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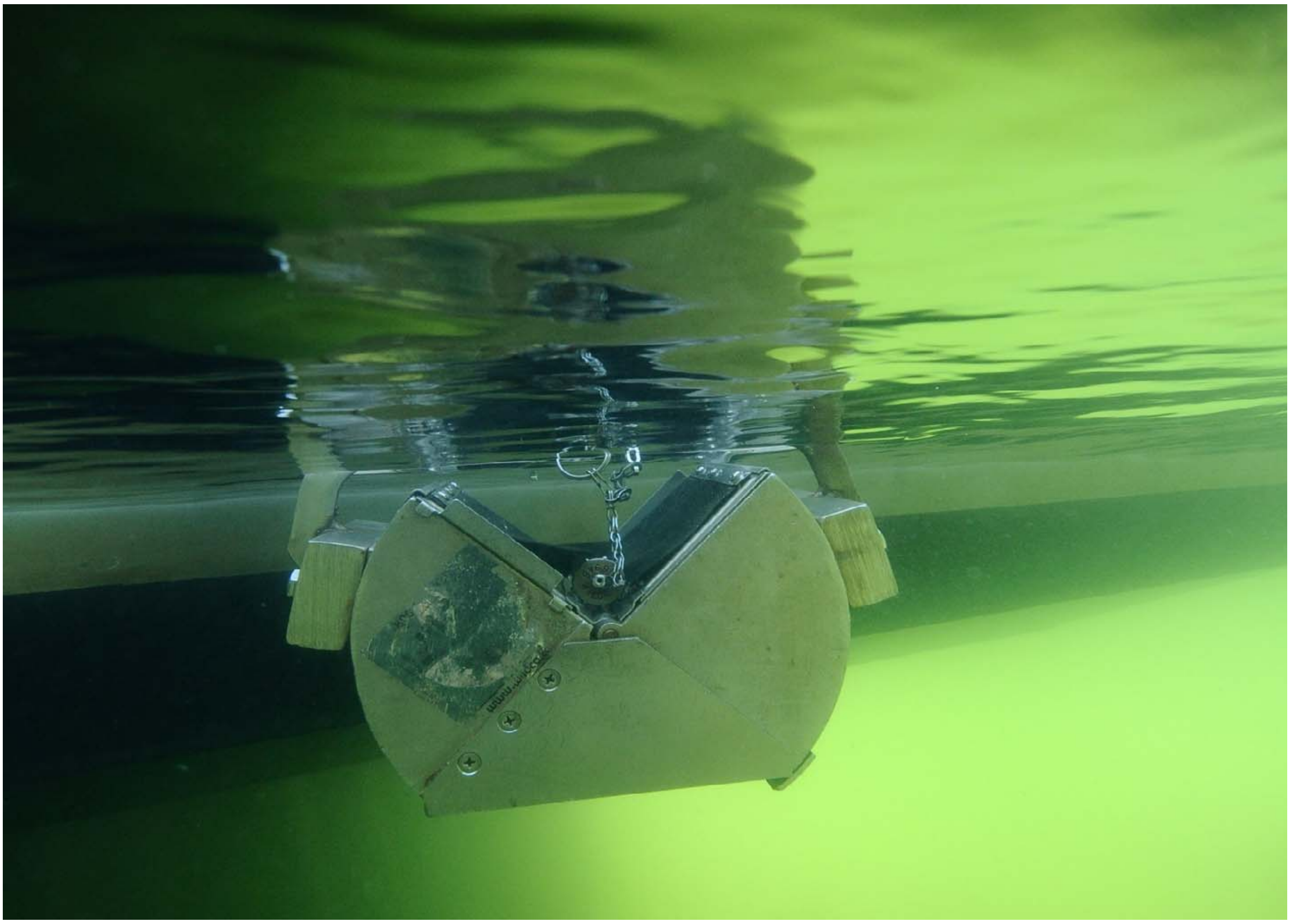

Nature Protection Publications of Metsähallitus. Series A 224
Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 224

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Översättning: Mats Westerbom.

Cover: Petite Ponar taking samples from a boat. Photo: Mats Westerbom.

ORGANISATION CERTIFIED BY Inspecta
ISO 14001

ISSN-L 1235-6549
ISSN (online) 1799-537X
ISBN 978-952-295-169-4 (pdf)

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METSÄHALLITUS

DOCUMENTATION PAGE

PUBLISHED BY	Metsähallitus	PUBLICATION DATE	8.7.2016
COMMISSIONED BY		DATE OF APPROVAL	
CONFIDENTIALITY	Public	REGISTRATION NO.	
PROTECTED AREA TYPE / CONSERVATION PROGRAMME			
NAME OF SITE			
NATURA 2000 SITE NAME AND CODE	Several Natura 2000 areas in western Uusimaa		
REGIONAL ORGANISATION	Parks & Wildlife Finland, Southern Finland		

AUTHOR(S)	Martin Snickars, Anna Arnkil, Jan Ekebom, Lasse Kurvinen, Aija Nieminen, Alf Norkko, Anu Riihimäki, Tero Taponen, Sebastian Valanko, Markku Viitasalo and Mats Westerbom
TITLE	Assessment of the status of the zoobenthos in the coastal waters of western Uusimaa, SW Finland – a tool for management

ABSTRACT

Marine Strategy Framework Directive (MSFD) targets a Good Environmental Status (GES) by 2020 for all the marine waters of all EU Member States. According to the Water Framework Directive (WFD), all EU member states should protect, enhance and restore all bodies of surface water in an aim to achieve a Good Ecological Status. The marine strategies to be developed by each Member State includes a detailed assessment of the state of the environment, a definition of GES at regional level and established targets based on indicators as well as monitoring. The structure of zoobenthos is one indicator that is being monitored. This study aimed at 1) elucidating the benthic condition of coastal waters in the western Uusimaa using zoobenthos as indicators, 2) evaluate the representativeness of the ongoing benthic monitoring programme and 3) compare hydrological monitoring data with proximate benthic data. To evaluate the representativeness of the ongoing monitoring, we used data from 36 official monitoring stations that were compared with an extended survey including > 440 samples.

The extended survey showed that there was a clear effect of sediment quality (normal or signs of oxygen shortage) on zoobenthos, generally, and Macoma balthica population structure, specifically, with a much more heterogeneous population structure in healthy sediments. Most of the zoobenthos indices were higher in the deep outer archipelago than in the deep inner archipelago, suggesting a better benthic status in the outer areas. Zoobenthos metrics were usually more similar in affected sediments, which indicate that decreased sediment quality makes the naturally occurring spatial and vertical gradients less marked and the benthic community less heterogeneous in a landscape perspective. The overall status of shallow coastal areas differed between the two data-sets. The extended survey resulting in overall higher ecological status of the Uusimaa coastal waters than results indicated by the monitoring data. The spatial linkage between water quality monitoring stations and zoobenthos indices was stronger at the extended survey sites. The extended survey sites near higher-oxygen stations had higher mean total abundance, species richness and diversity than the sites near low-oxygen stations. In addition, the water quality stations near extended survey sites with signs of oxygen shortage had clearly lower oxygen concentration than stations near sites with normal sediment quality.

The results of the study suggest that the current monitoring programme (using only zoobenthos as indicator) doesn't fully reflect the zoobenthic conditions in the entire western Uusimaa. The extended survey also indicated that midst among larger areas of poor condition, locally there may be areas that are in good or very good condition. The results of the study therefore suggest that the benthic monitoring programme in Uusimaa should be revised including a more diverse set of stations. For management and conservation, results pinpoint the need for fine scale surveys when assessing the state of any area in e.g. environmental impact assessments.

KEYWORDS	Baltic Sea, Gulf of Finland, coastal waters, monitoring, zoobenthos, benthic condition		
OTHER INFORMATION	VELMU – The Finnish Inventory Programme for the Underwater Marine Environment		
SERIES NAME AND NO.	Nature Protection Publications of Metsähallitus. Series A 224		
ISSN-L ISSN (ONLINE)	1235-6549 1799-537X	ISBN (PDF)	978-952-295-169-4
NO. OF PAGES	53 pp.	LANGUAGE	English
PUBLISHING CO.	Metsähallitus	PRINTED IN	
DISTRIBUTOR	Metsähallitus, Parks & Wildlife Finland	PRICE	

KUVAILULEHTI

Julkaisija	Metsähallitus	Julkaisuaika	8.7.2016
Toimeksiantaja		Hyväksymispäivämäärä	
Luottamuksellisuus	Julkinen	Diaarinumero	
Suojelualuetyyppi/ Suojeluohjelma			
Alueen nimi			
Natura 2000-alueen nimi ja koodi	Useita Natura 2000 -alueita läntisellä Suomenlahdella		
Alueyksikkö	Etelä Suomen Luontopalvelut		

Tekijä(t)	Martin Snickars, Anna Arnkil, Jan Ekebom, Lasse Kurvinen, Aija Nieminen, Alf Norkko, Anu Riihimäki, Tero Taponen, Sebastian Valanko, Markku Viitasalo ja Mats Westerbom
Julkaisun nimi	Länsi-Uudenmaan saariston merenpohjan tila: pohjaeläinyhteisöt tilan ilmentäjinä ja hallinnon työkaluna

Tiivistelmä

Meristrategiapuitedirektiivin mukaan kaikkien EU:n jäsenvaltioiden tulisi vuoteen 2020 mennessä ryhtyä toimiin meriympäristön hyvän tilan saavuttamiseksi. Direktiivin täytäntöönpanemiseksi tulee jäsenmaiden selvittää mm rannikkovesien ekologista tilaa. Tämän työn tarkoitus oli selvittää 1) rannikkovesien pohjien tilaa läntisellä Uudellamaalla käyttäen pohjaeläimiä tilan ilmentäjänä, 2) tarkastella Uudenmaan ELY-keskuksen pohjaeläinseuranta-asemien edustavuutta ja 3) verrata hydrologisia muuttujia pohjaeläinindikaattoreihin perustuvaan luokitukseen ja tarkastella näiden yhdenmukaisuutta. Seuranta on tutkimusalueella suoritettu 36 ELY-asemalla vuonna 2011, ja niitä vertaillaan tässä työssä Metsähallituksen luontopalvelujen vuonna 2012 suorittamaan laajempaan näytteenottoon 443 asemalta.

Tulokset osoittivat, että pohjan happitilanne vaikutti merkittävästi pohjaeläinten laji- ja populaatiokoostumukseen, eritoten liejusimpukan (*Macoma balthica*) populaatiorakenteeseen. Liejusimpukan populaatiorakenne oli monimuotoisempi ja myös isoja simpukoita esiintyi hapellisessa sedimentissä. Useimmat tutkittavat muutttujat antoivat viitteitä paremmista olosuhteista ulkosaaristossa kuin sisäsaaristossa.

ELY-asemien pohjaeläinnäytteet poikkesivat laajennetun otannan näytteistä, mikä näkyi selvimmin ekologisen tilan luokituksessa. Laajennettu otanta antoi paremman ekologisen tilan kuin ELY-seurannan perusteella tehdyt luokitukset. Laajennetussa otannassa saaristoalueet olivat pääosin tyydyttävässä tai jopa hyvässä tilassa. ELY-seurannan tulokset luokittelevat samat alueet huonoiksi tai jopa välttäviksi. Aineistot korreloivat kuitenkin osittain keskenään. EQR (Ecological Quality Index), perustuen BBIhin (Brackish Water Benthic Index), ei tuottanut selkeitä tuloksia, joskin saariston ulko-osa sai hieman korkeamman luokitusarvon kuin sisäsaaristo.

Tämän selvityksen johtopäätös on, että pohjaeläinseurannan asemaverkoston tulisi olla nykyistä monipuolisempi ja siinä tulisi olla laajemmin edustettuna saariston eri alueet. Laajennettu otanta paljasti, että läpi saariston löytyy sekä hyvin huonossa kunnossa olevia että hyvin monimuotoisia, yksilötiheitä ja laikuttaisia pohjia. Alueet ja vesimuodostumat voivat siis olla yleisesti tarkasteltuna hyvin heikossa tilassa, mutta samalla niistä löytyy alueita, jotka ovat säästyneet pahimmilta muutoksilta ja jotka voivat toimia elinvoimaisina saarekkeina muutoin epäedullisessa ympäristössä.

Avainsanat	Itämeri, Suomenlahti, rannikkovedet, pohjaeläimet, seuranta, pohjien tila		
Muut tiedot	VELMU – Vedenalaisen meriluonnon monimuotoisuuden inventointiohjelma		
Sarjan nimi ja numero	Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 224		
ISSN-L ISSN (verkkojulkaisu)	1235-6549 1799-537X	ISBN (pdf)	978-952-295-169-4
Sivumäärä	53 s.	Kieli	englanti
Kustantaja	Metsähallitus	Painopaikka	
Jakaja	Metsähallitus, luontopalvelut	Hinta	

PRESENTATIONSBLAD

Utgivare	Forststyrelsen	Utgivningsdatum	8.7.2016
Uppdragsgivare	Forststyrelsen	Datum för godkännande	
Sekretessgrad	Offentlig	Diarienummer	
Typ av skyddsområde/ skyddsprogram			
Områdets namn			
Natura 2000-områdets namn och kod	Flera Natura 2000-områden inom västra Finska viken		
Regionenhet	Södra Finlands naturtjänster		

Författare	Martin Snickars, Anna Arnkil, Jan Ekebom, Lasse Kurvinen, Aija Nieminen, Alf Norkko, Anu Riihimäki, Tero Taponen, Sebastian Valanko, Markku Viitasalo och Mats Westerbom
Publikation	En översikt av havsbottnens tillstånd i västra Nyland: bottendjur som verktyg för förvaltning

Sammandrag

Europeiska direktivet för havsmiljön förpliktigar medlemsländer att vidta åtgärder för att uppnå god status i Europas hav innan 2020. För att uppnå direktivets mål bör medlemsländerna utreda havets tillstånd. Målet med detta arbete är att 1) med hjälp av bottendjur utreda bottnens ekologiska tillstånd i västra Finska viken, 2) granska hur representativa de officiella uppföljningsstationerna är i västra Nyland och 3) utreda hur den ekologiska kvaliteten på hydrografiskt uppföljningsdata återspeglar sammansättningen av bottendjur. Nylands närings-, trafik- och miljöcentral (NTM) har 2011 samlat in bottenprover från 36 stationer med syfte att följa med tidsmässiga förändringar i bottendjursammansättningen. Forststyrelsen tog 2012 bottenprover från 443 stationer i västra Nyland för att kartlägga förekomsten av bottendjur. Denna rapport jämför resultaten i dessa två studier.

Studien visar att syresituationen i sedimentet påverkar avsevärt artsammansättningen och populationsstrukturen bland bottendjuren. Mest påfallande var syrets effekt på östersjömusslans (*Macoma baltica*) populationsstruktur. I sediment med god kvalitet var populationsstrukturen bland östersjömusslor mångformig, representerad av både små och stora individer. De flesta variabler som mättes, indikerade bättre förhållanden för bottendjur i ytterskärgården än i innerskärgården.

Bottenproven tagna av NTM-centralen avvek markant från bottenprov tagna i Forststyrelsens studie. Skillnaderna syntes bäst vid klassificeringen av det ekologiska statuset. Det större dataunderlaget från 2012 gav ett högre ekologisk status än data baserat enbart på NTM-datat. Klassificeringen som gjordes på basis av det material Forststyrelsen insamlat, indikerade ett nöjaktigt eller gott tillstånd. Samma områden klassificerades som dåliga, eller t.o.m. försvarliga. Resultaten från de två studierna korrelerade ändå i viss mån sinsemellan. EQR (Ecological Quality Index) baserat på BBI (Brackish Water Benthic Index) gav inga klara resultat, ävenom skärgårdens yttre delar fick högre status än de i innerskärgården.

Denna studie antyder att nätverket av stationer för uppföljningen av bottendjur borde vara mer mångformigt där skärgådens olika zoner och djup representeras vidare än i nuvarande uppföljningsprogram. Det större dataunderlaget från 2012 påvisade att skärgården i västra Nyland representeras av botten i mycket dåligt tillstånd. Samtidigt är skärgården en mosaik av områden i mycket gott tillstånd, representerade av hög biologisk mångfald och individtäthet. Områden och vattenformationer kan generellt vara i dåligt tillstånd, men samtidigt lokalt uppvisa hög status.

	Östersjön, Finska viken, skärgård, uppföljning, bottendjur, havsbottnens tillstånd		
Örviga uppgifter	VELMU Programmet för inventeringen av den marina undervattensmiljön		
Seriens namn och nummer	Forststyrelsens naturskyddspublikationer. Serie A 224		
ISSN-L ISSN (online)	1235-6549 1799-537X	ISBN (pdf)	978-952-295-169-4
Sidantal	53 s.	Språk	engelska
Förlag	Forststyrelsen	Tryckeri	
Distribution	Forststyrelsen, naturtjänster	Pris	

Foreword

In 2012, a considerable effort to map the sublittoral coastal area of Finland was initiated within the national VELMU programme (The Finnish Inventory Programme for the Underwater Marine Environment). The ultimate aim of VELMU was to map the underwater habitats, increase the understanding of how habitats are distributed in the archipelago and to become aware of their general condition. As part of VELMU, a sub-project concentrating on the benthos was initiated. The driving idea for the sub-project was to increase the understanding of the distribution of benthic soft-bottom species and map their distribution within the western Uusimaa area. While the distribution and condition of predominant sublittoral habitats in the national VELMU programme has been mapped using drop-down video recordings – and since this methodology doesn't produce any information of the quality of the soft sediment habitats, nor any information of the distribution of benthic infauna, a sampling programme taking these into consideration was necessary. We therefore sampled over 440 soft bottom samples from an equal number of stations in the western Gulf of Finland between Espoonlahti and Bromarv with an aim to map the regional distribution of benthic infauna. The gained experience was then used when planning and executing the soft-bottom sampling programme along the entire Finnish coast within VELMU during two consecutive years.

The sampling, done in 2012, was conducted alongside ordinary VELMU work, without any added funding. Therefore, due to this constraint, there are some limitations with the setup of the survey. Firstly, there are no intra-site replicates, because of time and financial constraints during sampling; only one sample was selected from each site. Secondly, of the same reasons, no sediment samples were taken making it impossible to relate sediment grain size with species occurrence. Thirdly, sediments were only visually described to assess their quality status, and such visual inspection doesn't guarantee a robust ecological assessment of sediment quality per se.

Monitoring of coastal habitats and biotopes has recently been under revision in Finland. However, a critical assessment of monitoring practices has never been conducted, including a critical evaluation of station design. One of the goals of this survey was therefore to evaluate the number of stations needed to produce monitoring results that can be considered representative of the area as a whole, and to classify the status of the archipelago using BQI as a measure.

This report was done as team-work with several persons involved. Martin Snickars analysed the data and was responsible for producing the core text. Mats Westerbom initiated the idea, planned the sampling, took most of the samples and finalized and edited the report. Anna Arnkil, Aija Nieminen, Anu Riihimäki assisted in the field and Anna Arnkil analysed most of the benthic samples. Jan Ekebom, Lasse Kurvinen, Alf Norkko, Sebastian Valanko and Markku Viitasalo functioned as co-writers. Jan Ekebom and Tero Taponen organized funding for the analysis of data through VELMU funding and Alf Norkko, Markku Viitasalo and Mats Westerbom from the Maj and Tor Nessling foundation.

