Proc. Estonian Acad. Sci. Biol. Ecol., 2007, **56**, 4, 270–277

Distribution of the eelgrass *Zostera marina* L. in the coastal waters of Estonia, NE Baltic Sea

Tiia Möller* and Georg Martin

Estonian Marine Institute, University of Tartu, Mäealuse 10a, 12618 Tallinn, Estonia

Received 4 August 2006, in revised form 11 June 2007

Abstract. All the available data on the distribution of *Zostera marina* meadows in the coastal waters of Estonia, NE Baltic Sea, were analysed in order to achieve a generic idea of the historical and present status of eelgrass. Altogether 44 localities with eelgrass present were recorded in 1995–2005 as compared to 36 sites recorded in 1959–1984. The percentage of findings in different water basins ranged from 1.3 to 5.1 in 1959–1984 compared to 0.6–3.6 in 1995–2005. This suggests that no significant decline or improvement of the eelgrass meadows has occurred in the Estonian coastal sea. Yet there are signs of a negative impact of eutrophication on eelgrass.

Key words: *Zostera marina*, Baltic Sea, Estonia, distribution, density, biomass, size structure.

INTRODUCTION

Zostera marina is the most common marine angiosperm in the Northern Hemisphere (den Hartog, 1970). It is well represented also in the brackish Baltic Sea where the species grows at its lower salinity tolerance limit. Yet eelgrass is one of the most abundant macrophytes on exposed sandy bottoms in the Baltic Sea and is regarded as a key species of this habitat.

In the Baltic Sea most of the research on eelgrass has been carried out in Denmark, Sweden, Finland, and Poland. Most of these studies have reported a significant decline of eelgrass meadows due to eutrophication in Danish, Swedish, and Polish coastal areas (Lundberg, 2005 and references therein).

In the northeastern part of the Baltic Sea, in the coastal waters of Estonia, the distribution of eelgrass has never been directly studied and thus the information on eelgrass communities is scarce and occasional. The aim of this paper is to summarize the available information on the distribution of eelgrass communities present in the coastal waters of Estonia. It was hypothesized that the distribution of eelgrass has decreased in recent decades.

* Corresponding author, tiia.moller@ut.ee

MATERIAL AND METHODS

Information on benthic macrophyte communities in the Estonian coastal waters has been gathered under several national and local-scale studies since 1959. All the available data regarding eelgrass (i.e. coverage and biomass estimations and in some cases just notes on presence/absence) were looked through and if the data brought up any doubts of representability, the samples were discarded. If a sample had eelgrass with biomass below 1 g (dry weight) we investigated the bottom topography and the available biomass structure of macrophyte communities of the site in order to decide whether it was an occasional and drifting eelgrass shoot or an attached form.

The material was divided into two groups: historical and recent. The historical data on the distribution of eelgrass cover the time period of 1959–1984 and are mostly redrawn from the dissertations of Trei (1973) and Kukk (1979) and available field notes on macrophytes surveys. Trei (1973) gathered the material in the Gulf of Riga and the West Estonian Archipelago Sea in 1959–1976. For the Baltic Proper area the data collected by T. Trei are unpublished and originate from 1980–1984. Fieldwork methods included bottom trawling, grab sampling, and diving (Table 1); the last method became prevailing since 1966. Bottom trawling was used occasionally and this gave only information on species presence. By diving the coverage estimations and in some cases also biomass estimations were gained (using a frame of 50 × 50 cm, recalculated to 1 m^2). Van Veen, Ookean, and Petersen types of grabs were used.

Kukk (1979) summarized the diving data of 1085 sampling points from field-work carried out in the Gulf of Finland in 1970–1978 (Table 1). For the Gulf of Finland area only the information on the presence of eelgrass is available.

The recent data cover the decade from 1995 to 2005 and were mainly gathered in the frame of the Estonian National Marine Monitoring Programme. The phyto-benthos monitoring methods follow the guidelines suggested by HELCOM (1999). Fieldwork methods include diving (coverage estimations, frame) and grab sampling. The frame used by a diver was 20 × 20 cm and the biomass estimations gained were recalculated to 1 m^2. Coverage was estimated in the scale 0–100%; patchiness and patch size were observed in some cases. Ekman–Lenz and Ekman–Birge grabs were used.

The distribution maps were produced with ArcGIS 9.1 (www.esri.com). For univariate analysis the statistical programme Statistica was used (StatSoft Inc, 2001); *t*-test analyses were performed.

