0%
Root Mean Square Error (RMSE)			4.71
Bray-Curtis dissimilarity			0.85
Wilcoxon signed rank test (n=7, 95% significance)			Difference exists

* Bray-Curtis dissimilarity is bound between 0 and 1, where 0 means that the two populations are the same, and 1 means the two populations do not share any features.

5.2.7 Total macrophyte biomass

The predicted total macrophyte biomass was calculated as the sum from the individual prediction models (5.2.1–5.2.6). The predictability of the vegetation model is fairly good across the full prediction range (Figure 5-7). However, the prediction error increases with predictive value. The vegetation model explains 39% of the variation in the observations. Tests of the difference indicate that there are small differences between predicted and observed biomass values (Table 5-2), i.e. the vegetation model seems to predict the total macrophyte biomass fairly well. Although, in areas with higher biomass the predictability of the vegetation model is lower.

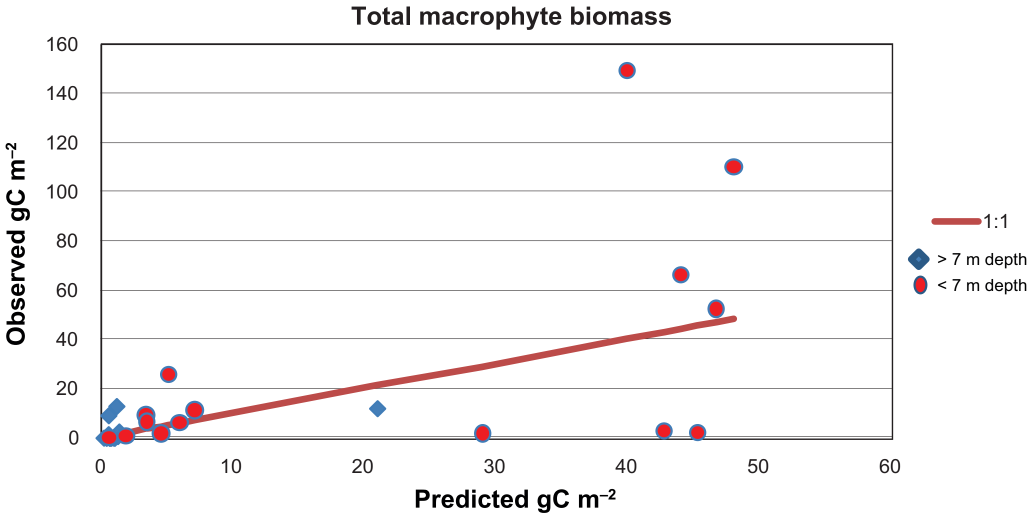


Figure 5-9. *Predicted biomass of total macrophyte vegetation in annual mean of gC m*$^{-2}$ *plotted against observed. Red dots denote sites in the depth interval 0–7 m, and blue squares denote sites in the depth interval 7–15 m. The red line represents the theoretical predicted to observed, 1:1, relationship.*

Table 5-5. Summary statistics and results from tests of Bray-Curtis dissimilarities and Wilcoxon signed rank test for total macrophyte biomass.

	Predicted	Observed	Divergence
Mean	12.4	16.9	
Std av	17.8	35.5	
Median	1.9	2.2	
N≠0	29	24	
r^2_{model}			39%
Root Mean Square Error (RMSE)			27.3
Bray-Curtis dissimilarity*			0.44
Wilcoxon signed rank test (n=29, 95% significance)			No difference

* Bray-Curtis dissimilarity is bound between 0 and 1, where 0 means that the two populations are the same, and 1 means the two populations do not share any features.

6 Conclusions

The GIS model were basically developed on data and observations from the less exposed marine areas in Forsmark (see Figure 1-1), and works well for predictions of the presence/absence of macrophyte vegetation in the investigated areas, with the exception of the red algae group. For *Fucus sp*., the vegetation model also predicts biomass fairly well. Since *Fucus sp*. has a high biomass, as compared to the other vegetation groups, the predictive power of the total biomass is similar to that of *Fucus sp.* on its own.