Mats Westerbom

Vantaa, 8.7.2016

Contents

1 Introduction

In the coastal waters of the Baltic Sea, zoobenthos (infauna, macroinvertebrates) community structure is mainly regulated by changes in salinity, oxygen concentration, sediment type, depth and nutrient concentrations (e.g. Bonsdorff *et al.* 2003, O'Brien *et al.* 2003). Coastal waters typically have clear gradients of environmental variables, which result in heterogeneous conditions and species assemblages. Under such circumstances, it is challenging to monitor and assess ecological status of any waters as demanded by the legislative framework of the Water Framework Directive (WFD, 2000/60/EC), as the natural variation is high.

The Marine Strategy Framework Directive, MSFD, (2008/56/EC) stipulates all EU Member States to take actions towards reaching a Good Environmental Status (GES) of their marine waters, by 2020. The marine strategies to be developed by each Member State includes a detailed assessment of the state of the environment, a definition of "good environmental status (GES)" at regional level and established targets based on indicators as well as monitoring programs for these indicators to assess progress towards GES. The MSFD identifies the following steps: 1) an initial assessment of the current environmental status of that Member State's marine waters; 2) a determination of what Good Environmental Status means for those waters; 3) a set of environmental targets and associated indicators designed to show whether a Member State is achieving GES; 4) a monitoring programme to measure progress towards GES, and 5) a programme of measures (POM) that defines the actions that each Member State will take to reach GES in their national waters and, begin the execution of the POM by 2016.

An initial assessment will require information on, for example, the spatial distribution of benthic biodiversity. It also requires understanding of dynamics, i.e. temporal aspects of diversity (Villnäs & Norkko 2011). This can ensure that a more robust monitoring programme can be established to measure progress towards GES. At a smaller spatial scale, this study can provide useful information in the national implementation of the MSFD by providing detailed knowledge on variation in current zoobenthic status of the Uusimaa coastal area. Similarly, the Water Framework Directive (WFD), urges all EU member states to protect, enhance and restore all bodies of surface water in an aim to achieve a good ecological status of all waters. Furthermore, the goal of the Habitats Directive (HD) is to achieve a favourable conservation status for the habitats in its Annex I and species in Annexes II, IV and V.

In order to implement these partly overlapping Directives simultaneously, all Member States must know the distribution, abundance and condition of marine species and habitats and, they also need to understand both anthropogenic and natural pressures these species and habitats face. Member States must also take action to guarantee the long-term survival of these species and habitats. Moreover, the change in species, habitat and pressure data must be known, i.e. a monitoring programme must be in place. In coastal areas the benthic monitoring in the WFD and MSFD are overlapping. Consequently, this study along with its conclusions will be useful for both of these Directives and to some extent even the Habitats Directive when discussing the benthic quality of predominant habitats.

Similarly to the MSFD, the WFD Member States must protect and, if needed enhance all waters (freshwater, coastal waters, transitional as well as groundwater). The aim of WFD is to achieve good ecological quality status (EcoQ) of all waters in EU by the end of 2015. EcoQ is a measure based on biological, hydrological and physicochemical quality elements. The biological elements of coastal waters include phytoplankton, macroalgae, zoobenthos as well as fish in the transitional waters. Following the WFD, the coastal waters of Finland consist of 11 water types, comprising inner and outer archipelago and sea areas (Perus *et al.* 2004). The water types may be sub-divided into smaller basins, for which the ecological status is assessed.

Before the WFD, the monitoring of coastal waters in Finland was largely based on physical and chemical factors, with only little biological information. With the WFD, the importance of biological elements increased. As a result, a network of biological monitoring stations was planned for all 11 water types, for which zoobenthos was monitored. The response of zoobenthos to stressors such as eutrophication is well known and includes changes in abundance and species composition as sensitive species decrease (e.g. Pearson & Rosenberg 1978). Thus, together with other elements, zoobenthos can be used as indicators of the effect of a magnitude of stressors on ecological status of the coastal waters.

In Finland, the ecological status of surface waters is assessed by the regional Centres for Economic Development, Transport and the Environment (ELY-centres) – in the present study, the Uusimaa ELY-centre. In 2011, the ELY monitoring stations for zoobenthos were sampled comprehensively for the first time in the coastal waters of Uusimaa in accordance with the WFD and based on the national guidelines of Vuori *et al.* (2008). According to the latest assessment, based on monitoring information from 2006 to 2012, many of the coastal areas are in a poor state in the western Gulf of Finland.

One of the goals of the study were to assess how representative the network of zoobenthos ELY monitoring stations is in relation to the coastal area of Uusimaa and to study the spatial factors affecting zoobenthos such as inner and outer archipelago and depth by comparing the network with an extended survey covering over 440 stations in the same area. The effects of water quality and sediment quality on zoobenthos were also assessed. The representativeness of ELY monitoring stations has not previously been assessed.

2 Materials and Methods

The study area was situated in the coastal waters of the western part of the county of Uusimaa, southern Finland, between Espoonlahti in the east and Bromarv in the west (Figure 1). In the extended survey in 2012, benthic samples were taken between August and September using Petite Ponar (231 cm^2) and Peterson samplers (450 cm^2). Samples were taken during calm days by hand (Figure 2). The maximum depth limit was therefore set to ca 20 meters; some samples however were sampled also deeper when conditions were favourable. Only samples with predominance of mud or silt were included in analyses, and only one sample was taken from each site. Stations were distributed with random stratification, where depth, wave exposure, salinity and turbidity were used as strata (the method is described Westerbom *et al.* 2015). The target was set to maximise stations, within a reasonably short sampling period, in order to cover a maximally broad area. Therefore, replicates were not taken and neither a measure of intra-station variability nor sampling accuracy can be assessed from this dataset. All samples with little material were discarded and new samples were taken. In the boat, samples were immediately processed where excess mud and clay was sieved out from the samples using a 0.5 mm sieve and samples were immediately stored in 70% ethanol for later analyses.

The zoobenthos ELY monitoring stations were extracted from the national environmental database HERTTA administrated by the Finnish Environment Institute (www.ymparisto.fi/oiva). All stations within the study area that had been sampled in 2011 were selected. Stations consisted of soft sediment at accumulation bottoms and were sampled with a Van Veen (0.1 m^2, 1 replicate) and an Ekman-grab (289 cm^2, 1 or 5 replicates). Samples were sieved trough a 0.5 mm sieve and preserved for later analyses. The sampling methods and guidelines for selection of monitoring stations are described in Vuori *et al.* 2008 (Annex 4) and follow the Standards SFS 5076:1989 and SFS-EN ISO 16665:2005.

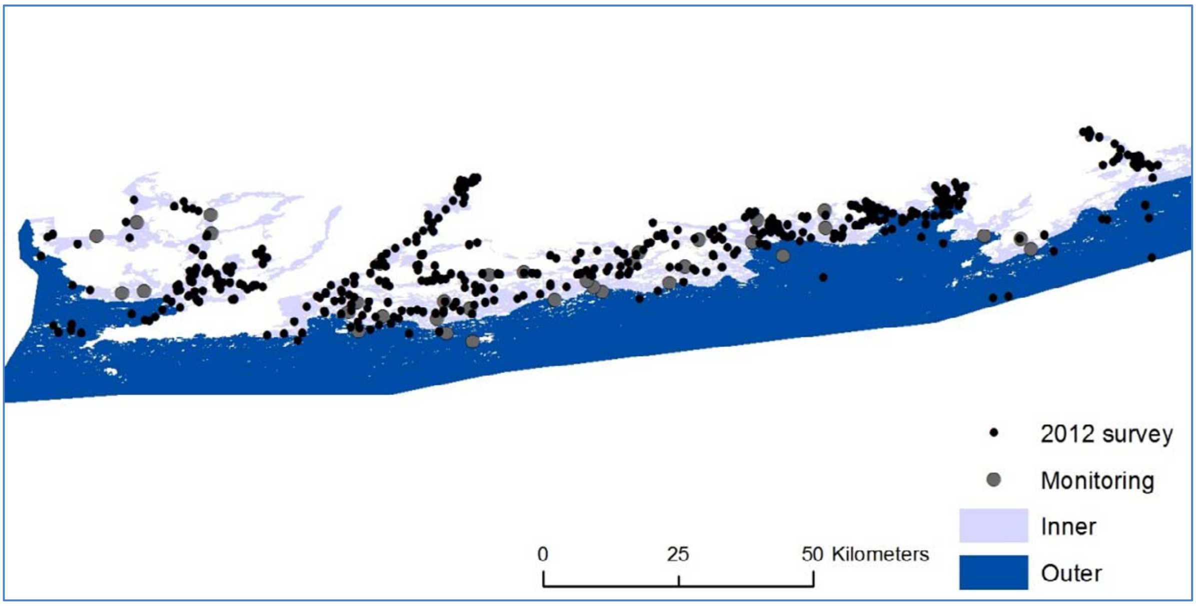

Figure 1. The study area in the county of Uusimaa (SW Finland) with ELY monitoring stations sampled 2011 and extended survey sites sampled in 2012 in inner and outer archipelago.

Kuva 1. Uudenmaan tutkimusalueen pohjaeläinnäyteasemat sisä-, väli- ja ulkosaaristossa. Seuranta-aineisto perustuu Uudenmaan ELY-keskuksen vuonna 2011 keräämään aineistoon, laajennettu otanta suoritettiin Metsähallituksen toimesta 2012.

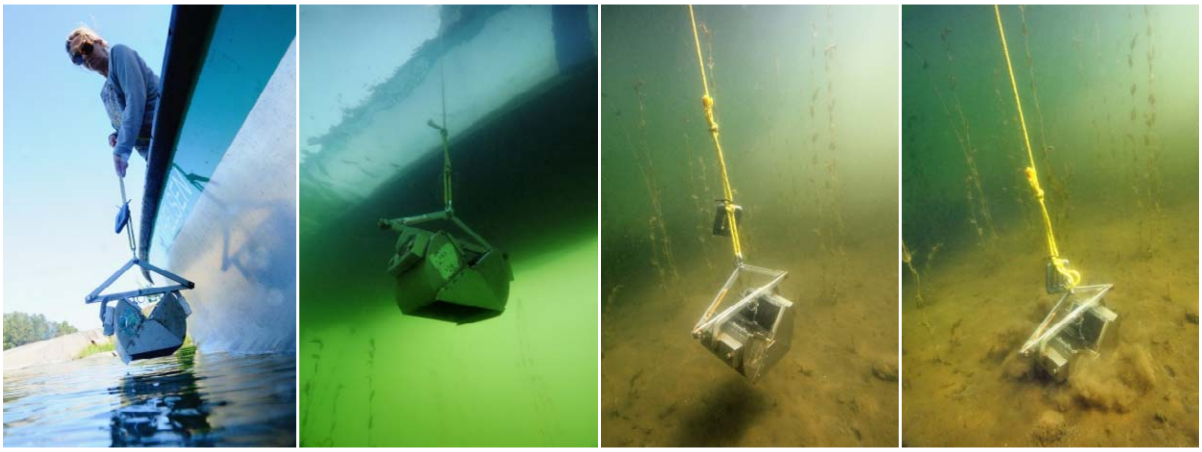

Figure 2. Petite Ponar in work during the 2012 extended sampling. Photos: Mats Westerbom/Metsähallitus.
Kuva 2. Näytteenotto Petit Ponar -noutimella laajennetussa näytteenotossa. Kuvat: Mats Westerbom/Metsähallitus.

During 2013, samples in the extended survey were processed further in the lab and species were identified to the nearest possible taxa and individuals were counted. Counting and identification was mainly done by one person only (Anna Arnkil). Animals in samples were separated by size using 2, 1 and 0.5 mm sieves. The material in the 0.5 mm sieve was analysed using a preparation microscope. Note that the list of stations monitored by the ELY-centre is not exhaustive for the area, and other stations sampled by the Finnish Environment Institute, as well as environmental obligations of industry and municipality are not included in the study. Also note that the year and month of sampling, as well as sampling gears differed between the extended survey site and the zoobenthos ELY monitoring stations.

2.1 Water Quality Stations

The water quality monitoring stations were extracted from the national environmental database HERTTA. Selected water quality stations were those sampled the previous year and the current year of respective zoobenthos sampling, i.e. 2010–2011 (for monitoring stations) and 2011–2012 (for extended survey sites). This selection resulted in 111 stations (2010–2011) and 98 stations (2011–2012). From these selections, the nearest station (within a maximum distance of 2.5 km) was linked to a zoobenthos monitoring station and extended survey, respectively. As the average depth of the extended survey sites differed markedly from the water quality stations, a depth difference of 5 m between the two data sets was used if depth of the water quality station was less than 20 m, and 10 m if depth exceeded 20 m. The depth-adjusted query was used to minimise the risk of linking stations with markedly different depths. 21 out of 36 zoobenthos ELY monitoring stations and and 62 of the 393 extended survey sites had a water quality station situated nearer than 2.5 km. To analyse the effect of oxygen concentration on the zoobenthos indices, a cut-off of oxygen concentration 6 mg/l was used. This level was used as a preliminary analysis revealed that a majority of the encountered hypoxia events during the 24-mo period occurred at water quality stations with a 24-mo average oxygen concentration <6 mg/l. Although the oxygen condition value per se does not imply severe negative conditions, this threshold value was used as a proxy for the long-term oxygen conditions in the area surrounding the monitoring stations, including hypoxia events. In total 43 of 46 (93%) hypoxia events at the water quality stations during 2010–2012 occurred at stations with an average oxygen concentration <6 mg/l.

In the extended survey, the sediment type was grouped into two types: soft and other. The sediment was classified into soft when a sample contained 100% mud, clay or silt, or the difference to other sediment types (sand, gravel) was less than or equal to 20%. If this difference was less than 20% or sand and gravel was dominating, the sediment type was other. The quality of the sediment (normal sediment or signs of oxygen shortage) was assessed directly in the field (Figures 3 and 4). Sediment with dark brown to black colour and/or strong smell of H_2S was noted as having signs of oxygen shortage. As such, differences in colour doesn't guarantee a fully reliable assessment of oxygen condition since colour differences indicate also differences in mineral content and not always oxygen penetration per se.

Figure 3. Samples were visually described based on colour and smell. The picture to the left shows a healthy and "normal" sample, whereas the sample to the right is considered affected showing signs of oxygen deficiency. Photos: Anna Arnkil/Metsähallitus.

Kuva 3. Näytteet kuvailtiin värin ja hajun perusteella. Vasemmalla terveeltä pohjalta otettu näyte, oikealla happivajetta indikoiva näyte. Kuvat: Anna Arnkil/Metsähallitus.

Figure 4. Ponar sample from harder clay-bottom with gravel on top. Photo: Anu Riihimäki/Metsähallitus.

Kuva 4. Ponar-näyte kovalta savipohjalta, jonka pinnassa esiintyy soraa. Kuva: Anu Riihimäki/Metsähallitus.

The size of *Macoma balthica* was grouped in three size classes according to the sieves (0.5–1, 1–2, >2 mm). In the northern Baltic Sea, *Macoma balthica* settles at a size of 0.3 mm and becomes fully developed at around 2 mm (Bonsdorff *et al.* 1995).

All stations were grouped based on archipelago zone (inner, outer) and depth (shallow, <10 m and deep, >10 m) following the typology of Finnish coastal waters (Perus *et al.* 2004) under The European Water Framework Directive.

2.2 Analyses

For each zoobenthos monitoring station and survey site, total abundance (ind/m^2), species richness, Shannon diversity index, BQI (Benthic Quality Index, Rosenberg *et al.* 2004) and BBI (Brackish water Benthic Index, Perus *et al.* 2007) was calculated. BQI is built on the sensitivity of species to eutrophication and the relative proportion of the species and the species number. Four levels of sensitivity of species (1, 5, 10, 15) was used, where 1 is very tolerant to pressure and 15 is very sensitive (Rosenberg *et al.* 2004, Perus *et al.* 2007). BBI uses BQI and incorporates the Shannon diversity index and abundance proportions of individual species to adjust for the conditions in the brackish Baltic Sea. BBI was not used because it co-varies with species richness and Shannon diversity index.

2.2.1 The role of sediment quality on zoobenthos

The effect of sediment quality on zoobenthos was analysed by grouping the extended survey sites into two sediment quality-groups, one with normal sediment and one with signs of oxygen shortage (hypoxia/anoxia). Comparisons were made between normal and affected sites in shallow and deep waters of the inner archipelago and deep waters of the outer archipelago, respectively. Normal sediments were compared between shallow and deep waters of the inner archipelago, and between deep waters of inner and outer archipelago. A similar depth-comparison was made for affected sediments.

2.2.2 The role of sediment quality on *Macoma balthica* population structure

The effects of sediment quality on the size of *Macoma balthica* was analysed by comparing the proportions of the three size classes in normal sediments and affected sediments. Difference in the size structure was assessed by comparing the proportions of sites with one, two or three size classes in normal sediments and affected sediments.

2.2.3 The role of sediment type on zoobenthos

The effect of sediment type (soft, other) was analysed for the extended survey sites separately for shallow and deep waters in the inner archipelago (Figure 5). The occurrence of the sediment type other was low (13 sites) in the outer archipelago and thus the comparison was made only for the inner archipelago.

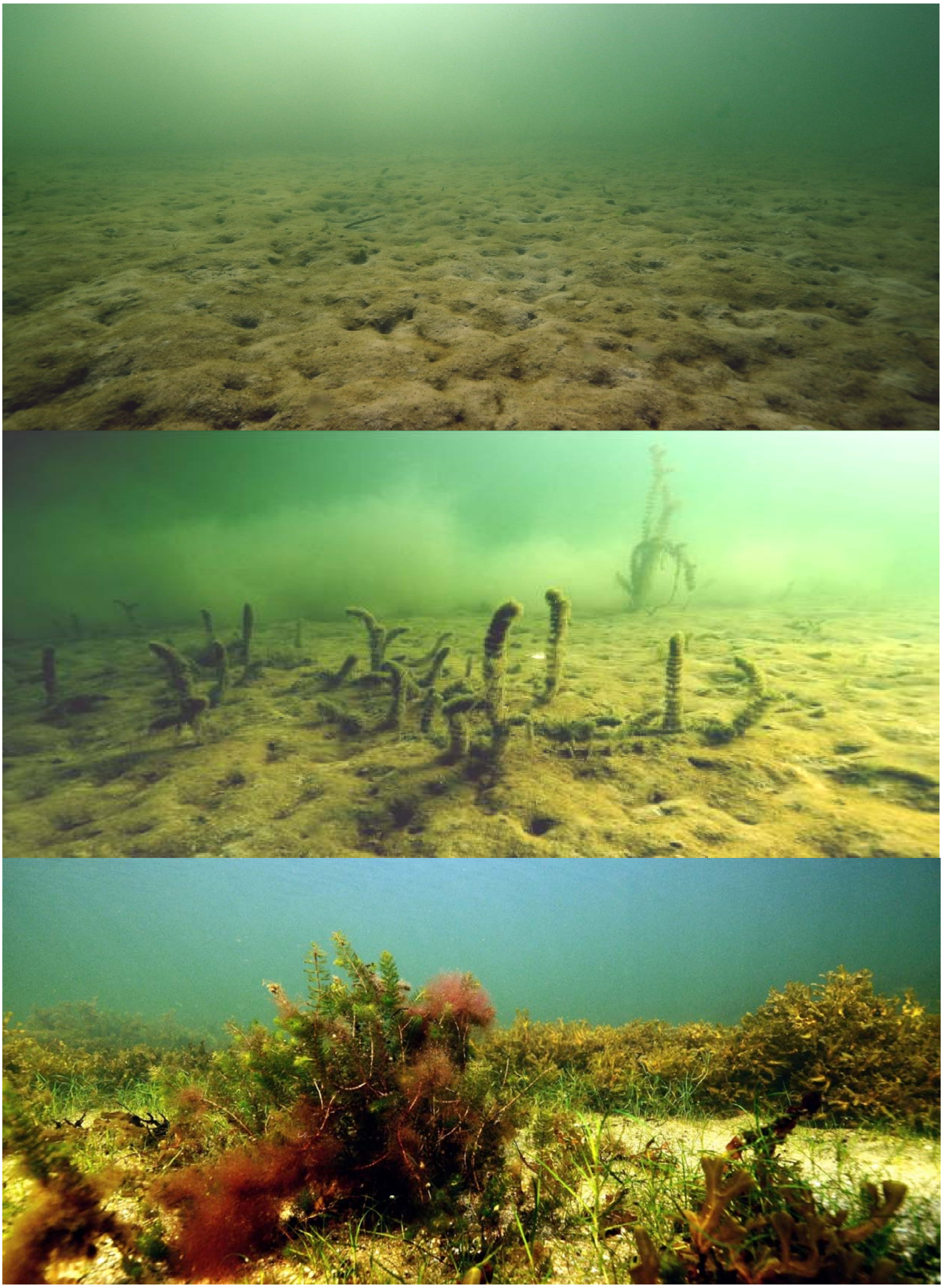

Figure 5. Samples in the survey are mostly sampled from muddy vegetation free bottoms (upper). Some shallow samples were sampled from muddy bottoms with vegetations (mid) and a small proportion from coarser sediments such as silt/sandy silt (bottom). Photos: Mats Westerbom/Metsähallitus.