The community analyses were performed with Primer. The relationship between the multivariate community structure and environmental variables was examined using the BIOENV procedure (Clarke & Ainsworth, 1993). A ranked similarity matrix was constructed using the Bray–Curtis similarity measure on root-trans-formed community data. The environmental parameters used in the BIOENV analysis were depth, coastal slopes, concentration of nutrients, and salinity. Data on water chemistry originate from the database of the Estonian National Marine Monitoring Programme and are determined from the depth of 10 m. The averages

Table 1. Data available on the phytobenthic communities studied. The sampling gear is pointed out separately. Letters refer to the study period: A, 1959–1984; B, 1995–2005

Area	Total No. of samples		By diving		By grab		By trawling		Eelgrass present		% of eelgrass findings		Matching findings
	A	B	A	B	A	B	A	B	A	B	A	B	A & B
Baltic Proper	268	532	201	449	46	83	21	0	5	7	2.2	1.3	2
Gulf of Riga	251	2052	71	945	157	1107	23	0	4	14	1.6	0.7	1
West Estonian Archipelago Sea	254	412	44	334	141	78	69	0	13	15	5.1	3.6	5
Gulf of Finland	1085	1252	1085	533	0	719	0	0	14	8	1.3	0.6	3
Total	1858	4248	1401	2261	344	1987	113	0	36	44	2.6 ± 1.7	1.5 ± 1.4	11

of winter nutrient values in 1995–2005 were used (the winter nutrient values are considered as a proxy for eutrophication in the Baltic Sea area (HELCOM, 2002)). The nearest water chemistry monitoring station to the studied eelgrass area was chosen. The coastal slopes were calculated using the spatial analyst tool in ArcGIS for each sampling point at 50 and 1000 m resolution. Coastal slopes of different resolution were used to describe the hydrodynamic processes of different spatial scales (e.g. small-scale slope is a proxy of the occurrence of anoxia and large-scale slope is a proxy of the exposure of a site).

RESULTS AND DISCUSSION

There were no significant differences in the number of findings of eelgrass communities between the historical and the recent time period. In 1959–1984 altogether 36 localities with growing eelgrass were recorded – 14 in the Gulf of Finland (Kukk, 1979) and 22 on the western coast (Gulf of Riga, West Estonian Archipelago Sea, north-western shallow bays) (Trei, 1973; T. Trei, unpubl. data) (Table 1, Fig. 1). In 1995–2005 *Z. marina* was found at 44 sites (Table 1, Fig. 2). The percentage of findings ranged from 1.3 to 5.1 in 1959–1984 and from 0.6 to 3.6 in 1995–2005. The difference was not statistically significant (*t*-test, $p > 0.05$).

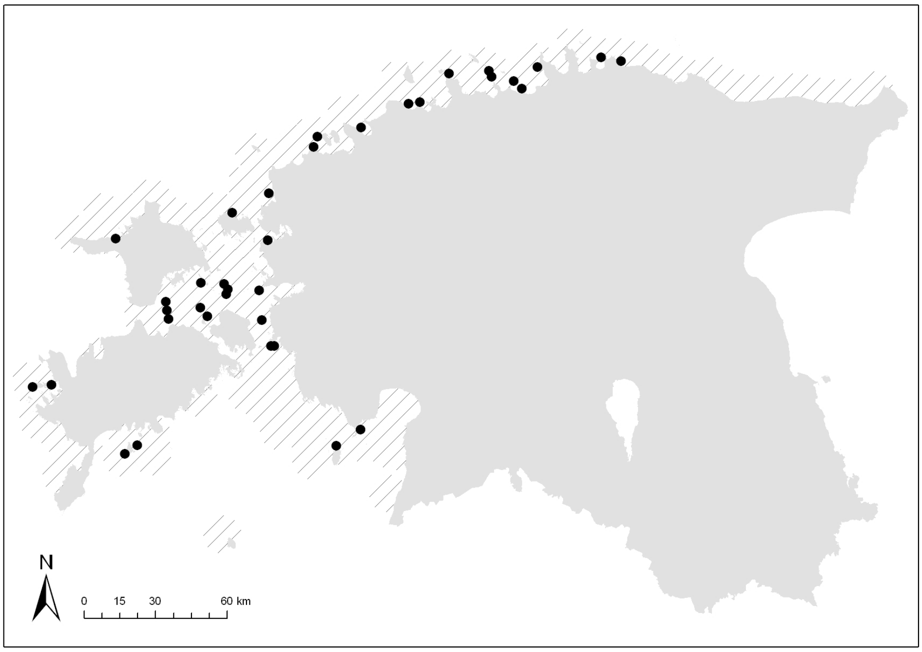

Fig. 1. Distribution of eelgrass in 1959–1984. Dots show the presence of eelgrass, stripes indicate the studied area.