However, quantitative predictions of biomass for *Chara sp*., phanerogams, filamentous and red algae were poor in the investigated areas. For *Vaucheria sp.* it is hard to make statements about the predictability of the model, as no observations from this macrophyte community were made in the relatively exposed areas sampled in this study.

The total carbon biomass of macrophytes per m^2 is an input parameter in the biosphere model used to calculate transport and accumulation of radionuclides in marine ecosystems. As the predictive power for the total macrophyte biomass was fair, the poor predictions of *Chara sp*. Phanerogams, filamentous and red algae biomass are not likely to have a significant effect of the parameter values for the investigated areas.

Nevertheless, the high sophistication of the marine model /Aquilonius 2010, Carlén et al. 2007/ stands in clear contrast to the poor prediction power of *Chara sp.,* Phanerogams, filamentous and red algae biomass in the investigated areas. Thus for simplicity and transparency, as well as from a perspective of predictive power, it seems reasonable to update the vegetation model for these more exposed areas.

A simple alternative modeling approach that would increase model predictability (for *Chara sp.* phanerogams and filamentous algae) would be to use the present method for predicting presence/absence, but to use a more robust predictor of biomass when present. The prediction of biomass could for example be based on the average or median values of biomass for appropriate strata, based on previous and present studies.

For predictions of the distribution of red algae in these relatively exposed areas it would be wise to fit a new model to the observed data, and possibly reexamine the fit of the original model.

Although, the deviation of predictions and observed data in this study may simply reflect that models describing vegetation patterns in relatively sheltered areas (see Figure 1-1) are not applicable to semi-exposed and exposed areas, the poor predictive power for *all* models that were derived from an additive combination of smoothing-functions (as opposed to the simpler method used for *Fucus sp.*), raise the questions whether these models were fit for the original purpose.

That is, although non-parametric smoothing functions are robust with respect to extreme values, they are highly flexible with respect to the functional response that can be captured. This is clearly a strength for a statistical method when the purpose is to describe or explore field data. However, combining several smoothing-functions leads to such a high degree of flexibility that there is an obvious risk for capturing sample specific properties, on top of the general macrophyte distributions patterns. Thus to avoid model over-fitting it is essential to evaluate predictive models with independent data, (by for example dividing the data into a model and a validation data sets).

As no attempt were made to validate the vegetation model with independent data in the original study /Aquilonius 2010, Carlén et al. 2007/ (in spite of 7,000 observations), it is unclear whether the model predictions are fair and unbiased even for sheltered areas, and to what extent the high degree of model complexity can be motivated in terms of predictive power.

7 References

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Appendix 1

Description of the sites

LRF000033: The boulders and stones on the clay bottom at 6.7 m depth had sparse coverage (10%) of the red alga *Polysiphonia fucoides* and the brown alga *Sphacelaria arctica*.

LRF000034: The boulders at 6–7 m depth had a thick layer of sediment (4) and only sparse vegetation consisting of the filamentous red alga *P. fucoides*.

LRF000036: The clay bottom at 7.8 m depth was covered by sediment (3) but was otherwise bare.

LRF000041: At 4.5 m depth the sandy bottoms were bare whereas the rock surfaces had lush vegetation comprised of several macroalgae and moss. The vegetation was dominated by the filamentous red alga *P. fucoides* (75%) but also the brown algae *Fucus sp.* and *S. arctica* occurred together with the green alga *Cladophora glomerata* and the moss *Fontinalis sp*.

LRF000046: At 8 m depth the seafloor consisted of boulders and sand covered by sediment (3). The vegetation, dominated by *P. fucoides*, grew on boulders covering ca 50%. Two other red algae occurred the coarse, perennial *Furcellaria lumbricalis* and the filamentous *Ceramium tenuicorne* as well as the brown filamentous alga *S. arctica*.