Kuva 5. Näytteet kerättiin pääosin paljailta liejupohjilta (kuva ylkäällä). Pieni määrä näytteitä oli harvan kasvuston peittämiltä liejupohjilta (kuva keskellä) ja muutama näyte edusti hietapohjia (kuva alhaalla). Kuvat: Mats Westerbom/Metsähallitus.

2.2.4 Representativeness of the zoobenthos monitoring sites

To analyse how representative the zoobenthos monitoring sites are for the whole area, the extended survey sites located less than 2.5 km from a monitoring station were extracted using GIS. This group was considered as representative for the monitoring area. Extended survey sites located farther than 2.5 km from a monitoring station represented the study area outside the monitoring area, i.e. the rest of the study area. The groups (monitoring sites, extended survey sites <2.5 km and >2.5 km from a monitoring site) were cross-compared to analyse differences between 1) monitoring sites and extended survey sites inside the monitoring area, 2) monitoring sites and extended survey sites outside the monitoring area, and 3) to analyse if extended survey sites differed inside and outside the monitoring area. Separate analyses were made for shallow inner, deep inner and deep outer archipelagos. To compare the role of sampling effort on species richness between the extended survey sites and monitoring stations, sample-based species rarefaction curves for deep inner archipelago, were calculated using EstimateS (Version 9.1, Colwell 2013), as sites and stations were most numerous here.

2.2.5 The spatial linkage with water quality stations

To analyse the potential linkage between the water quality monitoring stations and zoobenthos stations/sites, the mean of 24-mo oxygen concentration of the nearest station was related to the zoobenthos parameters. Two mean oxygen concentrations (<6, >6 mg/l) were used to group the nearest stations into a "low" and "high" oxygen level-group. In addition, these two groups were compared with the sediment quality of the extended survey sites to analyse if there was a relationship between the oxygen concentration of nearby water quality stations and the sediment quality (normal or signs of oxygen shortage).

2.2.6 The ecological status class of the basins

The status classification derived from the EQR based on BBI was averaged for all basins in the area that had zoobenthos ELY monitoring stations and or extended survey sites present. The EQR of each station/site was grouped into five classes (1–5, bad, poor, intermediate, good and high) according to the guidelines of the national assessment of ecological status (Aroviita *et al.* 2012). The classes were compared with the current national assessment from 2013, which uses information on water quality and biotic elements, including zoobenthos, from years 2006–2012. Hence, the current national assessment of ecological status uses a wider basis than used here, which focuses solely on zoobenthos. As several station groups did not meet assumptions of normality after transformation and size differences among some of the groups was large, Mann-Whitney Test was used to compare the groups.

3 Results

The ELY monitoring stations (total N in study area = 36) that were assessed in this study were mostly situated in the deep (>10 m) inner archipelago (17) in shallow (<10 m) inner archipelago (10), in outer deep archipelago (9) and none in the shallow outer archipelago. The extended survey sites (soft sediment sites N = 391, total N = 443) had a broader distribution in the study area with most of the sites situated in shallow (192) and deep (146) inner archipelago followed by deep (42) and shallow (11) outer archipelago (Table 1). The ELY monitoring stations were deeper than the extended survey sites in both depth categories in the inner archipelago and also in deep outer archipelago. The mean depth of the deep category differed between the two archipelago zones (p<0.001, Mann-Whitney Test), i.e. the outer archipelago sites were also deeper.

Table 1. Summary of the extended survey and the ELY monitoring stations in the study area grouped according to archipelago zone and depth category. The variance of means is 95% confidence interval. * = significance p<0.05, ** = significance p<0.01, *** = significance p<0.001, Mann-Whitney Test.

Taulukko 1. Laajennetun asemaverkoston ja seurantaverkoston jakauma saaristovyöhykkeiden ja syvyyden suhteen sekä asemien keskimääräiset yksilötiheydet ja lajimäärät. * = merkitsevyys p < 0,05, ** = merkitsevyys p < 0,01, *** = merkitsevyys p < 0,001, Mann-Whitney testi. Hajonta edustaa 95 prosentin luottamusväliä.

	Extended survey 2012	ELY monitoring stations 2011
Sites N tot.	391	36
Inner archipelago, <10 m	N = 192, Depth = 4.7 ± 0.3	N = 10, Depth = 6.9 ± 1.1**
Inner archipelago, >10 m	N = 146, Depth = 16.0 ± 1.1	N = 17, Depth = 19.2 ± 3.4*
Outer archipelago, <10 m	N = 11, Depth = 6.1 ± 1.6	-
Outer archipelago, >10 m	N = 42, Depth = 21.6 ± 2.4	N = 9, Depth = 27.1 ± 5.5*
Mean Ind/m^2	2,721	1,752
Species N	6.2	4.5
Species in common N	21	21
Method, Samplers	Ponar (230 cm^2), Peterson (450 cm^2), 0.5 mm 1 replicate	Van Veen (1,155 cm^2), Ekman (289 cm^2), 0.5 mm, 1–5 replicates

3.1 Effect of sediment oxygen quality on zoobenthos

58% of the sites in deep water in the inner archipelago had normal sediment. In the outer archipelago 80% had normal sediment (Figure 6, Table 2). Over 90% of the shallow (<10 m) sites in inner and outer archipelago had normal sediment.

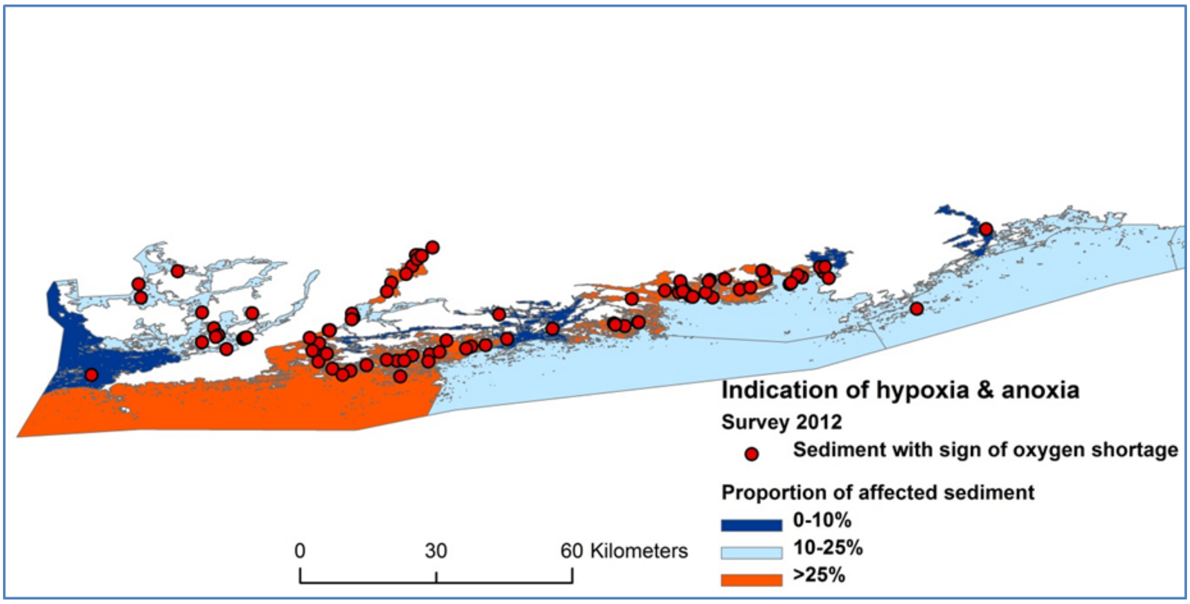

Figure 6. The oxygen status 'sign of oxygen shortage' at the extended survey sites sampled in 2012 and the proportion of sites with signs of oxygen shortage in the basins of the study area. Note that the distribution of sites does not necessarily represent the whole extent of the basins. It is noteworthy, that the Hanko basin is here shown as being in proportionately bad condition, only because the samples from the southern Hanko peninsula are left out from the dataset, because bottoms here are mainly sand. Also, the Kantvik and Espoonlahti area may be here indicated as being in proportionately good condition, because samples from these areas were abundant and predominantly sampled from shallow areas.

Kuva 6. Happitilanne laajennetussa tutkimuksessa ja vähähappisten tai hapettomien pohjanäytteiden osuus koko vesimuodostuman pohjanäytteistä. Kuvaa tulkittaessa on huomioitava, ettei Hankoniemen edustalta kerätty näytteitä, koska vallitseva pohjatyyppi on alueella hiekkaa. Kantvikin ja Espoonlahden näytteet olivat pääosin matalilta pohjilta, missä happiolosuhteet ovat hyvät. Tämä saattaa johtaa alueen syvempien pohjien yleistilan yliarviointiin.

In the shallow inner archipelago there were significantly higher abundance and species richness in normal sediments than in (affected) sediments with signs of oxygen shortage, whereas Shannon diversity and BQI were similar (Fig. 7, Table 2). In deep inner and outer archipelago all values were higher in normal sediments than in sediments with signs of oxygen shortage.

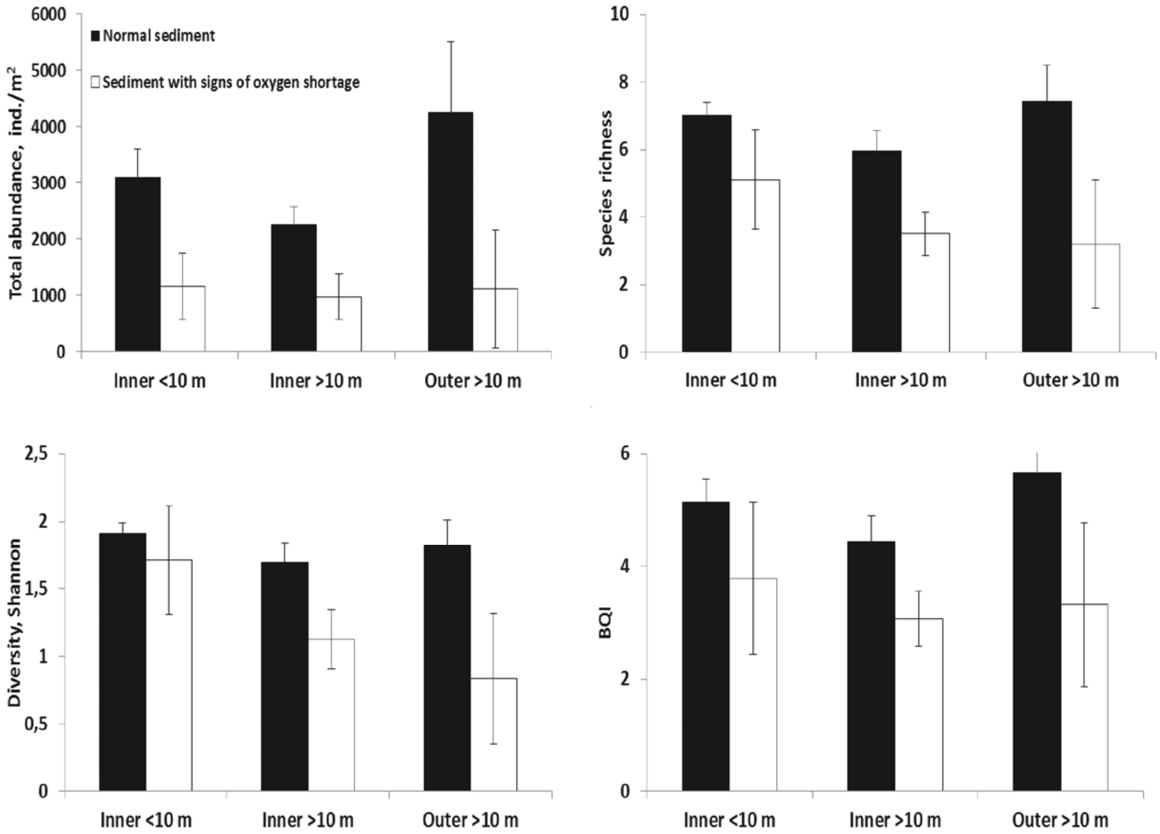

Figure 7. Total abundance, species richness in the extended survey. Shannon diversity and BQI in normal sediments (healthy) and sediments with signs of oxygen shortage in shallow (<10 m) and deep (>10 m) waters in the inner archipelago and deep waters in the outer archipelago. Error bars are 95% confidence interval.

Kuva 7. Yksilöiden kokonaismäärä ja lajirunsaus laajennetussa seurannassa. Shannonin monimuotoisuusindeksi ja BQI hapellisessa ja hapettomassa/vähähappisessa sedimentissä sisäsaariston sekä syvistä että matalista näytteistä ja ulkosaariston syvistä näytteistä. Hajonta edustaa 95 prosentin luottamusväliä.

Table 2. Results of Mann-Whitney tests comparing normal soft sediments and soft sediments with signs of oxygen shortage (affected) in shallow (<10 m) and deep (>10 m) waters in the inner archipelago and deep waters in the outer archipelago. Numbers within brackets are number of extended survey sites.

Taulukko 2. Pohjien sedimenttilaadun vaikutus yksilömäärään, lajirunsauteen ja monimuotoisuuteen vertailtaessa vähähappisia ja hapellisia pohjia sisä- ja ulkosaariston matalilla (alle 10 m) ja syvillä (yli 10 m) asemilla. Suluissa esitetään laajennetun otannan jakauma.

Mann-Whitney statistics	U	U	z-score	p-value
	Sediment quality			
Inner <10 m	Normal (176)	Affected (18)		
Abundance	1,020	2,617	-3.09	**0.002**
Richness	1,176	2,460	-2.48	**0.013**
Shannon diversity	1,629	2,007	-0.73	0.465
BQI	1,401	2,236	-1.61	0.107
Inner >10 m	Normal (85)	Affected (61)		
Abundance	1,098	4,793	-6.63	**>0.001**
Richness	1,471	4,419	-5.29	**>0.001**
Shannon diversity	1,844	4,047	-3.96	**>0.001**
BQI	1,865	4,026	-3.88	**>0.001**
Outer >10 m	Normal (32)	Affected (10)		
Abundance	61	339	-3.37	**>0.001**
Richness	63	338	-3.33	**>0.001**
Shannon diversity	56	345	-3.50	**>0.001**
BQI	71	329	-3.13	**0.002**

When comparing normal sediments across depths (<10 m vs. >10 m), the shallow waters had slightly higher total abundance of bottom animals than deep waters in the inner archipelago but the difference was not significant. Species richness, diversity and BQI were higher in normal shallow sediments than in corresponding deep sediments. In sediments with signs of oxygen shortage, species richness and diversity were higher in shallow waters while abundance and BQI were similar across depths (Fig 7, Table 3).

Normal deep sediments in the outer archipelago always had higher abundance, richness, diversity and BQI values than normal deep sediments in the inner archipelago, whereas deep sediments with signs of oxygen shortage only total abundance and BQI had higher values in the outer archipelago (Table 3).

Table 3. Results of Mann-Whitney tests comparing normal shallow (<10 m) and deep (>10 m) sediments and shallow and deep sediments with signs of oxygen shortage (affected) in the inner archipelago and deep outer archipelago. Numbers in brackets are number of sites in each group.

Taulukko 3. Syvyyden vaikutus yksilömäärään, lajirunsauteen ja monimuotoisuuteen vertailtaessa hapellisia ja hapettomia/vähähappisia pohjia sisäsaariston matalilla (<10 m) ja syvillä (>10 m) näytepisteillä ja ulkosaariston syvillä asemilla. Suluissa esitetään laajennetun otannan asemalukumäärää jokaisessa ryhmässä.

Mann-Whitney statistics	U	U	U	z-score	p-value
		Depth			
Normal sediment	Inner <10 m (176)	Inner >10 m (85)	Outer >10 m (32)		
Abundance	9,395	9,796		-0.29	0.771
		2,685	1,115	-3.78	**>0.001**
Richness	7,638	11,552		-2.83	**0.005**
		2,357	1,444	-2.20	**0.028**
Shannon diversity	7,899	11,291		-2.46	**0.014**
		2,075	1,726	-0.84	0.400
BQI	8,084	11,107		-2.19	**0.029**
		2,591	1,210	-3.33	**>0.001**
Affected sediment	Inner <10 m (18)	Inner >10 m (61)	Outer >10 m (10)		
Abundance	393	724		-1.91	0.057
		326	295	-0.25	0.800
Richness	370	746		-2.17	**0.030**
		288	333	-0.37	0.714
Shannon diversity	338	761		-2.47	**0.013**
		237	384	-1.20	0.231
BQI	503	613		-0.63	0.526
		345	276	-0.56	0.574

3.2 Effects of sediment quality on population structure of *Macoma balthica*

The proportion of larger *Macoma balthica* (sieve >2 mm) in deep soft sediments was higher in normal sediments than in affected sediments but the difference was not significant due to the large variation in sites with affected sediment. In comparison, the proportion of small (found in 0.5 and 1 mm sieves) *M. balthica* was higher in affected sediments but not significantly (Figure 8, left). Normal sediments with *M. balthica* present were dominated by three sizes, whereas the opposite was true in affected sediments, which were dominated by one size class (Figure 8, right, Figure 9).

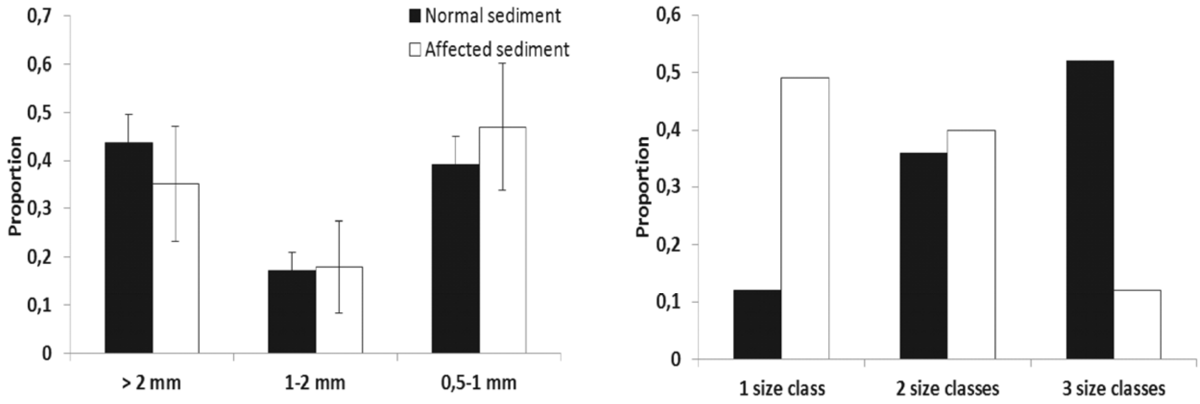

Figure 8. Left panel: average proportion of *Macoma balthica* sizes (according to sieves: 0.5–1 mm, 1–2 mm, >2 mm) in normal sediments and sediments with signs of oxygen shortage (affected) in the extended survey 2012. Error bars are 95% confidence interval. Right panel: Proportion of sites with three, two and one, respectively, size classes in normal and affected sediments (sites with *M. balthica* present only).

