ISSN 1736-2075

# EESTI MEREAKADEEMIA TOIMETISED NR. 3

## PROCEEDINGS OF ESTONIAN MARITIME ACADEMY № 3

TALLINN 2006

SCOPE OF THE JOURNAL

*Proceedings of Estonian Maritime Academy* is a scientific journal publishing original articles on various aspects of maritime affairs and related fields – fishery, hydrography, hydrometeorology, environmental protection.

The Journal is published twice a year.

*Proceedings of Estonian Maritime Academy* No 3 is a special issue in English devoted to *Harbours and Coastal Sea Environment Protection.*

PEER REVIEW

All papers in this issue have been reviewed by at least one referee.



ISSN 1736-2075

# Contents

# Preface

It is practically impossible to overvalue the importance of the Baltic Sea for both Estonian State as well as the Estonian nation. Historically, the success of the development of Estonian economy and culture has been most of all specified by the level of using its marine country status.

The Baltic Sea has been under a long and severe anthropogenic pressure due to being surrounded by one of the most technically developed regions of the last two centuries. To save the life in the Baltic Sea, the States located within the catchment basin of the Baltic Sea, agreed already in 1974 to establish a convention "Convention on the Protection of the Marine Environment of the Baltic Sea Area." Due to political changes, and developments in international environmental and maritime law, a new convention was signed in 1992 by all the states bordering on the Baltic Sea, and the European Community. After ratification new Convention on the Protection of the Marine Environment of the Baltic Sea Area, also known as HELCOM entered into force on 17 January 2000. Certainly Estonia is one of the Contracting Parties of HELCOM.

Therefore, the sustainable management and protection of the surrounded Baltic Sea and its living resources have been and will be continually one of the priorities of Estonian state environmental policy. Despite the relative smallness of territory, Estonia has a long coastline – about 3 800 km, including the islands, and this fact magnifies substantially the importance of nature conservancy activities in the coastal sea, in particular. Besides, the rapid enlargement of sea transport, including the port construction since the end of 1980ies, concurred with large amount of dredging, damping, sand extraction and other hydroengineering activities, should be highlighted.

It resulted in a large amount of marine investigations, both fundamental and applied ones which have been carried out during the last decade. Several governments, universities and also private institutions have been participating in these investigations. The main task of the current Volume is to make public the results of some studies of impacts of the various hydroengineering activities on the coastal environment, performed recently in Estonia.

As the only marine higher educational institution in Estonia, the Estonian Maritime Academy has directed its potential in the field of applied research mostly to the elaboration of the recommendations and solutions for the protection of the Baltic Sea environment, in particular regarding the port activities. Due to that it is fully justified to publish the Volume with specific above mentioned contents in the Proceedings of the Estonian Maritime Academy.

The editors are very grateful to all the authors and reviewers for their contribution.

# Developmental ties between Järve-Mändjala beach and Nasva harbour

**KAAREL ORVIKU**

Merin AS, Rävala pst. 8, 10143 Tallinn, kaarel@merin.ee

## Introduction

Activation of shore processes is not a local manifestation. Worldwide coasts have been severely damaged and the recession of shoreline has been observed mostly at sandy beaches for they are most vulnerable to environmental changes (Bird 1985, 1990, Orviku 2004 etc.). In the past decades the situation, invalidating the widely recognized theoretical opinions, has been observed at all worldwide coasts. It applies first of all to accumulation shores (sandy and gravel beaches).

How to explain then such a turn in the development of the shores in the world and Estonia? Researchers and practics of several fields have been involved in seeking answers to this issue that has been so vital for mankind. One of the main problems at solving this issue is the following causal tie: coastal zone development depends first of all on the intensity of waves, the latter depending in its turn on changes in cyclonic activity. In the last couple of decades an increase in the frequency of severe cyclones and the resultant storms has been observed all over our planet compared to the multi-year average.

In relation with the evident changes in the Earth climate there has been an increase in the frequency of extreme periods, e.g. in the Baltic Sea that has also been proven by the observations and measurements of meteorologists (Jaagus 1998, 2003 etc.).