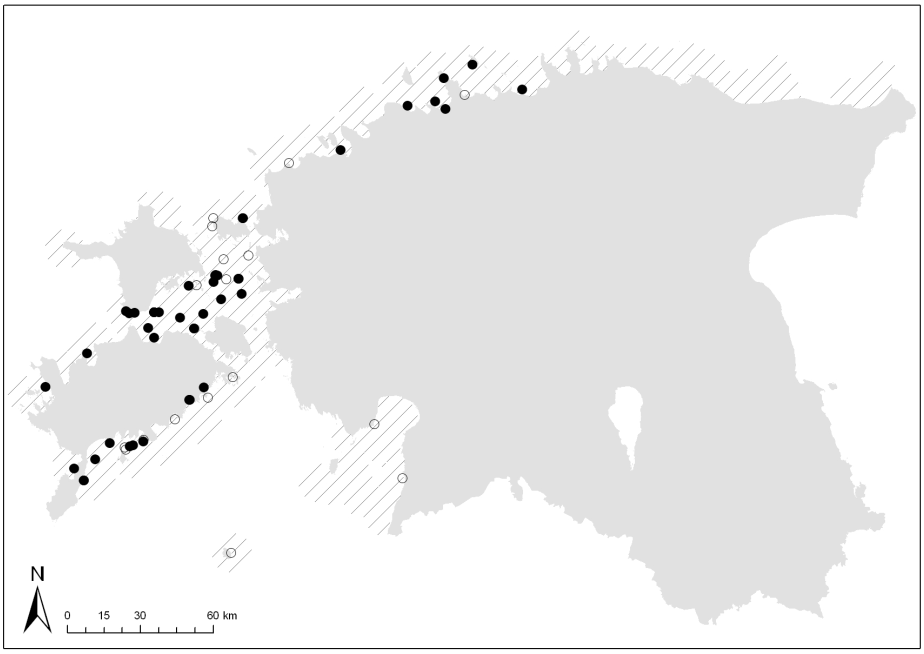

Fig. 2. Distribution of eelgrass in 1995–2005. Dots show the presence of eelgrass, stripes indicate the studied area. The empty circles indicate eelgrass biomass below 1 g m^{-2}.

In 1995–2005 *Z. marina* was recorded in the depth interval 0.3–8.4 m with its main distribution depth at 2–6 m (Fig. 3). The maximum values of biomass per square metre were recorded at depths of 2–3 m. A few direct field observations at Saarnaki Islet and Prangli Island suggest that at this depth range eelgrass grows in small dense patches (1–5 m^2) where the cover values reach 100%. In deeper areas the density of eelgrass decreases down to 10–60% whereas the distribution pattern is more continuous. In 1973 the average coverage in eelgrass beds was estimated similarly at 30–60% (Trei, 1973).

In this study the maximum biomass was 151 g m^{-2} (dry weight) recorded at a depth of 2.6 m at the east coast of the Sõrve Peninsula, the Gulf of Riga, on 21 August 1995. In all other sites the biomasses remained below 100 g dw m^{-2}. The biomass of eelgrass is rather low in the northern and eastern parts of the Baltic Sea being mostly below 200 g m^{-2} (Boström et al., 2003, 2004). In the Finnish waters (Åland and Tvärminne) the biomass values are in the same range (Boström et al., 2002, 2003). For the Western Baltic Sea the biomass range is 200–800 g dw m^{-2} (Feldner, 1977). Trei (1973) estimated the eelgrass biomass at 32–75 g dw m^{-2} (recalculated from 128–300 g wet weight m^{-2}), which agrees with the present situation.