LRF000035: A bare clay bottom with dense coverage of sediment (4) at 10 m depth.

LRF000043: At 3 m depth the seafloor consisted of rock and sandy substrate with occasional boulders sparsely covered with sediment (2). The vegetation covered ca 75% of the substrates and was comprised of both macroalgae and vascular plants. *Fucus sp.* was beltforming (50% coverage) on the rock surfaces and grew together with the filamentous macroalgae *P. fucoides*, *P. fibrillosa* and *Ectocarpus/Pylaiella*. On the sandy substrates the vascular plants covered 25–50% of the seafloor together with scattered charophytes (*Chara aspera*). The vascular plant community was dominated by *Potamogeton pectinatus* but also *Myriophyllum spicatum*, *Potamogeton perfoliatus* and *Zannichellia palustris* occurred.

LRF000037: The boulders at 3–4.5 m depth had little sediment cover (1) but lush growth of macroalgae and scattered moss. The macroalgae community was dominated by the filamentous red alga *P. fucoides* which covered 75–100% of the substrate. Other filamentous algae were *C. tenuicorne*, *P. fibrillosa*, *Ectocarpus/Pylaiella* and *C. glomerata* covering ca 10%. The coarse red alga *F. lumbricalis* and the large *Fucus sp*. each covered ca 5%.

LRF000042: The mosaic bottom comprised of bouldes, stones, gravel and sand at 4 m depth had sparce sediment cover (1–2) and lush vegetation cover (75–100%). The vegetation was dominated by the filamentous red alga *P. fucoides* (75% coverage). The other macroalgal species *F. lumbricalis*, *Chorda filum*, *C. glomerata*, *Cladophora rupestris* covered ca 5–10% together. Also the charophyte *Tolypella nidifica* and the moss *Fontinalis sp.* occurred.

LRF000053: The rocky bottom at 3–3.5 m depth had little sediment (1). The vegetation consisted of beltforming *Fucus sp.* (25% coverage) and sparse coverage of the macroalgae *F. lumbricalis*, *P. fucoides*, *Ectocarpus/Pylaiella*, *C. glomerata* and *C. rupestris*.

LRF000054: At 3.5–4 m depth the seafloor consisted of boulders with sections of stones and gravel. The vegetation covered 100% of the substrates and was dominated by the filamentous red alga *P. fucoides* and belt forming *Fucus sp*. Other macroalgae were the coarse red alga *F. lumbricalis*, the stringlike *C. filum* and the filamentous green alga *C. glomerata* together with *Entermorpha sp*. Moss also occurred on the hard substrates whereas the gravel had vegetation consisting of the charophyte *T. nidifica* and the vascular plants *M. spicatum*, *P. pectinatus* and *Z. palustris*.

LRF000051: The hard substrate seafloor consisting of rock and boulders at 11 m depth had a relatively dense vegetation cover (50–75%). The vegetation was dominated by the filamentous *P. fucoides* but also the coarse *F. lumbricalis* occurred as well as the brown alga *S. arctica*. The sediment cover was 2–3.

LRF000066: At 12–13 m depth the seafloor consisted of rock, boulders and stones covered by the filamentous brown alga *S. arctica*. Also the coarse red alga *F. lumbricalis* occurred. The vegetation cover was 50–75% and the sediment cover 3.

LRF000052: The hard substrates, boulders and stones, at 5 m depth had relatively little vegetation, only 10%, consisting of *P. fucoides* and *S. arctica*. On sandy substrate the vascular plants *P. pectinatus*, *P. perfoliatus*, *Z. palustris* and *Callitriche hermaphroditica* covered ca 10%. The sediment cover was 3.

LRF000067: At 10 m depth the seafloor comprised of stones, gravel and sand was almost completely bare. There was little sediment cover (2) and the vegetation covered only 5% consisting of *P. fucoides* and *S. arctica*.