The geological development of Järve-Mändjala sandy scarp shore is a classic example, characterizing the changes that have occurred on our shore during recent years. Namely coinciding extreme natural conditions (seasonal high sea level, exceptionally severe storm wind, accompanied by high storm surge, ice-free sea caused by warm winters and unfrozen sediments) are the primary cause behind the activation of shore processes.

The opinion that in connection with the construction of Nasva harbour major damage occurred to Järve-Mändjala beach was for years a part of agenda, but has not been proven in any way. In order to overthrow this statement several researches have been conducted in the observed area, proving with a high certitude the incompetence and also the tendentiousness of the given statement. It is very easy to blame human activity for unfavorable changes on the shore, without giving a thought to the actual reasons.

We shall observe below the essence of the disputed unified lithodynamic Järve – Mändjala – Nasva system.

According to older data, damage to this area has been recorded long before the construction of the harbour breakwaters. For example severe sand scarp damage occurred in 1933/1934, 1954, 1969, also in 1976 etc., hence several years before the construction of breakwaters was launched in the mouth of Nasva river. Intense destructive periods only appear to coincide with harbour enlargement operations. We need to state already in advance that instead of the harbour causing damage to Järve shore, there has been the opposite phenomenon – recent severe storm damage to Järve-Mändjala sand scarp has been adding a lot of new sand to sea, being transported south-east along the shore and endangering the exploitation of Nasva harbour! The standpoint, proven by similar research and expert opinions of special researchers has repeatedly been presented to the administrations at various levels since 1981 (in 1981 by K.Orviku – to the Executive Committee of Kingissepa city, in 1985 to the Council of Ministers of Estonian SSR, in 1985 to the Ministry of ESSR Forest Management and Nature Protection; by V. Zenkovich in 1985 – to the Administration of ESSR Fishing Industry; the research reharbour of the Geological Survey of Estonian Academy of Sciences in 1990; "PI-EST" – Saaremaa development project of 1991 etc.).

**) "PI-EST" research paper No. 90691, Album of Saaremaa development project 2.2., cypher: EP ÜE-I-90, 1991, the research of reciprocal interaction of Järve-Mändjala beach and Nasva harbour, Tallinn, 1991, 84 pp., authors K.Orviku, J.Lutt, E.Mäss.*

## General characterization of shore processes and evolution tendences

Considering the structure and development of coastal zone, especially the nature of shore processes, the whole Suure Katla western and north-western shore from Tehumardi area to Nasva harbour belongs into the common lithodynamic erosion-accumulation system: the sandy scarp of Tehumardi-Järve area being subject to marine erosion, the accumulative area of sands beginning about a kilometer from Männikäbi resort area in the south, stretching to the southern border of Nasva harbour and north-western Loode Tammiku. The beach sediment transit area remains in between the two zones. The shore development is relatively stable in the boundaries of this area – there is no noticeable damage and also the accumulation is of temporary nature. In nature the boundaries are conditional and relative

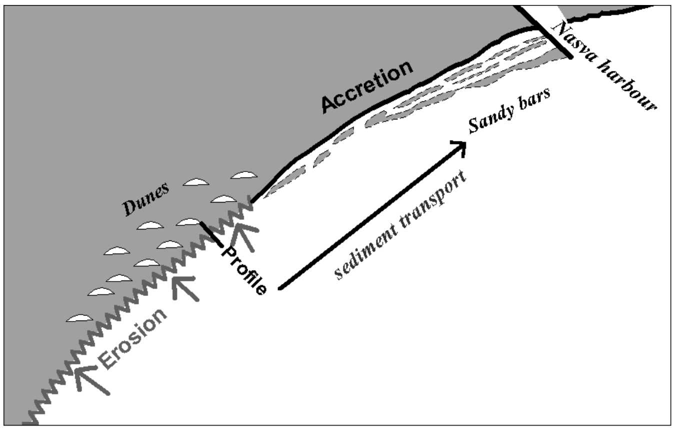


**Figure 1.** Järve–Mändjala–Nasva lito-morphodynamic scheme. Figure displays a levelled cross-section of the shore (see figure 2), its approximate location. (Compiled by H. Tõnisson).

**Photo 1.** Area of high dunes of Järve in January, 1990. Sandy bluff in dune sand is covered with extensive talus. Photo – K. Orviku, 1990.