Based on recent observations the phytobenthic community structure of eelgrass stands was best explained by a combination of depth, total nitrogen, and coastal slope

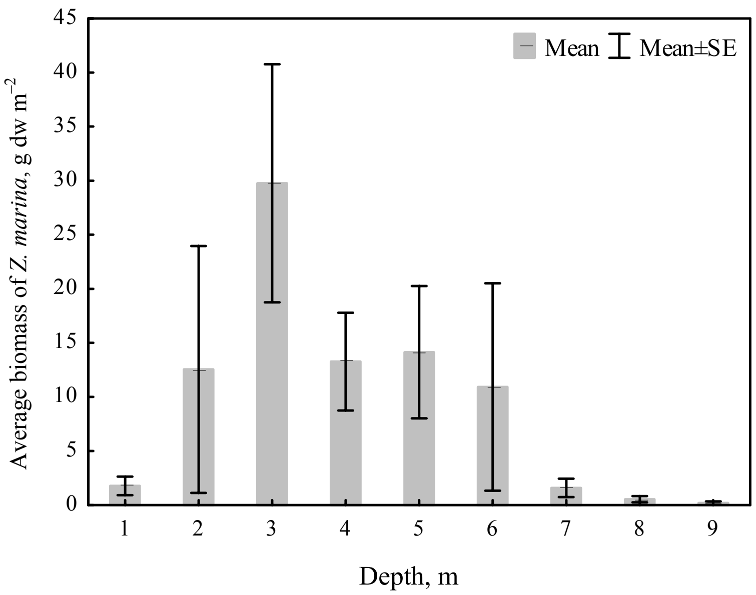

Fig. 3. Average biomass of eelgrass at different depths (depth is given in classes, 1 refers to depths of 0–1 m, 2 to 1.1–2 m, etc.).

calculated within a 50 m grid cell. (BIOENV, $\rho = 0.251$, $p = 0.01$). The most suitable habitat for *Z. marina* was found to be down to 6 m depth (Fig. 3). The depth distribution of eelgrass is determined by light conditions as light in combination with nutrients is the basic need for photosynthesis (overview in Borum et al., 2004). Wave action controls the upper depth limit of eelgrass (Fonseca et al., 1983). Loss of eelgrass populations has been largely associated with anthropogenic activities and increased nitrogen loading. The latter is mostly related to causing dominance of phytoplankton and macroalgae and thus smothering eelgrass (Short & Burdick, 1996; Hauxwell et al., 2001; McGlathery, 2001). Mass occurrence of filamentous algae has also been observed in the coastal waters of Estonia (Paalme et al., 2004).

In the eastern Baltic Sea area eelgrass populations grow at their distribution limit in terms of salinity. The species was not affected by the wasting disease in the 1930s (Rasmussen, 1973) and has also persisted through anthropogenic stress and physical stress (wind disturbance, sedimentation, ice cover, etc.). The complex Estonian coastline with numerous shallow, sandy, and moderately exposed bays suitable for submerged plants suggests that the actual number of sites with eelgrass present is larger than recorded so far. Here eelgrass does not form continuous meadows but grows in small patches and often together with *Potamogeton* spp. and *Zannichellia palustris* (Trei, 1973; T. Trei, unpubl. data). Thus eelgrass patches may easily stay out of the diver's visual field and may also stay untouched by a grab sampler.

It is believed that in the Estonian coastal sea *Z. marina* reproduces only vegetatively. No attached flowering shoots have been detected so far (Trei, 1973; authors' pers. obs.). In 2006 a loose flowering shoot was found in the West Estonian Archipelago Sea. We suggest that finding flowering shoots in the Estonian coastal range is only a matter of sampling effort as reproductive shoots have been found in the south of Finland (Boström, 1995).

Unfortunately neither the historical nor recent information on eelgrass communities includes depth limits. Due to non-systematically collected data the comparisons are unsatisfactory and at this point overall estimations of changes in eelgrass communities are difficult to follow. Yet despite the limited knowledge on the distribution of *Z. marina* we believe that the eelgrass communities are in a good state in the Estonian coastal sea as no clear indications of reduction of the distribution area of the species was documented in this study. To evaluate the effect of eutrophication and other anthropogenic influences on *Z. marina* communities in the Estonian coastal sea several targeted monitoring and experimental studies should be carried out in the future.

REFERENCES

Borum, J., Duarte, C. M., Krause-Jensen, D. & Greve, T. M. (eds) 2004. *European Seagrasses: an Introduction to Monitoring and Management*. The M&MS project. http://www.seagrasses.org/handbook/european_seagrasses_low.pdf

Boström, C. 1995. Flowering and fruit-bearing *Zostera marina*. Åland, Northern Baltic Sea. *Mem. Soc. Fauna Flora Fenn.*, **71**, 7–9.

Boström, C., Bonsdorff, E., Kangas, P. & Norkko, A. 2002. Long-term changes in a brackish-water *Zostera marina* community indicate effects of eutrophication. *Estuarine Coastal Shelf Sci.*, **55**, 795–804.