LRF000050: The sandy substrate at 6.5 m depth was bare whereas the scattered boulders had lush growth of *P. fucoides* and *S. arctica*.

Site no 4317: The rock at 6 m depth was completely covered by vegetation dominated by a *Fucus*-belt (cover 50–75%). Other common macroalgae were the filamentous *P. fucoides*, *Ectocarpus/Pylaiella* and *S. arctica*. More sparse were *C. tenuicorne*, *C. glomerata* and *F. lumbricalis*.

LRF000064: At 8–9 m depth the hard substrate seafloor comprised of rock, stones and boulders were almost completely covered by vegetation (75%). The vegetation was dominated by the filamentous red alga *P. fucoides* (50–75% coverage). The vegetation also included the macroalgae *C. tenuicorne*, *F. lumbricalis* and *S. arctica* as well as the moss *Fontinalis sp*.

LRF000040: The sand/clay bottom at 5 m depth was bare. The macroalgae *P. fucoides* and *Ectocarpus/Pylaiella* covered the few boulders.

LRF000044: The sand/clay bottom at 5 m depth was bare. The macroalgae *P. fucoides* and *S. arctica* covered the scattered boulders.

LRF000076: The boulders and stones at 7.5–8.5 m depth had lush growth of *P. fucoides* (50–100%). The vegetation also included the macroalgae *C. tenuicorne*, *F. lumbricalis* and *S. arctica* as well as the moss *Fontinalis sp*.

LRF000057: At 13 m depth the bare soft bottom had a thick sediment layer (4) and was partly covered by loose algae (25%).

LRF000060: At 12–13 m depth the sandy substrate areas were bare whereas hard substrates such as rock, boulders and stones were partly covered by macroalgae. The most common alga was the filamentous brown alga *S. arctica* which covered 10–25% of the seafloor. Also *P. fucoides* occurred.

LRF000069: At 13–14 m depth the sandy substrate areas were bare whereas hard substrates such as rock, boulders and stones were partly covered by the filamentous brown alga *S. arctica* which covered 5–25% of the seafloor. Also the freshwater fungus *Ephydatia fluviatilis* occurred.

LRF000073: At 15 m depth the sandy substrate areas were bare. The hard substrates rock, boulders and stones had sparse growth of the filamentous brown alga *S. arctica* which covered 5–25% of the seafloor.

LRF000059: A bare clay bottom with a thick layer of sediment (4) at 14 m depth.

LRF000063: A bare clay bottom with patches of gravel and occasional boulders at 13 m depth. There was a thick layer of sediment (4) and some barnacles (*Balanus improvisus*) and Hydrozoans on the boulders.

LRF000068: At 9 m depth the seafloor consisting of sand was bare. The filamentous brown alga *S. arctica* occurred on the occasional boulder. Sediment cover was estimated as a 3.

LRF000062: At 9 m depth the clay bottom was bare. Hydrozoans occurred on occasional stones.

LRF000061: At 12 m depth the filamentous brown alga *S. arctica* occurred on the occasional boulders but the seafloor consisting mainly of sand was otherwise bare.

Appendix 2

Brief description of the method used to derive predictive vegetation models

Macrophyte biomasses in Forsmark (7 communities) were modelled for separate vegetation communities named after dominant species or taxa found at the sites (Table A2-1). Modelling methods and assumptions is described in /Aquilonius 2010, Carlén et al. 2007/. The seventh vegetation community in Forsmark dominated by *Fucus sp*. was not modelled like the other functional groups, since the data density was too low. Instead, semi-quantitative cover data from 10 transects was used to generate the biomass distribution for the ecosystem model.

The extent of the modelling area is the same as for the digital elevation models for Forsmark. Predictors and resulting models are in 20×20 m grids.

Point and transect data from field surveys were used to fit a statistical model to the observed data. Transect data were converted to give one data point for every meter of the transect length. With this procedure observations 1 meter apart were treated as independent observations, and the procedure has proven effective when modelling marine biota /Sandman et al. 2008/.