Kuva 8. Vasemmassa kuvassa esitetään liejusimpukan suhteelliset esiintymät laajennetussa tutkimuksessa. Simpukat jaettiin kolmeen kokoluokkaan ja esiintymiä verrattiin hapelliseen ja vähähappiseen/hapettomaan näyt-teeseen. Oikeassa kuvassa liejusimpukan kokoluokkien suhteellinen määrä hapellisissa ja vähähappisissa/ hapettomissa näytteissä. Hajonta esitetään 95 prosentin luottamusvälillä.

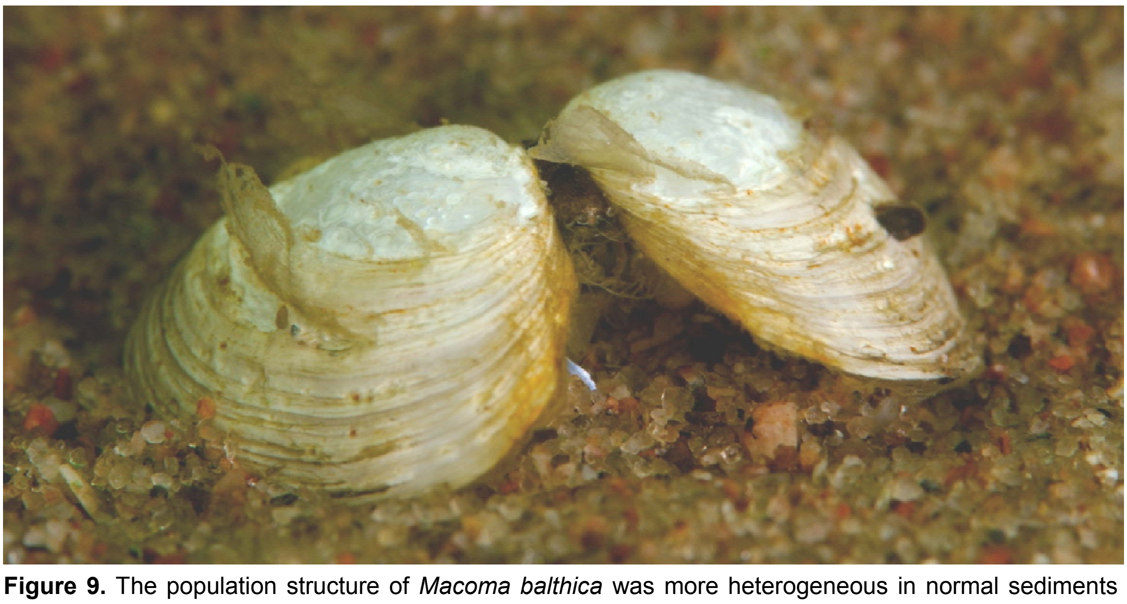

Figure 9. The population structure of *Macoma balthica* was more heterogeneous in normal sediments than in affected. Photo: Mats Westerbom.

Kuva 9. Liejusimpukan kokojakauma oli suurempi hapellisissa kuin hapettomuutta indikoivissa näytteis-sä. Kuva: Mats Westerbom.

3.3 Effect of sediment type (soft, other) on zoobenthos (extended survey)

The zoobenthos indices were always higher in the other sediment type than in soft sediment and half of the comparisons were significant (Figures 10 and 11, Table 4). The differences were pronounced regarding total abundance and species richness, and the effect of sediment type was stronger in shallow waters than in deep waters.

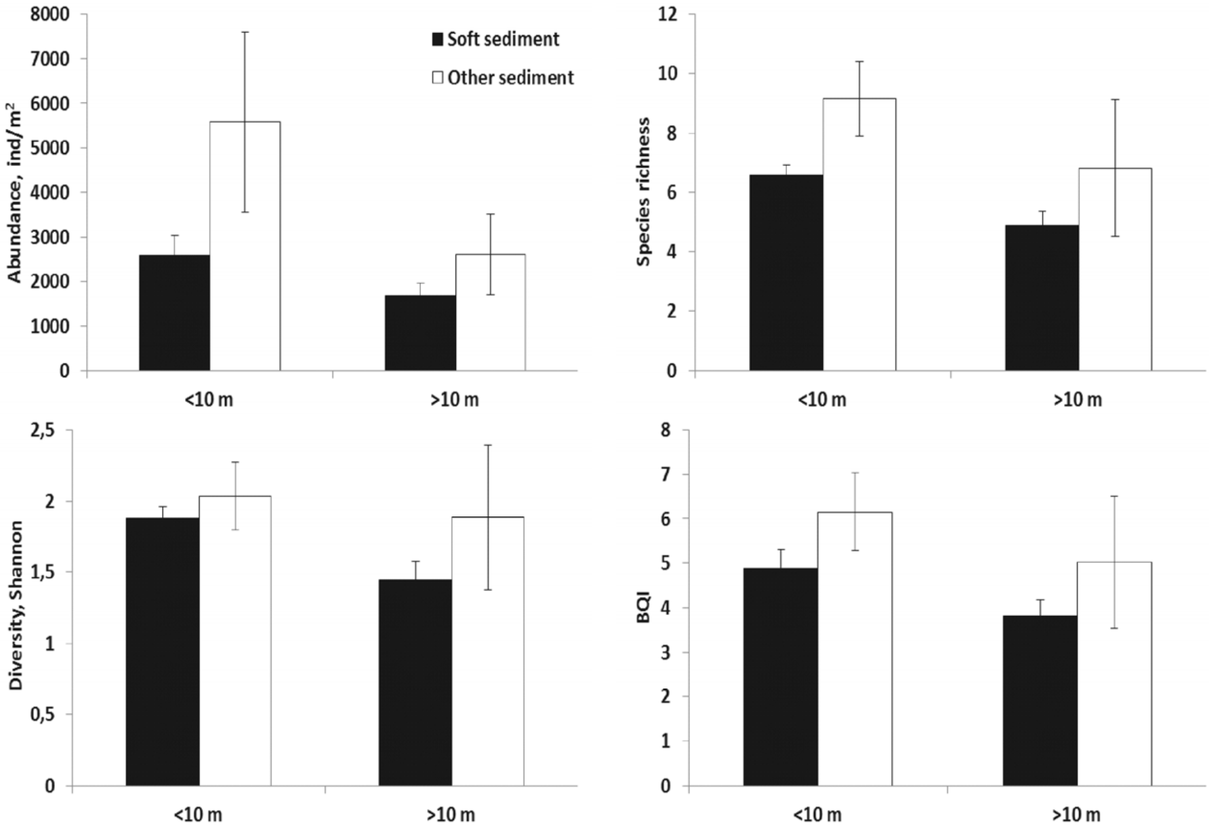

Figure 10. Total abundance and species richness. Shannon diversity and BQI in soft sediments and other (including mixes of soft, sand and gravel) sediments in shallow (<10 m) and deep (>10 m) waters in the inner archipelago. Error bars are 95% confidence interval.

Kuva 10. Yksilömäärä ja lajurunsaus eri pohjatyypeillä sisäsaariston matalilla ja syvillä pohjilla. Shannonin monimuotoisuusindeksi ja BQI liejupohjilla tai muilla pohjatyypeillä (sora, hiekka & lieju/hiekkaseos). Hajonta kuvaa 95 prosentin luottamusväliä.

Figure 11. Pure soft sediment (left) and mix of mud and sand (right). Photos: Mats Westerbom.

Kuva 11. Kuvassa vasemmalla puhdas liejupohja ja oikealla hietapohja. Kuvat: Mats Westerbom.

Table 4. Results of Mann-Whitney tests comparing soft sediments with other sediment types in shallow (<10 m) and deep (>10 m) waters in the inner archipelago. Numbers in brackets are number of sites in each group.

Taulukko 4. Eliöstövertailu lieju- ja muissa pohjatyypeissä sisäsaariston matalilla (< 10 m) ja syvemmillä (> 10 m) pohjilla. Suluissa asemamäärä.

Mann-Whitney statistics	U	U	z-score	p-value
	Sediment type			
<10 m	**Soft (194)**	**Other (26)**		
Abundance	3,808	1,236	-4.22	**<0.001**
Richness	3,693	1,351	-3.84	**<0.001**
Shannon diversity	2,949	2,096	-1.40	0.081
BQI	3,212	1,832	-2.26	**0.024**
>10 m	Soft (146)	Other (11)		
Abundance	1,133	474	-2.27	**0.023**
Richness	1,073	534	-1.85	0.064
Shannon diversity	1,044	562	-1.66	0.097
BQI	1,064	542	-1.79	0.073

3.4 Comparison between the zoobenthos monitoring area and the rest of the study area

In the inner archipelago, total abundance was highest in the extended survey sites inside the monitoring area (sites <2.5 km from a zoobenthos monitoring station) in shallow waters, although not significantly different from the other groups due to large variation. In deep waters, total abundance was similar between the station groups (Figure 12, Tables 5 and 6). There was higher species richness in the sites inside the monitoring area than similar stations outside (>2.5 km) the monitoring area and the ELY monitoring stations in both shallow and deep waters, whereas there was no difference in richness between ELY monitoring stations and stations outside the monitoring area. Diversity (Shannon index) and BQI showed similar pattern as species richness, but the differences were clearer with markedly higher values at sites both within and outside the monitoring area than the ELY monitoring stations. The difference was also clearer in deep waters than in shallow waters.

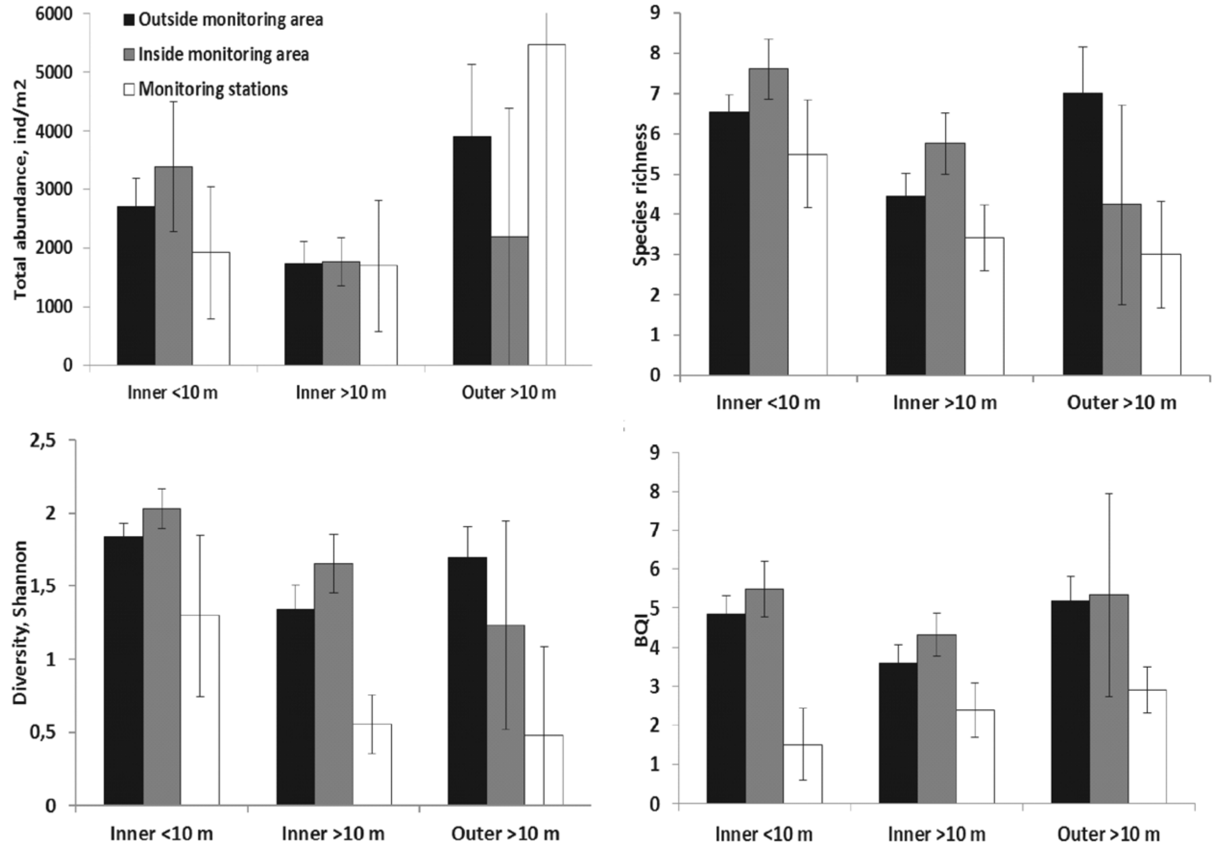

Figure 12. Total abundance, species richness, Shannon diversity and BQI outside and inside the monitoring area and the ELY monitoring stations in shallow (<10 m) and deep (>10 m) waters in the inner archipelago and deep waters in the outer archipelago. Error bars are 95% confidence interval. Confidence interval in upper left panel, Outer >10 m, Monitoring stations = 11,980.

Kuva 12. Kuvassa verrataan pohjaeläinten määriä ja monimuotoisuutta seuranta-asemilla, niiden lähiympäristössä (alle 2,5 km ELY-seuranta-asemasta) ja laajemmalla ympäristössä (yli 2,5 km ELY-seuranta-asemasta) sekä sisä- että ulkosaaristossa. Hajonta kuvaa 95 prosentin luottamusväliä. Y-akseli kuvan vasemmassa yläkulmassa on leikattu ja hajonta yltää arvoon 11 980.

Table 5. Results of Mann-Whitney tests comparing shallow (<10 m) sites outside (>2.5 km from a monitoring station) and inside (<2.5 km from a monitoring station) the monitoring area and the monitoring sites in the inner archipelago. Numbers in brackets are number of sites in each group.

Taulukko 5. Asemaverkoston edustavuuden vertailu sisäsaaristossa. Analyysissä verrataan matalien pohjien pohjaeläinten määrää ja monimuotoisuutta seuranta-asemilla suhteessa lähellä oleviin (alle 2,5 km ELY-seuranta-asemasta) ja kauempana oleviin laajennetun otannan näytteisiin (yli 2,5 km ELY-seuranta-asemasta).

Mann-Whitney statistics	U	U	U	z-score	p-value
	Station group				
Shallow <10 m	Outside (155)	Inside (67)	Monitoring (8)		
Abundance	5,506	4,879		-0.71	0.475
	581		659	-0.30	0.764
		238	298	-0.51	0.607
Richness	6,097	3,979		-2.46	**0.014**
	475		766	-1.12	0.264
		135	386	-2.22	**0.027**
Shannon diversity	6,115	3,960		-2.50	**0.012**
	330		910	-2.23	**0.026**
		96	424	-2.90	**0.004**
BQI	5,627	4,448		-1.37	0.171
	178		1,063	-3.40	**0.001**
		45	475	-3.80	**<0.001**

Table 6. Results of Mann-Whitney tests comparing deep (>10 m) sites outside (>2.5 km from a monitoring station) and inside (<2.5 km from a monitoring station) the monitoring area and the monitoring sites in the inner archipelago. Numbers in brackets are number of sites in each group.

Taulukko 6. Asemaverkoston edustavuuden vertailu sisäsaaristossa. Analyysissä verrataan syvien pohjien pohjaeläinten määrää ja monimuotoisuutta seuranta-asemilla suhteessa lähellä oleviin (alle 2.5 km ELY-seuranta-asemasta) ja kauempana oleviin laajennetun otannan näytteisiin (yli 2,5 km ELY-seuranta-asemasta).

Mann-Whitney statistics	U	U	U	z-score	p-value
	Station group				
Deep, >10 m	Outside (91)	Inside (66)	Monitoring (17)		
Abundance	3,093	2,913		-0.32	0.749
	699		849	-0.63	0.527
		481	642	-0.91	0.364
Richness	3,769	2,237		-2.72	**0.006**
	637		911	-1.16	0.248
		308	814	-2.85	**0.004**
Shannon diversity	3,779	2,227		-2.76	**0.006**
	313		1,234	-3.88	**<0.001**
		174	948	-4.37	**<0.001**
BQI	3,598	2,409		-2.11	**0.035**
	528		1,019	-2.07	**0.038**
		273	849	-3.25	**0.001**

In deep outer archipelago, species richness at the sites outside the monitoring area was higher than at the sites inside the monitoring area and the ELY monitoring stations. Also the diversity and BQI were higher outside the monitoring area than in the ELY monitoring stations. There were no differences in total abundance due to high variation (Figure 12, Table 7).

Table 7. Results of Mann-Whitney tests comparing deep (>10 m) sites outside (>2.5 km from a monitoring station) and inside (<2.5 km from a monitoring station) the monitoring area and the monitoring sites in the outer archipelago. Numbers in brackets are number of sites in each group.

Taulukko 7. Asemaverkoston edustavuuden vertailu ulkosaaristossa. Analyysissä verrataan syvien pohjien pohjaeläinten määrää ja monimuotoisuutta seuranta-asemilla suhteessa lähellä oleviin (alle 2.5 km ELY-seuranta-asemasta) ja kauempana oleviin laajennetun otannan näytteisiin (yli 2,5 km ELY-seuranta-asemasta).

Mann-Whitney statistics	U	U	U	z-score	p-value
	Group				
Outer deep	**Outside (34)**	**Inside (8)**	**Monitoring (6)**		
Abundance	110	227		-1.55	0.122
	65		187	-1.90	0.057
		28	20	-0.52	0.606
Richness	93	244		-2.00	**0.046**
	36		217	-2.82	**0.005**
		20	29	-0.58	0.561
Shannon diversity	120	217		-1.27	0.204
	26		226	-3.12	**0.002**
		15	33	-1.16	0.245
BQI	161	175		-0.19	0.853
	21		222	-2.98	**0.003**
		11	37	-1.68	0.093

The rarefaction curves of the two data sets show that the extended survey sites in the deep inner archipelago sampled approximately 2 species more than the corresponding ELY monitoring stations (Figure 13). Approximately 24 of the estimated 31 species (77%) were sampled in the extended survey with a sampling effort equaling the ELY monitoring stations that estimated a total of 22.1 species with 40 samples.