Boström, C., Baden, S. P. & Krause-Jensen, D. 2003. The seagrasses of Scandinavia and the Baltic Sea. In *The World Atlas of Seagrasses* (Green, P. & Short, F. T., eds), pp. 27–37. University of California Press, Berkeley, USA.

Boström, C., Roos, C. & Ronnberg, O. 2004. Shoot morphometry and production dynamics of eelgrass in the northern Baltic Sea. *Aquat. Bot.*, **79**, 145–161.

Clarke, K. R. & Ainsworth, M. 1993. A method of linking multivariate community structure to environmental variables. *Mar. Ecol. Prog. Ser.*, **92**, 205–219.

den Hartog, C. 1970. *The Seagrasses of the World*. North Holland Publ. Co, Amsterdam.

Feldner, J. 1977. Ökologische und Produktionsbiologische Untersuchungen am Seegrass *Zostera marina* L. in der Kieler Bucht (westliche Ostsee). *Reports Sonderforschungsbereich 95: Wechselwirkung Meer-Meeresboden*. Kiel University.

Fonseca, M. S., Zieman, J. C., Thayer, G. W. & Fisher, J. S. 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. *Estuarine Coastal Shelf Sci.*, **17**, 367–380.

Hauxwell, J., Cebrián, J., Furlong, C. & Valiela, I. 2001. Macroalgal canopies contribute to eelgrass (*Zostera marina*) decline in temperate estuarine ecosystems. *Ecology*, **82**, 1007–1022.

HELCOM, 1999. Guidelines for monitoring of phytobenthic plant and animal communities in the Baltic Sea. Annex for HELCOM COMBINE programme. http://www.helcom.fi/Monas/CombineManual2/PartC/CFrame.htm (04.2007).

HELCOM, 2002. Environment of the Baltic Sea area 1994–1998. *Baltic Sea Environ. Proc.*, 82B.

Kukk, H. 1979. Bottom vegetation in the Gulf of Finland. Cand. Sci. thesis. Tallinn. Manuscript in the Library of the University of Tartu.
Lundberg, C. 2005. *Eutrophication in the Baltic Sea – from Area-Specific Biological Effects to Interdisciplinary Consequences*. PhD thesis. Faculty of Mathematics and Natural Sciences, Department of Biology, Åbo Akademi University, Åbo.
McGlathery, K. J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. *J. Phycol.*, **37**, 453–456.
Paalme, T., Martin, G., Kotta, J., Kukk, H. & Kaljurand, K. 2004. Distribution and dynamics of drifting macroalgal mats in Estonian coastal waters during 1995–2003. *Proc. Estonian Acad. Sci. Biol. Ecol.*, **53**, 260–268.
Rasmussen, E. 1973. Systematics and ecology of the Isefjord marine fauna (Denmark) with a survey of the eelgrass (*Zostera*) vegetation and its communities. *Ophelia*, **11**.
Short, F. T. & Burdick, D. M. 1996. Quantifying seagrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries*, **19**, 730–739.
Trei, T. 1973. Lääne-Eesti rannikuvete fütobentos. Cand. Sci. thesis. Eesti Mereihtüoloogia laboratoorium, Tallinn. Manuscript in the Library of the University of Tartu.

Meriheina *Zostera marina* L. levik Eesti rannikumeres

Tiia Möller ja Georg Martin

Merihein (*Zostera marina*) on põhjapoolkeral laialt levinud mereline õistaim. Riimveelises Läänemeres on merihein üks arvukamaid kõrgemaid taimi, olles võtmeliigiks liivastel pehmetel põhjadel. Artiklis on antud ülevaade meriheina varasemast ja praegusest levikust Eesti rannikumeres. Aastail 1995–2005 registreeriti kinnitunud meriheina kooslus 44 juhul võrrelduna 36 kasvukohaga ajavahemikul 1959–1984. Merihein esines sügavusel 0,3–8,4 m, peamine kasv oli sügavusel 2–6 m. Eesti rannikumeres kasvab merihein oma soolsustaluvuse piiril peamiselt hõredates väikestes laikudes ega moodusta püsivaid n-ö aasu. Biomassi maksimum oli 151 g m^2 kohta kuivkaalus (Sõrve poolsaare idaküljel, 2,6 m sügavusel, 21.08.1995). Enamikul juhtudest jäid biomassi väärtused alla 100 g m^2 kohta, mis on samas suurusjärgus võrrelduna varasemate uuringutega Läänemere põhja- ja idaosas. Käesolevas töös meriheina levikus statistiliselt olulisi muutusi ei registreeritud.