Data used in Forsmark in the modelling of macrophytes were mainly collected in August–September 2004 and consist of dive transects, general survey dive transects and point sampling with an Ekman grab sampler /Borgiel 2005/. In all, 7,145 data points were used in modelling, 7,080 of which were created by dividing dive transect data into one-metre segments (see Figure 1-1).

For each data point in the dataset, the vegetation was assigned to one of the vegetation communities/functional groups depending on the dominant species/family according to percent cover degree /Fredriksson 2005/. Before modelling, percental cover was converted to grams dry weight per m^2 (g dw m^{-2}) using a specific conversion factor for each community, and then from g dw m^{-2} to gram carbon per m^2 (gC m^{-2}) using species/family-specific conversion factors (Table A2-2).

The initial modelling was done using data from surveys performed in August and September (in Forsmark), Seasonal variation /Kiirikki 1996/ together with information on algal lifecycles /Tolstoy and Österlund 2003/, was used to convert the modelled biomasses into yearly means. (Table A2-2).

Table A2-1. Vegetation communities/functional groups of macrophytes in the vegetation model for Forsmark.

Vegetation community
Filamentous brown and green algae (mostly *Pilayella*)
Chara sp.(mostly *Chara sp*., but also *Najas marina* if present together with *Chara sp.*)
Phanerogams (*P. pectinatus, P. perfoliatus, Myriophyllom, Caltriche, Zanichellia* if dominant together or alone)
Potamogeton perfoliatus (if present alone, otherwise under former group)
Vaucheria sp. (if alone or dominant)
Red algae (if dominant)
Fucus sp.

Table A2-2. Conversion factors from covering degree to g dw m^{-2}, for the macrophyte groups present in Forsmark /Fredriksson 2005/, conversion factor from g dw m^{-2} to gC m^{-2} from /Kautsky 1995/ and conversion factors to yearly mean.

Forsmark	Conversion factor from percent cover to g dw m^{-2}	Conversion factor from g dw/m^2 to gC m^{-2}	Conversion factor to yearly mean
Filamentous brown and green algae	0.29	~ 0.3	×2
Chara sp.	1.6	~ 0.14	×0.5
Phanerogams	0.59	~ 0.3	×0.5
Vaucheria sp.	4.0	~ 0.4	×1
Red algae	0.74	~ 0.35	×0.5

Modelling for all macrophytes except *Fucus sp.* and emergent macrophytes was done in GRASP (Generalized Regression Analysis and Spatial Predictions), a set of S-PLUS/R functions developed for modelling and analysis of the spatial distribution of species /Lehmann et al. 2002/. GRASP communicates with ArcView, and resulting distribution maps are in ArcView format.

GRASP uses GAM, generalized additive models /Hastie and Tibshirani 1990/, to fit predictor variables independently by means of non-parametric smooth functions. The best model is selected by a stepwise procedure where progressively simpler models are compared with the measure Akaike's Information Criterion. Abundance modelling was used here, and the results are presented in the form of grids with estimates of biomass (in this case gC m^{-2}) for each grid cell.

Available predictors in the modelling of macrophytes in Forsmark and Laxemar-Simpevarp were depth, slope, aspect, bottom temperature, pelagic temperature, Secchi depth, wave exposure, light percentage at the bottom and days with solar insulation above 5 MJ. The wave exposure grid was log transformed and this grid was used throughout the modelling.

Because field data cover was denser in shallow waters than in deep waters, the models could not always distinguish at what depth algae no longer are present. To avoid having algae too deep, biomass below a certain depth was set to zero, and observations beyond this depth was excluded from the general model fit procedure. The depth limits for the different functional groups were set according to literature /Tolstoy and Österlund 2003, Leinikki et al. 2004, Mossberg et al. 1992/, and are shown in Table A2-3.