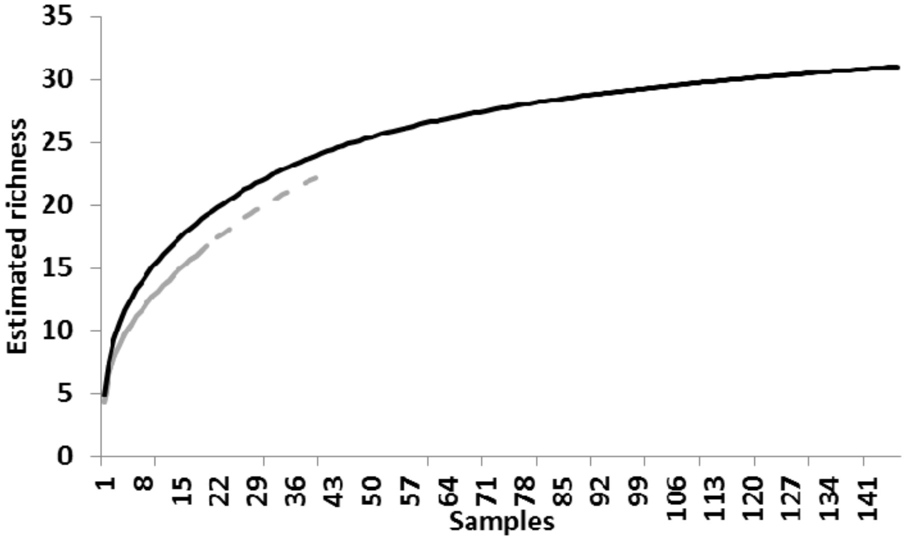

Figure 13. Sample-based rarefaction curves estimating species richness for the ELY monitoring stations in deep inner archipelago (grey line 19 samples, dotted line indicate extrapolated samples, 21 samples) and extended survey sites in deep inner archipelago.

Kuva 13. Otantamäärän vaikutus lajirunsauteen sisäsaariston syvillä pohjilla. Kuvassa ELY-asemien otantamäärän lisääminen ja sen vaikutus näytteiden lajirunsauteen seuraa harmaata käyrää. Laajennettu otanta seuraa mustaa käyrää.

3.5 Spatial linkage between water quality ELY monitoring stations and zoobenthos indices

Average depth of the water quality stations situated <2.5 km from the zoobenthos ELY monitoring stations was 20.3 ± 3.8 CI. Average depth of these zoobenthos ELY monitoring stations was 18.4 ± 3.7 CI, average depth difference being 2.7 m, max 8.5 m. Grouped according to the average 24-month oxygen concentration at the nearest water quality station (high, <6 mg/l, low >6 mg/l), the group with higher average oxygen conditions also had higher average total abundance of zoobenthos, although the variance was high (Figure 14, Table 8). Other benthos indices had higher values near high oxygen stations, but did not show significant difference depending on the oxygen status of the near water quality station.

Mean depth of the water quality stations situated nearest to the extended survey sites was 16.6 ± 3.0 CI. Average depth of these survey sites was 14.7 ± 2.8 CI, the mean depth difference being 2.8 m, max 8.5 m. The group of sites with higher average 24-mo oxygen conditions had higher mean total abundance of zoobenthos, species richness and diversity than the groups of sites with lower mean 24-mo oxygen conditions (Figure 14, Table 8). The water quality stations (max 2.5 km) near extended survey sites with signs of oxygen shortage had lower oxygen concentration than corresponding stations near sites with normal sediment quality ($p < 0.001$, z-score -4.20, Mann-Whitney Test). There was no difference in the oxygen concentration of the water quality stations near the zoobenthos stations compared with those near the extended survey sites.

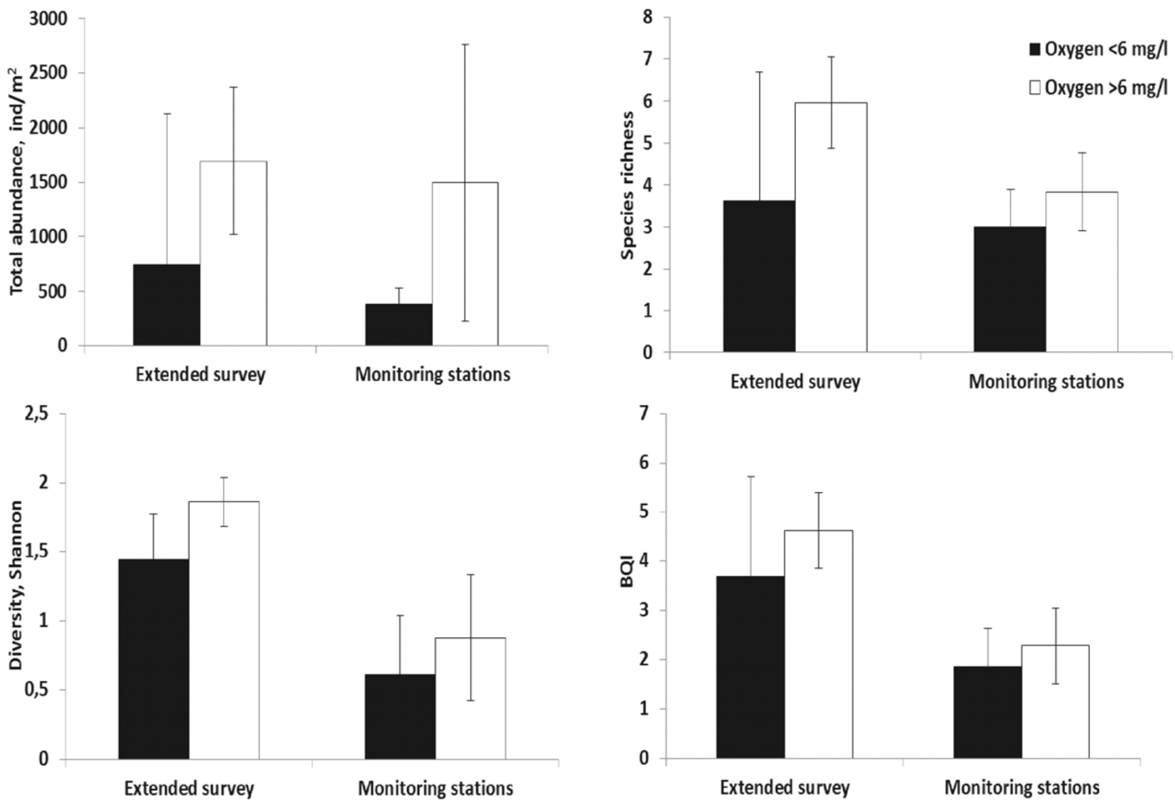

Figure 14. Total abundance, species richness, Shannon diversity and BQI based on the 24-mo average oxygen concentration at the nearest water quality monitoring station in the extended survey and the zoobenthos ELY monitoring stations. Error bars are 95% confidence interval.

Kuva 14. Yksilörunsaus, lajirunsaus, Shannonin monimuotoisuusindeksi ja BQI. Kuvassa verrataan keskimääräisen hapen vaikutusta pohjaeläimiin. Veden happipitoisuus on mitattu vedenlaadun seuranta-asemilla ja edustaa tässä 24 kuukauden keskiarvoa. Hajonta kuvaa 95 prosentin luottamusväliä.

Table 8. Results of Mann-Whitney tests comparing the role of the oxygen concentration at the nearest (<2.5 km) water quality monitoring station. Numbers in brackets are number of sites in each group.

Taulukko 8. Lähimmän vedenlaadun seuranta-aseman happipitoisuuden vaikutus pohjaeläinten yksilörunsauteen ja monimuotoisuuteen. Suluissa esitetään asemien lukumäärä.

Mann-Whitney statistics	U	U	z-score	p-value
	Oxygen			
ELY monitoring stations	**<6 mg/l (9)**	**>6 mg/l (12)**		
Abundance	87	22	-2.31	**0.021**
Richness	72	36	-1.28	0.201
Shannon diversity	68	40	-0.99	0.32
BQI	68	40	-1.00	0.32
Extended survey sites	**<6 mg/l (8)**	**>6 mg/l (27)**		
Abundance	180	36	-2.83	**0.005**
Richness	170	47	-2.42	**0.016**
Shannon diversity	158	58	-1.96	**0.05**
BQI	128	80	-0.99	0.32

3.6 Current status class of the basins and the EQR of the study area

There was no clear spatial pattern of the EQR based on the BBI in the study area, but with a tendency of higher values towards the outer areas. An overlay comparison of the EQR and the sediment quality of the extended survey sites gave that 41 of the 317 sites (13%) with good or high status (class 4–5) were sites with signs of oxygen shortage. Corresponding numbers for the bad to poor (class 1–2) were 39 of 69 sites (57%) and for bad or intermediate (class 1–3) 50 of 126 (40%) (Figure 15).

Based on the extended survey sites, the basins of the study area had an average status class based on the EQR of 3.8 (moderate to good) compared to 2.0 (poor) when based on the ELY monitoring stations (Figure 16, Table 9). The mean status class was higher in shallow waters than in deep waters. Also, some similarities can be seen in the distribution of the lowest class (bad) between the two data sets. The correlation of the average status class (1–5) between the ELY monitoring stations and the extended survey sites was r = 0.47 (N = 14). According to the official status assessment, 17 of the 22 basins were classed as poor or bad and five as moderate status (Figures 16, 17 and 18).

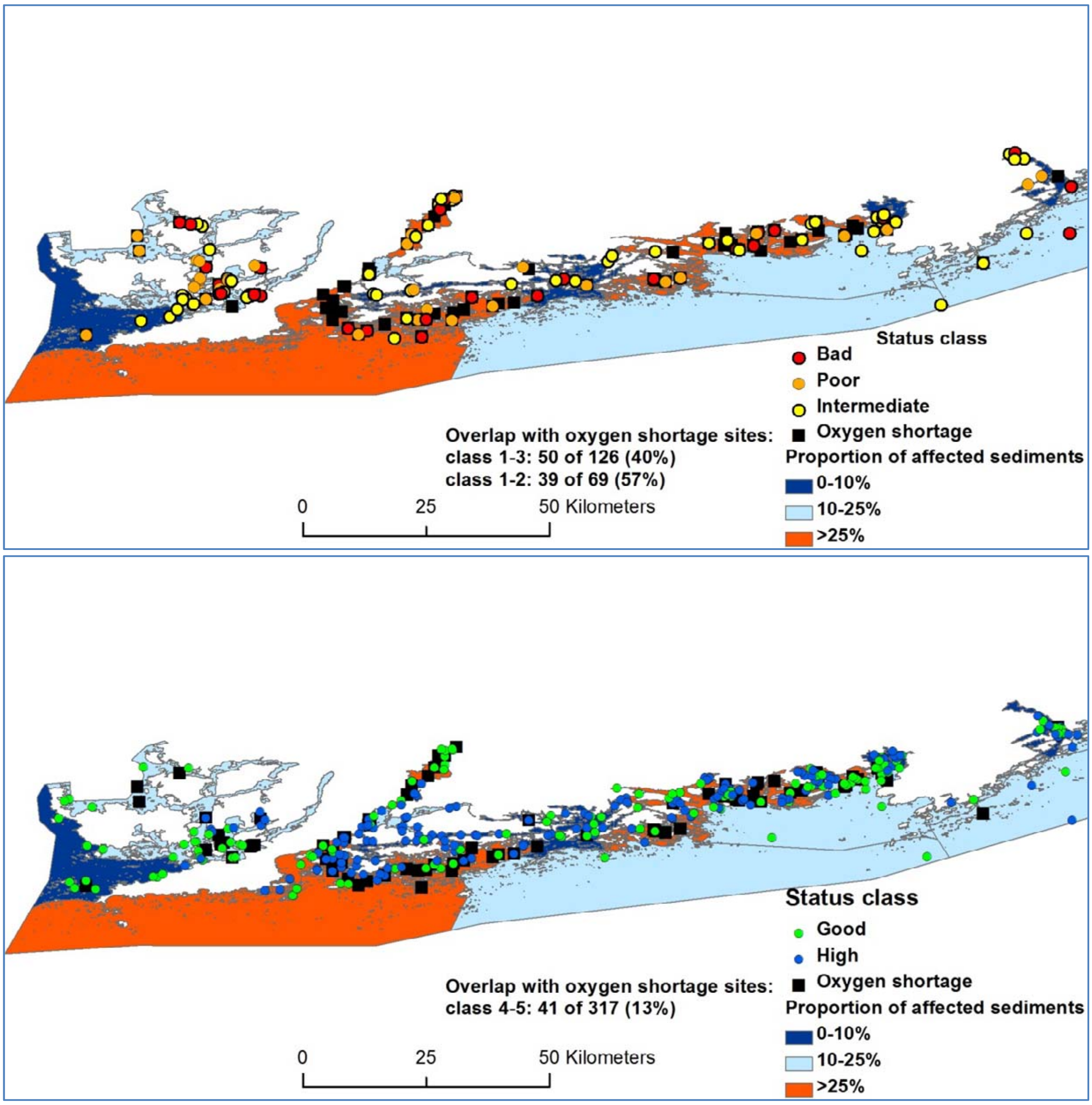

Figure 15. The distribution of EQR (Ecological Quality Ratio, Status class 1–5, poor to high) based on the BBI (Brackish water Benthic Index) and sites with signs of oxygen shortage in the study area. Upper panel: classes 1–3 (bad, poor, intermediate status), lower panel: classes 4–5 (good and high). The figure shows the extended survey sites 2012.

Kuva 15. Ekologisen tilan (EQR) jakautuminen saaristossa sekä hapettomien että vähähappisten asemien jakautuminen otanta-alueella. Ylemmässä kuvassa huonossa, välttävässä tai tyydyttävässä tilassa olevien asemien jakautuminen. Alemmassa kuvassa hyvässä tai erinomaisessa tilassa olevien asemien esiintyvyys. Mustat neliöt edustavat hapettomia tai vähähappisia asemia.

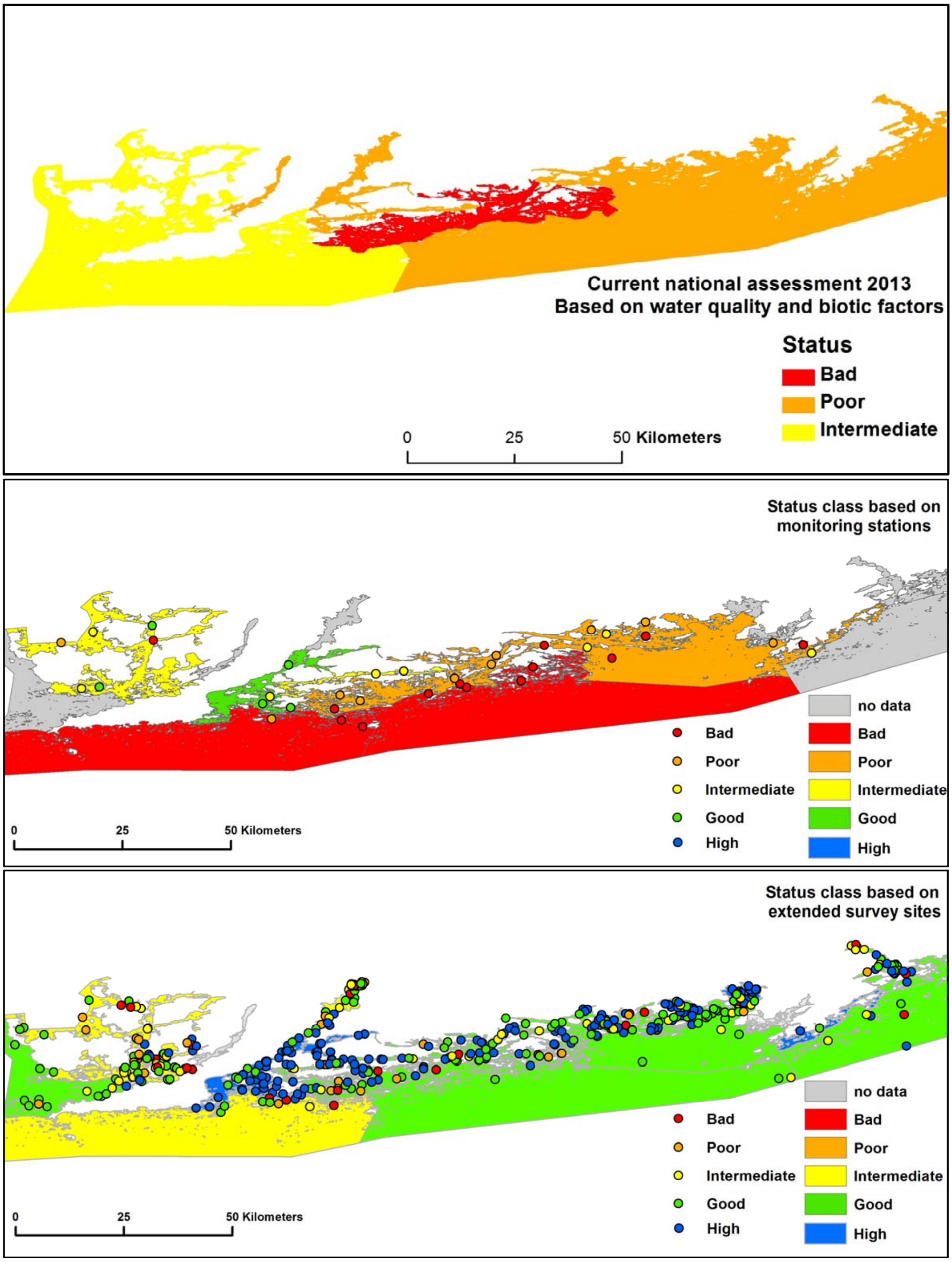

Figure 16. The ecological status of surface waters in Uusimaa based on chemical and biological measures of both benthos and the water column (upper). The EQR (Ecological Quality Ratio, Status class 1–5, bad, poor, intermediate, good and high) for the basins in the study area. Mid panel: based on the BBI (Brackish water Benthic Index) for zoobenthos ELY monitoring stations 2011 (N = 36), and lower panel: based on the BBI for extended survey 2012.

Kuva 16. Merellisten pintavesien ekologinen luokittelu Uudenmaan ELY-keskuksen alueella (yläkuva). EQR tutkimusalueella kahteen erilliseen aineistoon perustuen. Keskimmäisessä kuvassa tila Uudenmaan ELY:n seurantaverkostoon, alimmassa kuvassa laajennettuun otantaan perustuen.

Figure 17. Healthy bottom and bottom with signs of oxygen deficit at sediment surface. Photos: Mats Westerbom.

Kuva 17. Ylemmässä kuvassa terve pohja. Alemmassa kuvassa pohja, jossa sedimentin pinnassa näkyy merkkejä hapenpuutteesta. Kuvat: Mats Westerbom.

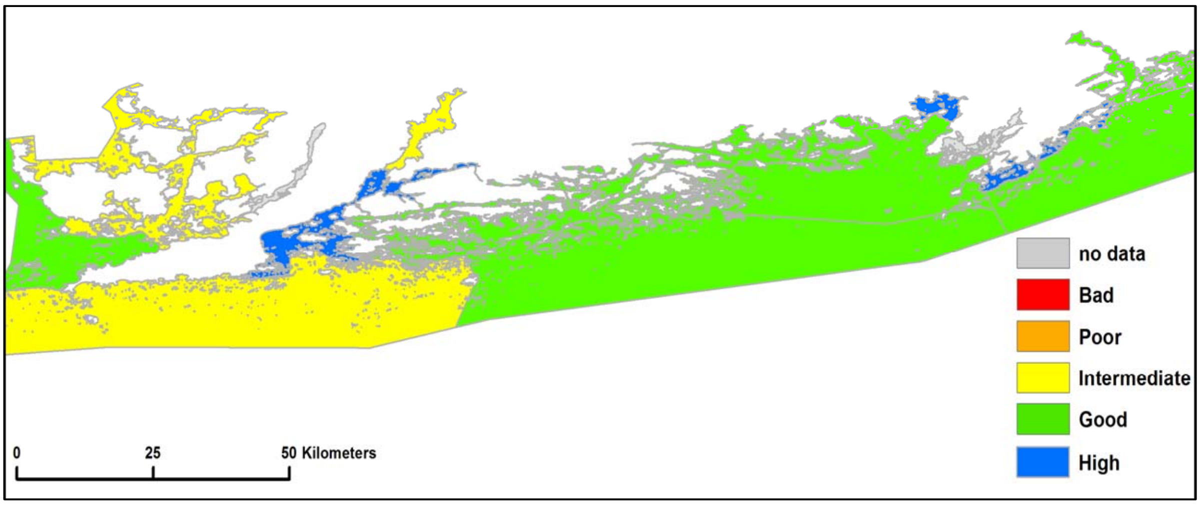

Figure 18. The EQR (Ecological Quality Ratio, Status class 3–5, intermediate, good and excellent) for the basins in the study area based on the entire extended data.

Kuva 18. Ekologisen tilan luokittelu tutkimusalueen vesimuodostumilla perustuen koko tutkimuksen pohjaeläinaineistoon.

3.7 The effect of sample size on the ecological classification of sub-basins

To evaluate the effect of sample size on the ecological class for each sub-basin, a set of sites within sub-basins were randomly drawn from each sub-basin. 1, 3 and 5 sites were sampled three times from each sub-basin. From these random sites, the class for the sub-basin was re-calculated by taking the average of the random samples. Only sub-basins with five or more sample points were included in the analysis. The results are shown in Figure 19. A map showing the classes obtained with the full set of points are shown in Figure 18. As can be seen, and expected, with only one point the EQR class can vary drastically, even from *Bad* to *Good,* or *Poor* to *High*. Using five points the changes were much smaller. Nonetheless, there was still some variation, indicating that at least 5 random points from each sub-basin should be sampled for a representative sub-basin classification.

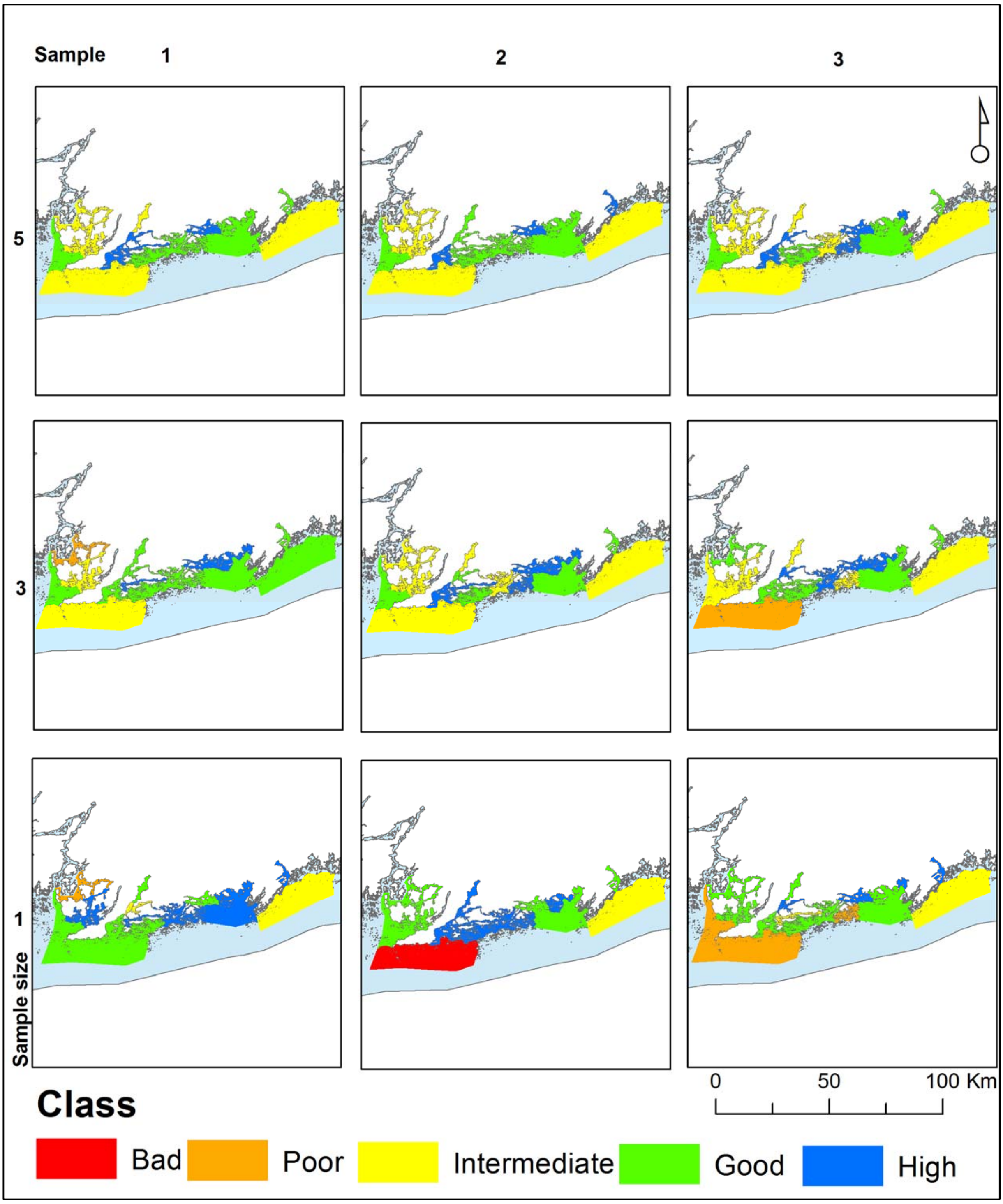

Figure 19. Change in EQR with change in sample size. The maps in the top row show the change in classification using five random samples from each sub-basin, in the mid row using three random samples and at the bottom using one random sample. While the classification is much similar on the top, at the bottom classification varies dramatically because of the randomness of samples.

Kuva 19. Ekologisen tilan luokittelun muutos suhteessa näytemäärään. Kuva havainnollistaa, kuinka näytemäärän lisäys vaikuttaa ekologiseen luokka-arvoon. Ylimmällä rivillä luokka-arvon laskemiseen on käytetty viisi satunnaista näytettä, keskimmäisellä rivillä kolme ja alimmaisella rivillä yksi.

One sub-basin was selected for a more detailed analysis into how the standard deviations of the class values change with increasing sample size. The standard deviation was calculated first between two points and recalculated by adding one point at a time until, in the end; all the points were included in the calculation. The order by which the points were added was randomly rearranged, producing four different curves. The standard deviation was calculated by the following formula: SD = $\sqrt{(1/n\sum(X-Avg(X))^2)}$. From Figure 20, we can see that variation in EQR is logically high with small sample sizes, but variation even out after 6–10 points.

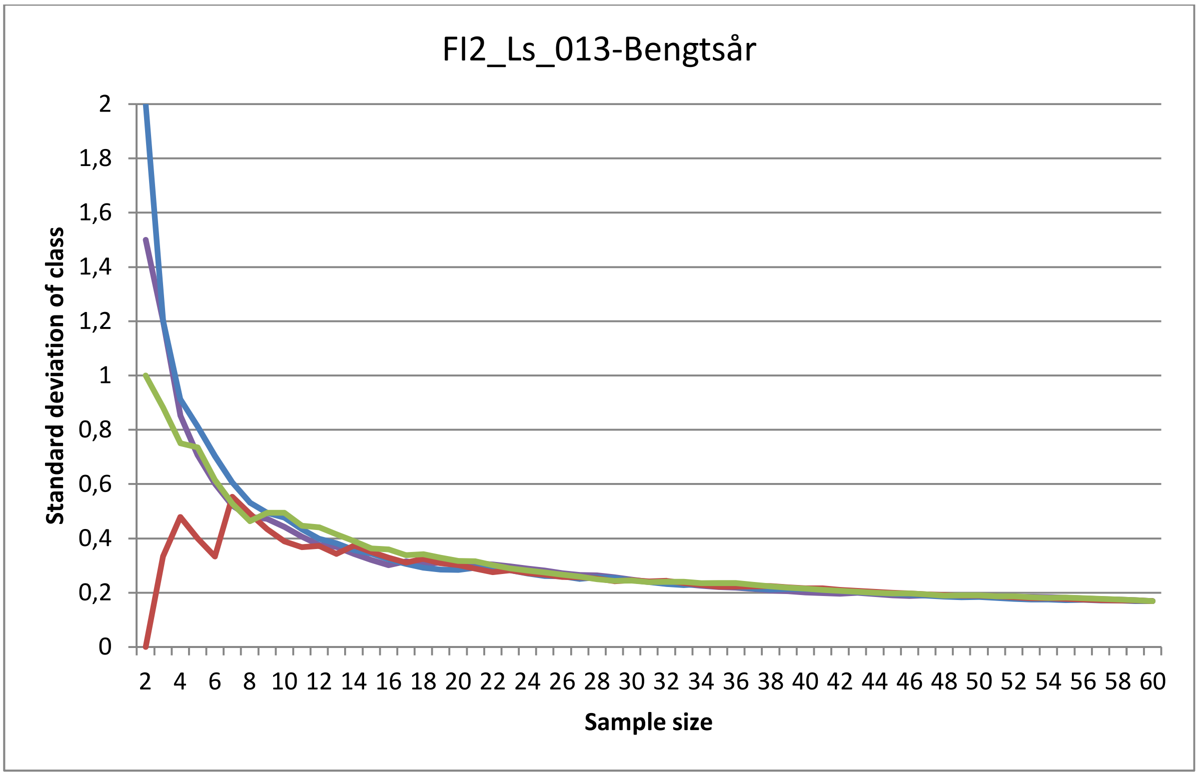

Figure 20. The effect of sample size on the standard deviation of the class value for sub-basin FI2_Ls_013 (Bengtsår). The calculation has been done four times with randomized order of added sample points.

Kuva 20. Näytemäärän vaikutus ekologisen tilan luokan hajontaan Bengtsårin vesimuodostumassa.

Table 9. The ecological status (water quality and biotic factors, 2006–2012) of the sub-basins, the average status class of total extended survey sites, shallow sites, deep sites and ELY monitoring stations in the present study, and the proportion of normal sediments. For further details, see Appendix 1.

Taulukko 9. Vesialueiden ekologinen tila eri syvyyksissä ja eri tutkimuksissa (ELY-seurannan, laajennetun otannan ja vesialueiden luokituksen perusteella) sekä sedimentin tila laajennetussa tutkimuksessa. Liitteessä 1 on esitetty tarkemmin asemakohtaiset tiedot.

Code	Name	Status	Extended Survey	Shallow <10 m	Deep >10 m	ELY monitoring stations	Normal sediment
FI2_Ls_001	Porkkala länsi	Poor					
FI2_Ls_002	Pikkalanlahti	Poor	4.5	4.6	4.4		1.00
FI2_Ls_003	Inkoo Degerö	Poor	4.2	4.2	4.3	1.5	0.74
FI2_Ls_004	Inkoo Fagervik	Poor	4.2	4.6	3.9	2.0	0.72
FI2_Ls_005	Orslandet	Bad	3.7	4.3	2.8	1.0	0.62
FI2_Ls_006	Barösund	Bad	3.9	4.0	3.8	1.8	0.90
FI2_Ls_007	Box	Poor	4.4	4.5	3.0	3.0	1.00
FI2_Ls_008	Sandöfjärden	Bad	4.0	4.7	3.5	2.3	0.60
FI2_Ls_009	Pohjanpitäjänlahti	Poor	3.3	3.4	2.9		0.76
FI2_Ls_010	Dragsvik	Poor	4.8	4.7	5.0	4.0	0.80
FI2_Ls_011	Storfjärden	Moderate	4.6	5.0	4.5	3.5	0.67
FI2_Ls_012	Gennarbyviken	Poor					
FI2_Ls_013	Bengtsår	Moderate	3.1	3.8	2.6	2.7	0.80
FI2_Ls_014	Bromarv	Moderate	2.9		2.9	3.0	0.73
FI2_Lu_010	Porkkala-Jussarö	Poor	2.8	4.0	3.5	1.0	1.00
FI2_Lu_011	Upinniemenselkä	Poor	3.8	3.4	3.9	2.0	0.82
FI2_Lu_020	Hankoniemi	Moderate	3.0	4.5	2.5	1.3	0.63
FI2_Lu_021	Hankoniemi W	Moderate	3.7	4.0	3.6		0.93
FI2_Ss_029	Suvisaaristo-Lauttasaari	Poor	3.7	5.0	3.0		1.00
FI2_Ss_030	Espoonlahti	Poor	3.9	3.9			0.96
FI2_Ss_031	Porkkala itä	Poor	4.5	4.5		2.0	1.00
FI2_Su_050	Helsinki-Porkkala	Poor	3.5		3.5		0.83
Total			3.8	4.3	3.5	2.2	0.8
CI			0.3	0.2	0.4	0.5	0.1

3.8 Distribution of high abundance of *Hydrobia* ssp., *Macoma balthica* and *Marenzelleria* ssp.

Hydrobia spp., *Macoma balthica* and *Marenzelleria* spp. were the three most common species in the extended survey, and constituted 56% of the total animal abundance. Figure 21 (upper panel) shows the distribution of the sites that constitute 90% of each of the species abundance. *M. balthica* and *Hydrobia* ssp. showed high abundances in the entire study area with a few small aggregations of sites. *Marenzelleria* ssp. had a more aggregated distribution with high abundances in the western and eastern part, e.g. in the Bromarv area and the Kantvik harbour area. High abundances of *M. balthica* (35 sites) and *Hydrobia* ssp. overlapped more (8 of 25 *Hydrobia* ssp. sites) than *Marenzelleria* ssp (4 of 28 sites). *Hydrobia* ssp. and *Marenzelleria* ssp. did not overlap at all. *Marenzelleria* ssp. also seemed less sensitive to affected sediments as six high abundance sites had affected sediment, whereas one and two sites for *M. balthica* and *Hydrobia* ssp., respectively. 45 sites had a Shannon diversity index >2.5, which can be compared with the overall average of 1.7 (Figure 21, lower panel). 58 sites had total abundance exceeding 2,500 ind/m^2 (overall average 2,721 ind/m^2, median 1,950). Only ten sites had both high abundance and diversity, when grouped according to these criteria. Naturally, did the distribution of high abundance to a large extent follow the distribution of dominating species, whereas the distribution of high-diversity sites did not (Figure 21, upper panel). Nevertheless, the average total abundance of the high-diversity sites was high (3,693 ind/m^2), whereas the average diversity of high-abundance sites was just above the overall average (1.9)

The abundance of adult *M. balthica* (>2 mm) was highest at sites west and east of the Hanko peninsula and outside Kantvik in the eastern part of the study area, and was often absent in the innermost areas (Figure 22, upper panel). The abundance of juvenile or small adults *M. balthica* (<2 mm) was more evenly distributed and overall higher compared to the adult individuals, and was more often present also in the inner part of the study area (Figure 22, lower panel).

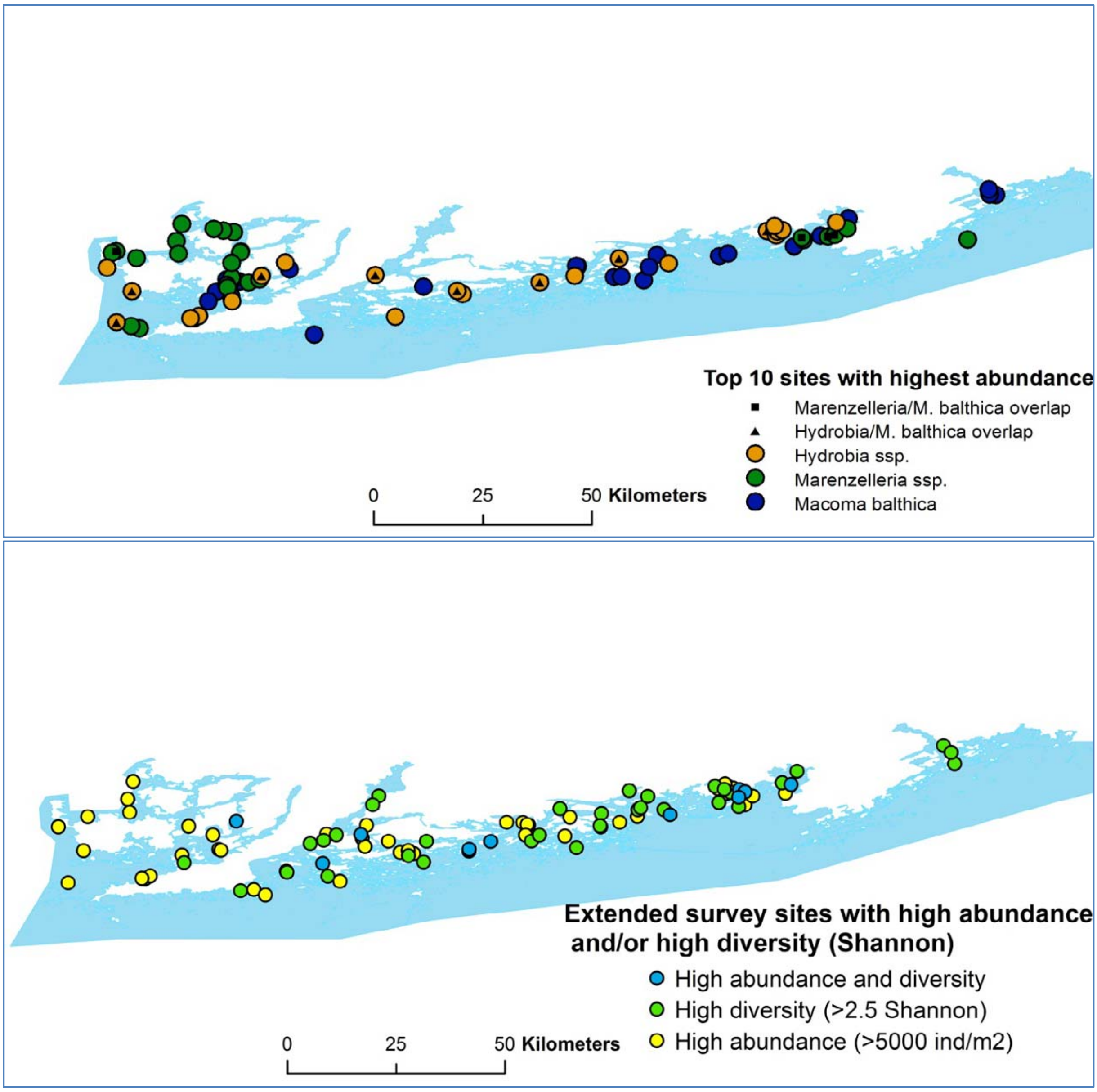

Figure 21. Distribution of the three most common zoobenthic species in the extended survey sites (top 10% of species abundance). The sites with highest abundances are shown (upper panel) and distribution of sites with high abundance and/or high Shannon diversity (lower panel).

Kuva 21. Kolmen runsaimman lajin esiintyminen laajennetussa otannassa. Ylemmässä kuvassa asemat, joilla nämä lajit olivat runsaimmillaan. Alemmassa kuvassa asemat, joissa monimuotoisuus ja/tai yksilötiheys oli korkeinta.