Data cover was also less dense in areas of both low and high wave exposure. This is probably the reason that the model for *Vaucheria sp.* failed to capture the fact that this taxon is exclusively found in very sheltered areas. Therefore, a limit was also set for *Vaucheria sp.* in wave exposure. This limit was set by finding the highest log-transformed wave exposure for *Vaucheria sp*. presence and rounding this number up to the nearest five hundred. Above this value *Vaucheria sp*. biomass was set to zero.

Fucus sp.

Data density for *Fucus sp.* was lower and not enough for GRASP modelling in Forsmark. Semi-quantitative cover (%) data on *Fucus sp.* are found in 10 transects in the Forsmark area from four studies /Borgiel 2004, 2005, Kautsky et al. 1999, Wallström et al. 2000/, six of which were used in this study. Four of the transects are located in Asphällsfjärden, and as these are affected by the intake channel for the nuclear power plants, the environmental conditions are assumed to be atypical with regard to abiotic factors (e.g. water transparency) determining the distribution of this macro algae. Depth, substrate and wave exposure (or correlated characteristics) are among the structuring factors for *Fucus sp.* (e.g. /Isæus 2004, Kautsky et al. 1986/) and depth determines the maximum depth distribution. These factors were used to define probable habitats for *Fucus sp.* in the vegetation model of Forsmark.

Observed cover (%) of *Fucus sp.* was plotted against depth and wave exposure index presented in /Carlén et al. 2007/. *Fucus sp.* was found in areas with a wave exposure index (SWM) of between 100,000 and 300,000 and a depth of between 0 and 7 m. The distribution, increasing from the surface and decreasing at depths deeper than 4 to 6 m, is similar to that found by /Kautsky et al. 1986/. A curve was fitted to data on cover of *Fucus sp.* at depth intervals 0–1 m, 1–2 m etc. The relationship between cover and dry weight /Fredriksson and Tobiasson 2003/ and between dry weight and carbon /Engdahl et al. 2007/ was used to calculate the biomass of *Fucus sp.* (gC m^{-2}) in Forsmark.

Table A2-3. Limitations in depth and wave exposure in the macrophyte vegetation model for the macrophyte species/ Functional groups present in the Forsmark area.

Forsmark	Delimitation in depth (m)	Delimitation in log-transformed wave exposure
Filamentous brown and green algae	20	–
Chara sp.	4	–
Phanerogams	5	–
Vaucheria sp.	7	> 10.15
Red algae	25	–

Appendix 3

Predicted and observed biomass in annual mean of gC m^{-2}

SIte	Depth interval (m)	Predicted Total macrop. (gC m^{-2})	Observed Total macrop. (gC m^{-2})	Predicted *Chara sp.* (gC m^{-2})	Observed *Chara sp.* (gC m^{-2})	Predicted Phanerog. (gC m^{-2})	Observed Phanerog. (gC m^{-2})	Predicted Filament. (gC m^{-2})	Observed Filament. (gC m^{-2})	Predicted *Fucus sp.* (gC m^{-2})	Observed *Fucus sp.* (gC m^{-2})	Predicted Red algae (gC m^{-2})	Observed Red algae (gC m^{-2})	Predicted *Vaucheria sp.* (gC m^{-2})	Observed *Vaucheria sp.* (gC m^{-2})
LRF000033	0–7	28.9	1.6	0.0	0.0	0.0	0.0	0.2	0.9	28.2	0.0	0.5	0.6	0.0	0.0
LRF000034	0–7	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0
LRF000035	7–15	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
LRF000036	7–15	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
LRF000037	0–7	5.1	25.1	0.0	0.0	0.0	0.0	5.1	1.8	0.0	9.3	0.0	14.0	0.0	0.0
LRF000040	0–7	1.9	0.4	0.0	0.0	0.4	0.0	1.2	0.2	0.0	0.0	0.3	0.3	0.0	0.0
LRF000041	0–7	6.0	6.1	1.1	0.0	0.0	0.0	4.9	0.8	0.0	1.5	0.0	3.9	0.0	0.0
LRF000042	0–7	7.1	11.2	0.4	0.0	0.0	0.0	6.7	1.3	0.0	0.0	0.0	9.9	0.0	0.0
LRF000043	0–7	44.0	66.1	1.1	0.2	0.0	4.7	4.9	0.1	38.0	59.5	0.0	1.7	0.0	0.0
LRF000044	0–7	4.6	1.6	0.1	0.0	0.8	0.0	3.6	0.9	0.0	0.0	0.1	0.6	0.0	0.0
LRF000046	0–7	3.5	6.5	0.0	0.0	1.4	0.0	2.0	0.9	0.0	0.0	0.2	5.5	0.0	0.0
LRF000047	0–7	39.9	139.8	0.0	0.0	0.0	0.0	2.1	6.8	37.8	130.1	0.0	3.0	0.0	0.0
LRF000050	0–7	45.3	2.2	0.0	0.0	0.0	0.0	2.3	0.9	42.7	0.0	0.3	1.3	0.0	0.0
LRF000051	0–7	3.4	9.1	0.0	0.0	0.0	0.0	3.4	0.3	0.0	0.0	0.1	8.8	0.0	0.0
LRF000052	0–7	42.7	2.9	0.0	0.0	0.1	1.3	0.0	0.9	0.0	0.0	0.5	0.6	42.1	0.0
LRF000053	0–7	46.7	48.8	0.2	0.0	0.4	0.0	5.9	2.2	40.3	46.4	0.0	0.2	0.0	0.0
LRF000054	0–7	48.0	103.5	0.2	0.0	0.1	2.9	4.9	3.1	42.8	92.9	0.0	4.5	0.0	0.0
LRF000057	7–15	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
LRF000059	7–15	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
LRF000060	7–15	1.3	2.6	0.0	0.0	0.0	0.0	0.9	2.4	0.0	0.0	0.4	0.2	0.0	0.0
LRF000063	7–15	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
LRF000064	7–15	0.5	9.2	0.0	0.0	0.0	0.0	0.5	0.9	0.0	0.0	0.0	8.2	0.0	0.0
LRF000066	7–15	1.2	13.0	0.0	0.0	0.0	0.0	0.8	11.8	0.0	0.0	0.4	1.2	0.0	0.0
LRF000067	7–15	0.9	0.1	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0
LRF000068	7–15	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0
LRF000069	7–15	0.5	1.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.5	0.0	0.0	0.0
LRF000073	7–15	1.2	0.7	0.0	0.0	0.0	0.0	0.8	0.7	0.0	0.0	0.5	0.0	0.0	0.0
LRF000076	7–15	20.9	12.1	0.0	0.0	0.0	0.0	1.9	0.8	18.9	0.0	0.1	11.2	0.0	0.0
LRF000061/ LRF000062	7–15	1.0	0.4	0.0	0.0	0.0	0.0	0.6	0.4	0.0	0.0	0.4	0.1	0.0	0.0
medel		**12.4**	**16.0**	**0.1**	**0.0**	**0.1**	**0.3**	**1.8**	**1.4**	**8.6**	**11.7**	**0.3**	**2.6**	**1.5**	**0.0**
stdav		**17.8**	**33.2**	**0.3**	**0.0**	**0.3**	**1.0**	**2.1**	**2.4**	**16.0**	**31.3**	**0.3**	**4.0**	**7.8**	**0.0**
median		**1.9**	**2.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**0.8**	**0.0**	**0.0**	**0.3**	**0.6**	**0.0**	**0.0**
Min		**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Max		**48.0**	**139.8**	**1.1**	**0.2**	**1.4**	**4.7**	**6.7**	**11.8**	**42.8**	**130.1**	**1.0**	**14.0**	**42.1**	**0.0**