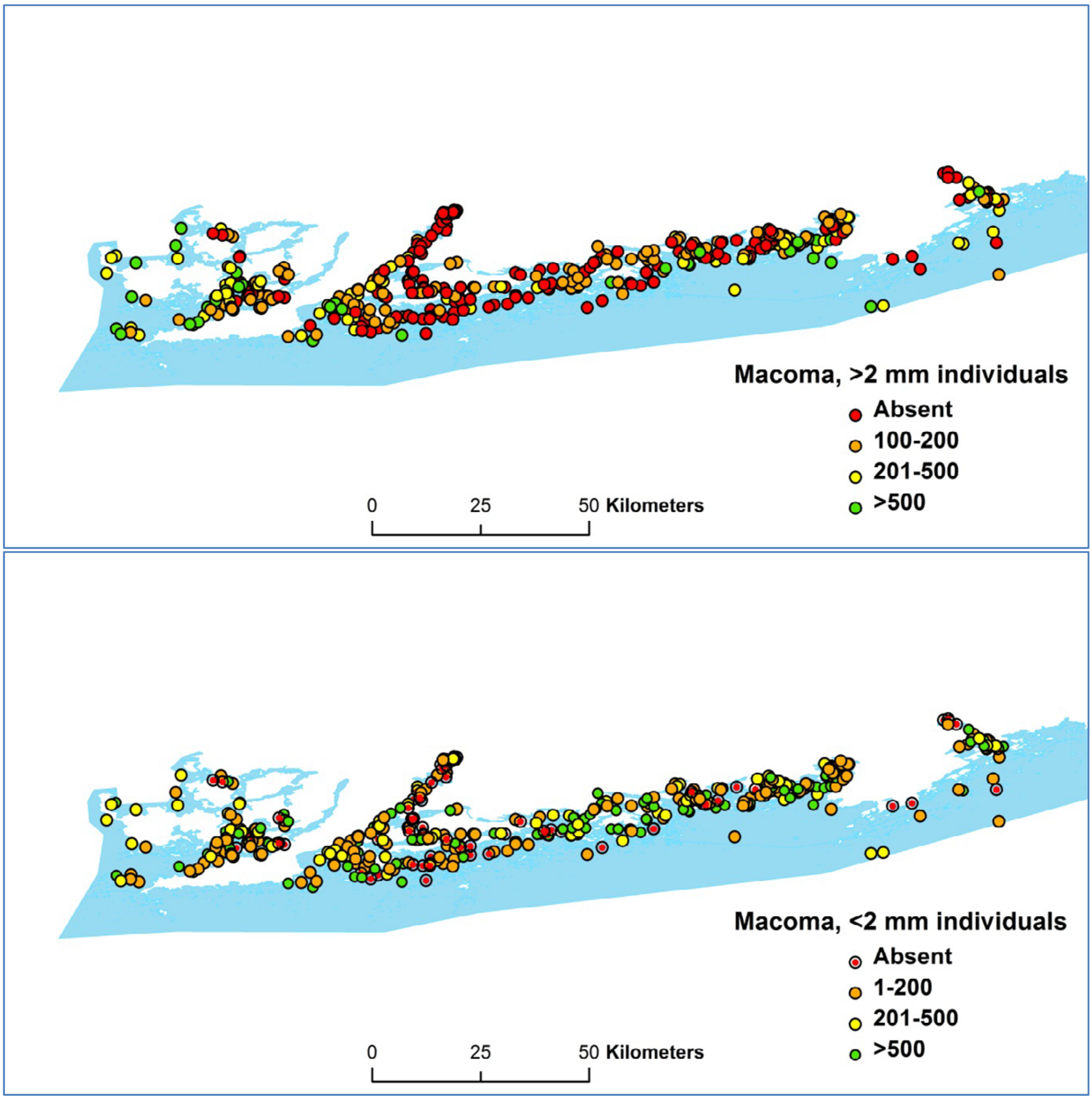

Figure 22. Distribution and abundance of adult (upper panel) and juvenile or small adults (lower panel) *Macoma balthica* in the extended survey sites (based on number of individuals in sieve 2 mm and in sieves 1 mm and 0.5 mm, respectively.

Kuva 22. Aikuisen (ylempi kuva) ja juveniilin (alempi kuva) liejusimpukan tiheys laajennetussa otannassa. Jako perustuu siiviläkokoon. Simpukat, jotka jäivät 2 mm:n (kokoluokiltaan 4 mm ja suuremmat yksilöt) siivilään on esitetty ylemmässä kuvassa, alemmassa esitetään tätä pienempien liejusimpukoiden esiintyvyyttä.

4 Discussion

Overall, there was large difference in the analysed metrics between the two data sets, i.e. the extended survey sites and the zoobenthos ELY monitoring stations. It is not fully clear what causes the difference. Part of the difference in abundance and other metrics was likely due to the fact that the studies were from two different years and slightly different seasons. However, the extended survey sites had higher species/taxa number and overall species count and half of the encountered species did not occur in the monitoring sites. The larger number of sampling sites in combination with a wider range of habitats sampled have also influenced on species richness. For example, the extended survey sites had more herbivorous Crustacean species, which may be a result of the large number of sites in shallow waters (<10 m), in the photic zone that allow benthic primary production. In shallow coastal waters, the species number is higher in August–September than in May, whereas abundance may decrease towards the end of the summer (Bonsdorff & Blomqvist 1989). Thus by sampling a wider range of habitats (shallow, deep, different sediment types), it is likely that the number of species will increase as the species richness varies in different habitats. This affects the status assessment positively.

4.1 What is the role of sediment quality on zoobenthos?

Shallow inner archipelago areas with normal sediment quality had higher species richness, diversity and BQI than deep areas with normal sediments. Shallow coastal waters usually are more diverse than deep waters (e.g. Bonsdorff 2006). However, the abundance of zoobenthos was similar in shallow and deep waters comparing only healthy sediments in the inner archipelago, but higher when potentially deteriorated sediments also were added to the comparison. As more than 40% of the deep water sites in the inner archipelago had signs of oxygen shortage, the status of the sediment is an important factor to account for when comparing zoobenthos abundance across depths. Sediment quality and sediment grain size measures should also be included in any monitoring programme. There was no difference between depths regarding total abundances and BQI in sediments with signs of oxygen shortage (Figure 23) while species richness and diversity was higher in shallow sediments. Unlike normal sediments, no differences between deep inner and outer archipelago was detected in sediments with signs of oxygen shortage. The lack of difference in affected sediments suggests that deteriorated sediment quality affects the differences in zoobenthos due to depth as well as archipelago zones and make these naturally different habitats more uniform.

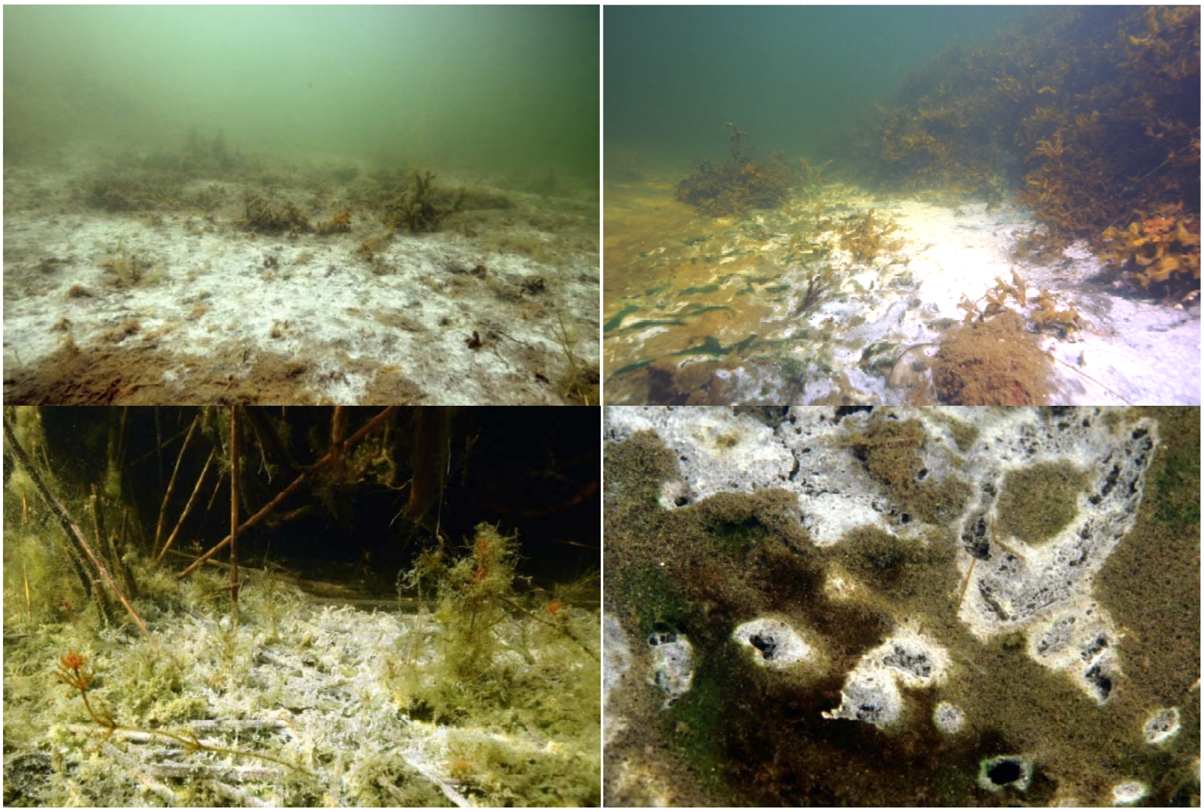

Figure 23. Severely affected sediments with oxygen shortage at shallow depths in the outer archipelago. Photos: Mats Westerbom.

Kuva 23. Pintasedimentin happivajetta ulkosaariston matalilla pohjilla. Kuvat: Mats Westerbom.

4.2 What is the role of sediment quality on *Macoma balthica* population structure?

The population structure of *Macoma balthica* was more diverse in normal sediments where also large individuals tended to be more common than in affected sediments, which instead had a more uniform size structure and overall consisted of smaller individuals. A diverse population structure of long-lived bivalves, including both small and large individuals, indicates environmental conditions that enable recruitment as well as longevity of the bivalve population (Bonsdorff *et al.* 1997). Events of low oxygen concentration and other sediment disturbances reduces recruitment success and increases mortality of large *M. balthica*, which are important for the functioning of the ecosystem (Bonsdorff *et al.* 1995, Norkko *et al.* 2013).

4.3 What is the role of sediment type on zoobenthos?

Sediment type had a clear effect on the zoobenthos metrics with higher values in the coarser sediment types. Grain size is known to affect many of the analysed metrics (e.g. Gray 2002), and is also correlated with other environmental variables that may influence the zoobenthos.

4.4 How representative are the zoobenthos monitoring sites?

The results from the extended survey sites suggest that the monitoring area had higher values of most of the zoobenthos metrics compared to other areas in the shallow as well as deep inner archipelago. This may result in an overestimation of the status if extrapolated results from ELY monitoring stations to other inner archipelago areas. On the other hand, the monitoring area in the outer archipelago had lower species richness than other outer archipelago areas in the study area. The number of sites was low in the outer archipelago, which makes the comparison less robust than in the inner archipelago. In addition, the proportion of sediments with signs of oxygen shortage was somewhat higher in the monitoring area compared with the rest of the study, which contradicts with the usually higher zoobenthos metrics. In the studied coastal area, the current network of zoobenthos ELY monitoring stations are mostly deep, soft sediment habitats situated in the inner areas and they are comparatively fewer in the outer archipelago and none of them are here found at shallow depths. As such, the network is not representative for the coastal area as a whole considering the depth gradient, archipelago type and sediment type. The study shows that the zoobenthos indices are affected by both the vertical and horizontal gradient. The type and quality of the sediment also affected the zoobenthos with usually more positive indices in the other sediment type group than pure soft sediment. The quality of the sediment, e.g. in terms of signs of sediment shortage, was shown to clearly affect the zoobenthos indices.

4.5 Is there a spatial linkage with water quality stations?

In comparison to the zoobenthos station, the extended survey sites near water quality stations with mean oxygen exceeding 6 mg/l (high) during the previous two year had better zoobenthos metrics. One explanation to this difference could be that the number of extended surveys sites near water quality stations with good oxygen conditions was more than double that of the zoobenthos ELY monitoring stations. Thus, although the zoobenthos ELY monitoring stations had signs of better metrics when situated near good oxygen stations, the relationship was much clearer for the extended survey sites. There seemed also to be a link between the oxygen conditions of the water quality stations and the sediment quality of the nearest extended survey sites.

4.6 The ecological status class of the basins

There seemed to be some level of agreement between the two data sets although the extended survey sites on average showed a much higher status class for the basins. Higher species richness and abundance of sensitive species likely result in a better status due to the effect on BQI and BBI, which incorporates the diversity metric in the formula (Perus *et al.* 2007). For example, Ostracods were common in the sites inside as well as outside the monitoring area, while it was much less common in the ELY monitoring stations. Ostracods are ranked as a sensitive group of species (ES50=15 in the BQI index), and high abundance of sensitive species contributes to a high BQI value, which eventually affects the assessment of ecological status. A single sample gives higher BBI than replicated sampling (Aarnio *et al.* 2011), which may contribute to an overestimation of the status. At basin level, the affected sediments did not lower the status class, likely because the normal sediments compensated for the reduction seen at the site-level comparison. As the sediment quality affected most of the zoobenthos metrics, it is logical that the sites with good and high ecological status had only little overlap with the affected sediments.

The study clearly showed the importance of replicating sites within sub-basins and indicated that reliable status classification of sub-basins needs to be based on a sufficient number of sites. Using only a few sites for classification of sub-basins easily falsifies status conditions on a basin level. Any monitoring programme at regional or larger scales needs therefore to be carried out at a sufficient number of replicated sites. Currently, this basic condition is not met in the Finnish monitoring programme.

4.7 Conclusion and recommendation

There was a clear difference between assesment of ecological status using the current monitoring dataset (36 sites) and the extended survey (443 sites). The extended survey's zoobenthos data had higher ecological status. The reasons behind the difference cannot be fully explained within this report, but species richness and the abundance of sensitive species affect the EQR and thus directly the status. A broader network of sites in the extended survey – sampling a wider range of habitats, regarding depth and archipelago zone – may positively influence the status but probably also provide a more credible description of the state of the study area than the more subjectively chosen monitoring sites where the benefits of easily sampled sedimentation areas unfortunately also accentuate the less oxic conditions in these sites. Sediment quality and sediment type as well as depth clearly affected the zoobenthos metrics in the extended survey, suggesting that these factors should be closely followed in the monitoring of zoobenthos as they ultimately affect the status of coastal waters. This pinpoints the need to include a sufficient set of background variables into any monitoring programme. The overall problem of comparability between habitats (and datasets), highlights the importance of sustaining long-term monitoring including different benthic habitats.

The current network of zoobenthos ELY monitoring stations seems reasonable representative for deep soft sediments in the inner archipelago, but seems to underestimate the ecological status in this type of coastal waters as a whole. Additional monitoring stations, or relocation of existing one, is recommended to shallow inner areas as well as to outer areas, as it likely would result in a more representative network of monitoring stations in these coastal waters, better mirroring changes in the environment. The aim of the MSFD is to reach GES for larger areas and its status assesment would thus benefit from a more representative network of monitoring stations. The present study did not include monitoring stations sampled by the Finnish Environment Institute in the offshore areas, or stations sampled in environmental obligations of industry and municipality programmes. A comprehensive analysis of all available zoobenthos data from the area would likely provide a more equal comparison. Nevertheless, the present study provide examples of sites that could be included in the network, e.g. by selecting candidate stations following a stratified random process with depth, salinity, archipelago zone and sediment as selection criteria. It also shows the importance of including shallow stations in a monitoring programme across the archipelago. This report recommends the inclusion of shallow and deep stations in a monitoring programme across the archipelago to secure a comprehensive, in time and space comparable assessment of the changes in the marine environment.

5 Extended Summary

Based on the Marine Strategy Framework Directive (MSFD), the marine waters of all EU Member States should reach a Good Environmental Status (GES) by 2020. Similarly, according to the Water Framework Directive (WFD), all EU member states should protect, enhance and restore all bodies of surface water in an aim to achieve a Good Ecological Status. Furthermore, the goal of the Habitats Directive is to achieve a Favorable Conservation Status for the habitats in its Annex I and the species in Annexes II, IV and V. In order to implement these Directives simultaneously, all Member States must have knowledge of the distribution, abundance and condition of marine species and habitats. We also need to understand the pressures these species and habitats face. Knowledge of this pressure-state (structure and function) relationship is particularly important when Member States take action (in the MSFD this step is called Programme of Measures) to guarantee the long-term survival of species and habitats. Moreover, the changes in species, habitat and pressure levels must also be known, i.e. monitoring programmes must be in place. Biological, hydrological and physicochemical quality elements are used to monitor the status of the marine and coastal waters. Benthic monitoring is carried out as a part of both the wider scale MSFD and coastal WFD monitoring programmes that have many synergies and overlaps in their approaches. Here, we focus on the WFD since it has been in force for a longer time than the MSFD.

Benthic macrofauna are very useful for defining ecosystem health, due to their relative longevity, range of biological traits, and well-established responses to different environmental stressors. Benthic invertebrates are often used as indicators to detect and monitor environmental change in both structure and function. Zoobenthos is one of the main biological element for which a monitoring programme has been made. This study aims at analysing a network of soft sediment zoobenthos stations monitored by the Uusimaa ELY-centre (henceforth ELY monitoring stations) in the coastal waters of western Uusimaa, S Finland (W Gulf of Finland). The stations were monitored according to the programme for the first time in 2011. In 2012, an extended survey with 443 random sites was carried out in the same area. In this report, these two data sets of zoobenthos as well as nearby water quality stations are analysed and compared to a) assess the status of zoobenthos in the area, b) assess the representativeness of selected “official” monitoring sites and c) to explore if zoobenthos and results from water quality measurements give comparable results regarding the ecological state of the area. The overall aim of the study is to evaluate the status of the sea, using zoobenthos as an indicator and a reasonably high network of sites, in order to gain an improved estimate of the spatial resolution of sampling effort needed to adequately assess the status of the sea.

In the extended survey, there was a clear effect of sediment quality (normal or signs of oxygen shortage) on zoobenthos, generally, and *Macoma balthica* population structure, specifically. The effect of sediment quality on zoobenthos was more pronounced in deep (>10 m) than in shallow (<10 m) waters. Around 60% of the deep soft sediments sites in the inner archipelago had normal sediment quality and over 90% in shallow waters (normal defined as no clear marks of oxygen shortage in sediment colour or smell). It is, however, worth mentioning that the sampler, Petite Ponar, doesn’t penetrate very deep into the bottom and only enclose conditions in the upper sediment layers. Normal sediments mostly had higher zoobenthos metrics than affected sediments. The effect of depth was more pronounced in normal sediments, as species richness, diversity and BQI (Benthic Quality Index) were higher in shallow waters, whereas depth had no effect on total abundance neither in healthy nor in affected sediments. Neither seemed BQI to change across depths in affected sediments. Normal sediments tended to have larger individuals of *Macoma balthica* and a more diverse size structure including all three size classes, which further indicates that there were differences in the environmental conditions due to sediment quality. Most of the zoobenthos indices were higher in normal sediments in the deep outer archipelago than in the deep inner archipelago, suggesting a better benthic status in the outer areas. Zoobenthos metrics were usually more similar in affected sediments, which indicate that decreased sediment quality makes the naturally occurring spatial and vertical gradients less marked and the benthic community less heterogeneous in a landscape perspective. In addition, the zoobenthos indices were higher in the other sediment type than in soft sediment and more pronounced in shallow waters.

The zoobenthos ELY monitoring stations seemed to differ from the rest of the study area. The ELY monitoring stations (total 36 in the study area) were mostly situated in deep waters of the inner archipelago (17) and none was situated in the shallow outer archipelago. The extended survey sites (total sites 443, soft sediment sites 393) had a broader distribution with most sites in shallow (<10 m) waters (194). With regards to several zoobenthos indices the zoobenthos monitoring area (ELY monitoring stations and the extended survey sites within 2.5 km from a monitoring station) differed from the rest of the study area (extended survey sites >2.5 km from a monitoring station). Species richness and diversity were higher at extended survey sites within the monitoring area (2.5 km radius from an "official" station) compared with the rest of the study area, while BQI only differed in deep waters.

The spatial linkage between water quality monitoring stations and zoobenthos indices was stronger at the extended survey sites. Grouped according to the average 24-month oxygen concentration at the nearest water quality station (high, >6 mg/l, low <6 mg/l), total abundance was clearly higher at the zoobenthos ELY monitoring stations near high-oxygen water quality monitoring stations. The extended survey sites near high-oxygen stations had higher mean total abundance, species richness and diversity than the sites near low-oxygen stations. In addition, the water quality stations near extended survey sites with signs of oxygen shortage had clearly lower oxygen concentration than stations near sites with normal sediment quality.

The status classification differed based on the extended survey sites and zoobenthos ELY monitoring stations, respectively, which reflects the differences in the zoobenthos metrics between the two data sets. However, there was a positive correlation between the two data sets, indicating some level of agreement. In the heterogeneous archipelago, no clear spatial pattern of the EQR (Ecological Quality Rate) based on the BBI (Brackish Water Benthic Index) was found with a small tendency for better status towards the outer areas. Only 13% of the extended survey sites with good or high status had affected sediments, while 40% of the bad to intermediate status had affected sediments.

There was a difference between the two zoobenthos data sets, which resulted in different assessments, the extended survey resulting in overall higher ecological status of the Uusimaa coastal waters. Differences in methodology, different years and time of year sampled likely explain part of the differences, but not all. A majority of the present ELY zoobenthos monitoring stations are situated in the deep waters of the inner and middle archipelago and do not necessarily represent the ecological status of the entire archipelago. It is also possible that the on average shallower sites of the extended survey resulted in high status that is likewise not representing the quality of the entire area, as the water circulation may mask ongoing changes in the conditions, e.g. in oxygen. Differences in depths between the two data sets, may therefore explain most of the disparity seen. Such an explanation, however urge for a much more heterogeneous set of monitoring stations, including e.g. a broader range of various depth strata. A monitoring programme that centres upon only deep stations may only represent the deeper areas and not the area as a whole. In such a case, one may ask if deep water stations are able to flag changes towards even poorer conditions. Likewise, are such stations, e.g. due to internal loadings, able to detect positive changes in the status? Thus, in order to monitor the status of zoobenthos in a representative way, the variation within predominant habitats of an area (deep and shallow inner and outer archipelagos) should be covered by stations in the program. At present, the persistence of such a network is not guaranteed, neither is the network of stations sampled for different purposes designed in a statistically optimal way. Currently, the monitoring stations have been selected based on depth and bottom quality parameters, also, taking into consideration the network of environmental obligations of industry and municipality. In this paper, we want to assess how well these stations represent the area as a whole. The extended survey sites were designed based on stratified random sampling accounting for the entire study area. As a result, the sites reflect better the heterogeneity and seafloor patchiness of the coastal area. As a whole, the basins and larger areas may be in an intermediate or poor state, but throughout the area, individual sites may still have high status, providing healthy environments in an otherwise deteriorated environment. These "high status" sites can also be used as local reference points that make it possible to assess the zoobenthos status and set levels towards which the overall zoobenthos status should strive.

6 Yhteenveto

Meristrategiapuitedirektiivin (MSD) mukaan kaikkien EU-jäsenvaltioiden tulisi ryhtyä toimiin meriympäristön hyvän tilan saavuttamiseksi vuoteen 2020 mennessä. Vastaavasti, vesipolitiikan puitedirektiivin (VPD) tavoitteena on suojella, parantaa ja ennallistaa vesiä niin, ettei vesien tila heikkene ja että niiden tila on vähintään hyvällä tasolla koko EU:n alueella. Direktiivin täytäntöönpanemiseksi tulee jäsenmaiden selvittää pohja-, pinta- ja rannikkovesien ekologista tilaa. Ekologista tilaa määritetään biologisten muuttujien sekä niitä tukevien hydrologisten ja kemiallisten laatukriteereiden perusteella. Näiden avulla pintavedet jaetaan viiteen ekologiseen luokkaan, heikosta erinomaiseen. Lisäksi Luontodirektiivin tavoitteena on saavuttaa Direktiivin liitteen I luontotyyppien ja liitteiden II, IV ja V lajien suotuisa suojelutaso. Jotta jäsenmaat pystyisivät toimeenpanemaan nämä osin päällekkäiset tavoitteet, niiden olisi tunnettava lajien ja luontotyyppien esiintymis- ja levinneisyysalueet, määrät ja pinta-alat sekä luontotyyppien tila. Tämän lisäksi tulee tuntea näihin vaikuttavat paineet. Jäsenmaiden tulee ryhtyä toimenpiteisiin, jotka takaavat näiden lajien ja luontotyyppien pitkän aikavälin säilymisen. Lisäksi on tiedettävä lajien, luontotyyppien sekä paineiden muutokset. Näitä varten on siten kehitettävä ympäristöseurantaohjelmat, joilla kaikkien näiden direktiivien tilan muutosta voidaan tarkkailla. Seurannan tavoitteena on tuottaa tietoa ympäristön tilasta, sen muutoksista ja muutosten syistä. Pohjaeläimiä käytetään ympäristöseurannassa bioindikaattoreina. Ne ilmentävät lyhyt- ja pitkäaikaisia muutoksia ympäristössä, mm. muutoksia pohjaeläinlajiston koostumuksessa. Tämän työn tarkoitus oli a) selvittää rannikkovesien pohjien tilaa läntisellä Uudellamaalla käyttäen pohjaeläimiä tilan ilmentäjinä, b) tarkastella Uudenmaan elinkeino-, liikenne- ja ympäristökeskuksen pohjaeläinseuranta-asemien (jäljempänä ELY-asemat) ja koko verkoston edustavuutta ja c) verrata hydrologisia muuttujia pohjaeläinindikaattoreihin perustuvaan luokitukseen ja tarkastella näiden yhdenmukaisuutta. Yleisenä periaatteena perusseurannassa on, että seurantaan valitut asemat ovat edustava otos seurattavasta muuttujasta ja että ajalliset muutokset seuranta-asemilla kuvaavat yleistä ympäristön muutosta. Tässä työssä tarkastelemme vain valtakunnallisen ympäristöhallinnon perusseurannan edustavuutta tutkitulta alueelta. Tarkastelussa ei täten huomioitu avomerellä suoritettavaa seurantaa (Combine, Helcom), kuntien ja kaupunkien seurantaa, MaaMet havaintoja (Maa- ja metsätalouden kuormituksen ja sen vaikutusten arviointi) eikä toiminnanharjoittajien ympäristölupiin perustuvaa ns. velvoitetarkkailua. Tarkastelun pääasiallinen tavoite ei ollut palvella perustutkimusta eikä käytetty metodiikka (rinnakkaisnäytteiden puute, asemien autokorrelaatiota ei huomioitu) täytä kaikkia perustutkimuksen näytteenotolle asettamia oletuksia. Tavoite ei myöskään ollut kriittisesti tarkastella nykyistä seurantaa, vaan asettaa se laajempaan kokonaisuuteen ja tarkastella kuinka edustavasti nykyiset seuranta-asemat kuvaavat saariston tilaa laajemmin. Pohjaeläinseuranta Uudellamaalla on vastikään uusittu. Seurantaa on tutkimusalueella suoritettu 36 ELY-asemalla vuosina 2011 ja 2014. Tässä työssä tarkasteltiin vuoden 2011 näytteenoton tuloksia ja niitä vertailtiin Metsähallituksen luontopalvelujen vuonna 2012 suorittamaan laajempaan näytteenottoon 443 asemalta (jäljempänä laajennettu otanta).

Laajennetun otannan tulokset osoittivat odotetusti, että pohjan happitilanne (jaettu kahteen ryhmään: hapellinen ja vähähappinen/hapeton) vaikutti merkittävästi pohjaeläimiin, eritoten liejusimpukan (*Macoma balthica*) populaatiorakenteeseen. Sedimentin laadun merkitys korostui syvemmillä (yli 10 m) pohjilla. Sisäsaariston syvillä pohjilla 60 % näytteenottopisteistä luokiteltiin hapellisiksi, ja jopa 90 % sisäsaariston matalista pohjista (alle 10 m) oli hapellisia. Laajennetussa näytteenotossa käytettiin pääosin Petite Ponaria, joka ei poraudu syvälle pohjan eri kerroksiin, ja siten näyte kuvastaa happitilannetta vain pohjan ylemmissä kerroksissa (5–10 cm). Happipitoisilla pohjilla pohjanäytteissä oli runsaammin pohjaeläinyksilöitä ja ne olivat lajirikkaampia verrattuna vähähappisempiin pohjiin. Syvyys vaikutti eliöstön koostumukseen (lajirunsauteen ja Baltic Quality indeksiin – BQI) hapellisissa pohjanäytteissä rannikon matalilla alueilla. Sen sijaan syvyydellä ei ollut vaikutusta yksilörunsauteen eikä myöskään BQIhin. Liejusimpukan populaatiorakenne oli monimuotoisempi ja myös isoja simpukoita esiintyi hapellisessa sedimentissä. Simpukoiden kokojaukaumaa käytetään yleisesti ympäristön tilan ilmentäjänä. Useimmat tutkittavat pohjaeläinparametrit olivat korkeampia normaalissa sedimentissä ulkosaariston syvemmissä näytteissä kuin sisäsaariston vastaavissa. Tulos viittaa parempiin happiolosuhteisiin ulkosaaristossa kuin sisäsaaristossa. Pohjaläinten rakenne oli kauttaaltaan homogeenisempi (köyhempi) vähähappisissa näytteissä. Luontaiset ympäristömuuttujat vaikuttavat vähemmän pohjaeläinten rakenteeseen heikoissa happiolosuhteissa. Ympäristön parempaa tilaa kuvaavat pohjaeläinlajit olivat runsaampia muissa sedimenttiluokissa kuin liejussa, erityisesti matalassa vedessä.

ELY-asemien pohjaeläinnäytteet poikkesivat laajennetun otannan näytteistä. ELY-asemat olivat keskivertoisesti syvempiä, sijoittuivat enemmän sisäsaariston syville pohjille ja asemia puuttui ulkosaariston matalilta pohjilta kokonaan. Laajennetun otannan asemat esiintyivät suhteellisesti enemmän matalassa vedessä, ja ne esiintyivät tasaisemmin saariston eri vyöhykkeissä. Kun ELY-asemien ympärille asetettiin 2,5 kilometrin puskurivyöhyke ja vyöhykkeen sisälle jääviä pisteitä verrattiin laajennetun tutkimuksen vyöhykkeen ulkopuolelle jääviin pisteisiin, havaittiin, että alueet vyöhykkeen sisällä eivät edustaneet pohjaeläimistöltään koko saaristoa. Lajimäärä ja lajirunsaus olivat suurempia puskurivyöhykkeen sisäpuolella. BQI matalilla pohjilla oli vyöhykkeen sisäpuolella sama kuin ulkopuolella, mutta syvillä pohjilla vyöhykkeissä ilmeni eroja BQIssä.

Vapaan vesimassan happipitoisuudet mitataan ympäristöhallinnossa vedenlaadun seuranta-asemilta. Happipitoisuudet olivat yhdenmukaisempia pohjaeläinindeksien kanssa laajennetussa seurannassa kuin ELY-seurannassa. Kun vedenlaadun seuranta-asemat jaetaan kahteen ryhmään pohjautuen kahden vuoden keskiarvoiseen happipitoisuuteen (yli tai alle 6 mg happea/litra), pohjaeläimet sekä ELY-seurannassa että laajennetussa otannassa osoittivat suurempaa tiheyttä niissä asemissa, joiden lähettyvillä vapaan veden happipitoisuus ylitti 6 mg happea litrassa merivettä. Kuitenkin vain laajennettussa otannassa näillä asemilla esiintyi pohjaeläinten korkeampaa monimuotoisuutta ja lajirunsautta. Vedenlaadun seuranta-asemien keskivertoinen happipitoisuus oli myös yhdenmukainen havaittuun sedimenttilaatuun laajennetussa otannassa. Näytepisteillä, joilla ilmeni hapettomuutta tai happivajetta sedimentissä, esiintyi vastaavasti vedenlaadun seuranta-asemilla matalampia happipitoisuuksia vesimassassa.

Kun merenpohjan ekologista tilaa luokitellaan aineistojen perusteella, tulokset poikkeavat toisistaan. Laajennettu otanta antaa hieman paremman tuloksen kuin ELY-seuranta. Laajennetussa otannassa saaristoalueiden tila oli pääosin tyydyttävässä tai jopa hyvässä tilassa. ELY-seurannan tulokset luokittelevat samat alueet huonoiksi tai jopa välttäviksi. Aineistot korreloivat kuitenkin osittain keskenään. EQR (Ecological Quality Index), perustuen BBIhin (Brackish Water Benthic Index), ei tuottanut selkeitä tuloksia, joskin saariston ulkoreuna sai hieman korkeamman luokitusarvon kuin sisäsaaristo.

Tässä tarkastelussa käytetty aineisto kerättiin hieman eri menetelmin, eri vuosina ja eri vuodenaikana. Osa eroista luokituksessa laajennetun ja seurantaverkoston välillä voi johtua näistä seikoista. Pohjaeläinseurannassa näytteenottopaikoiksi tulisi valita olosuhteiltaan erityyppisiä ympäristöjä, jotta saataisiin mahdollisimman kattava kuva koko tutkittavan alueen pohjaeläimistön tilasta. Nykyseuranta sijoittuu pääosin sisä- ja välisaariston syville alueille, ja on mahdollista, ettei seuranta siten edusta koko saariston ekologista tilaa. On myös mahdollista, että laajennettu otanta, joka perustuu keskivertoisesti matalampiin näyteasemiin kuin ELY-asemat, viittaa siksi parempaan ekologiseen tilaan. Vaikka saaristo yleisesti ottaen voi olla hyvin heikossa kunnossa, on ekologisen muutoksen oltava erityisen suuri, jotta se heijastuisi myös hyvin sekoittuvaan ja alati liikkeessä olevaan matalaan veteen. Siksi syvät alueet sisä- ja välisaaristossa voivat olla matalia alueita herkempiä kuvaamaan muutosta, eritoten muutoksen alkuvaiheessa. Toisaalta, jos asemat ovat jo seurannan aloitusvaiheessa erittäin heikossa tilassa, pystyvätkö asemat enää heijastamaan muutosta yhä huonompaan suuntaan? Vai ovatko ne jo niin huonossa kunnossa, etteivät ne sisäisen kuormituksen takia heijasta muutosta parempaan? Tämän selvityksen johtopäätös on, että pohjaeläinseurannan asemaverkoston tulisi koostua nykyistä monipuolisemmista asemista, joissa on edustettuna monipuolisemmin sekä matalia että syviä kohteita saariston kaikilta alueilta. Kun nykyistä seurantaverkostoa täydennetään alueen kaikilla seurannoilla, saadaan monipuolisempi verkosto, mutta silloinkaan se ei välttämättä edusta saaristoa yleistettävällä tavalla. Laajennettu otanta perustui pääosin ositettuun (stratifioitu) satunnaisotantaan, ja sen voidaan siksi katsoa edustavan koko tutkimusaluetta. Laajennetun otannan tulokset osoittivat, että läpi saariston löytyy sekä hyvin huonossa kunnossa olevia pohjia että myös hyvin monimuotoisia, yksilötiheitä ja laikuttaisia pohjia. Alueet ja vesimuodostumat voivat siis olla yleisesti tarkasteltuna hyvin heikossa tilassa, mutta koko tutkimusalueelta löytyy kuitenkin asemia, jotka ovat vielä säästyneet pahimmilta muutoksilta ja jotka voivat toimia elinvoimaisina saarekkeina muutoin epäedullisessa ympäristössä.

Vesipolitiikan puitedirektiivissa vesistöjen ekologinen luokittelu noudattaa ”vertailuololähestymistapaa”, jossa ihmistoiminnan takia muuttuneiden kohteiden arvoja verrataan luonnontilaisten tai lähes luonnontilaisten vesistöjen vastaaviin arvoihin. Luonnontilaisia pohjia ei Itämeren rannikkoekosysteemissä löydy, mutta rannikolta löytyy alueita, joiden tilaa voidaan tavoitella ja jotka voivat toimia referenssialueina. Näiden kohteiden löytäminen helpottaa tavoitellun hyvän tilan määrittämistä ja vähimmäistavoitteen – eli hyvän tilan – asettamista. Tutkimuksemme osoittaa, etteivät huonoimmassakaan tilassa olevat alueet ole kauttaaltaan heikossa tilassa. Tämä tosiasia pitäisi huomioida paremmin aluesuunnittelussa ja ympäristölupien arvioinneissa ja myönnöissä.

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Sea basins included in the study

Area, depth, water type, number of sites and ELY monitoring stations of the basins. South-western inner archipelago(SWI), SW outer archipelago (SWO), Gulf of Finland inner archipelago (GFI), Gulf of Finland outer archipelago (GFO) Depth is based on the extended survey sites

Code	Name	Area (km)	Depth (m)	Water type	Extended survey sites (N)			ELY monitoring stations (N)		
					Total	<10 m	>10 m	Total	<10 m	>10 m
FI2_Ls_001	Porkkala länsi	16		SWI	0			0	0	0
FI2_Ls_002	Pikkalanlahti	12	76	SWI	17	12	5	0	0	0
FI2_Ls_003	Inkoo Degerö	40	82	SWI	39	23	16	2	1	1
FI2_Ls_004	Inkoo Fagervik	39	87	SWI	41	21	19	3	1	2
FI2_Ls_005	Orslandet	34	80	SWI	13	8	5	1	0	1
FI2_Ls_006	Barösund	48	74	SWI	30	20	10	4	1	3
FI2_Ls_007	Box	18	49	SWI	23	22	1	2	2	0
FI2_Ls_008	Sandöfjärden	60	96	SWI	30	13	17	4	0	4
FI2_Ls_009	Pohjanpitäjänlahti	22	83	SWI	34	24	10	0	0	0
FI2_Ls_010	Dragsvik	17	49	SWI	20	18	2	1	1	0
FI2_Ls_011	Storfjärden	44	165	SWI	30	7	23	2	0	2
FI2_Ls_012	Gennarbyviken	11		SWI	0			0	0	0
FI2_Ls_013	Bengtsår	84	130	SWI	60	25	35	3	2	1
FI2_Ls_014	Bromarv	62	189	SWI	11	0	11	3	1	2
FI2_Lu_010	Porkkala-Jussarö	488	268	SWO	4	1	2	3	0	3
FI2_Lu_011	Upinniemenselkä	223	151	SWO	34	7	27	3	0	3
FI2_Lu_020	Hankoniemi	498	177	SWO	8	2	6	3	0	3
FI2_Lu_021	Hankoniemi W	120	154	SWO	14	5	9	0	0	0
FI2_Ss_029	Suvisaaristo-Lauttasaari	49	88	GFI	3	1	2	0	0	0
FI2_Ss_030	Espoonlahti	19	43	GFI	24	24	0	0	0	0
FI2_Ss_031	Porkkala itä	22	44	GFI	2	2	0	2	1	1
FI2_Su_050	Helsinki-Porkkala	400	296	GFO	6	0	6	0	0	0

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ISSN-L 1235-6549
ISSN (verkkojulkaisu) 1799-537X
ISBN 978-952-295-169-4 (pdf)

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