**Photo 2.** Area of high dunes of Järve (the same place that is displayed at photo 1) in March, 1990 after severe February storms. From the foot of scarp the sandy talus has been destroyed by storm waves and the scarp itself is in the form of a recently formed bluff and has at places receded up to 5 meters towards the land. Photo – K. Orviku, 1990.

and can be changed corresponding to the hydrodynamic conditions, caused by specific storm periods. The development of all the three shore areas of dynamically different nature and their natural evolution are in close reciprocal dependence.

In the researched area a multi year average migration of beach sediments from south to north prevails i.e. from Järve region towards the Nasva river (Fig. 1) According to the present knowledge, the ca 2 km long coastal stretch from high Järve dunes towards north-east should be considered as the prevalent erosion area. Namely such a ca. 2,0 – 2,5 km long coastal area has been repeatedly and most of all suffering from storm damage. Various archive materials as photos etc. dating back to various time periods prove that the erosion scarp

**Photo 3.** Forming longshore bar between the Mändjala shore and Nasva harbour.
(Photo – K.Orviku, 1991).

formed to Järve dunes with storms had also earlier a fresh look – due to its being with no protective talus. Therefore it is justified to state that the active bluff has evidently receded dozens of meters in the course of repetitive storm damage during dozens (hundreds) of years and the highest part of former high dunes has been destroyed (Photo 1 and 2). Also the peculiarity of the dune range relief subject to erosion refers to this also at present. The surface relief descends from the edge of the terrace subject to abrasion towards the earth surface. It demonstrates clearly that it has to do already with the ground surface edge of the dune range. Also the ca 1.2 km coastal stretch in the vicinity of the so-called Järve Central Shore and the former Life Guard station area have been formed in a similar manner. Also the memories of the local inhabitants refer to the long term and noticeable recession of erosion bluff formed to coastal dunes towards the ground surface (O. Pütt, K. Järv etc.).

The following ca 1.8 km long shore stretching south-east, almost all the way to Mändjala camping, should be considered as accumulative area from the perspective of beach sand dynamics. This is predominantly a relatively stable sandy shore. The coastal area is characterized by an extensive sandy accumulative area located inland from the shoreline. Directly at the landward boundary of the active sandy shore spreads a well-developed foredune zone with coastal vegetative cover. A stable development of the southern area of such sandy shore covered by foredunes refers to the relatively stable nature of beach sediments carried along the shore i.e. the transit of longshore sediment drift.

Approximately from the middle of the central part of the given shore stretch begins a vast accumulative underwater sand formation – longshore bar (Fig. 1 and Photo 3) that begins to retreat from the shoreline south of Männikäbi beach and arches towards the mouth of Nasva river, detaching gradually from the regular boundary of water. The developed position of sand formation corresponds in this area of shelving nearshore bottom relief to the already formed arching direction of the prevailing storm surge front. The accumulated sand formation (longshore bar) is located in shallow sea more or less parallel to the deforming and bending wave front. There is a reason to suggest that in the conditions of the continuing earth crust uplift the future Suure Katla shoreline will be formed to the outer edge – longshore bar of this line.

Observing the position of the present day shoreline in Mändjala area in nature or when studying accurate plans we can see that the current position of a natural shoreline has a slightly shelving creek reclining towards the land. Such a shoreline position does not correspond actually with the prevailing direction of storm surge front – shoreline is not in a naturally balanced position. Therefore also the sand carried alongshore movement the shore from the south and accumulating there tries to retain the position of balance peculiar to the natural wave front and preserve the direction of movement respective to the natural conditions of sediments and the massive accumulated underwater sand formation will thus be detached from the shoreline.

The tract between the sand formation and shoreline will descend gradually, being filled by fine sediments hurled over the longshore bar by the waves. In the conditions of a low sea level that is peculiar to the spring-summer period the shelving ridge of the longshore bar will remain dry and it is possible to walk "dryshod" from the Mändjala beach directly through the sea to the Nasva harbour. The shallow area behind the longshore bar is like a kind of a trap to the marine flora hurled and accumulated there, that makes at times due to process of decay and spread of nasty aroma the use of the whole resort area an unpleasant experience. This is a favorable growth area to the gradually spreading coastal thicket of reeds.

The formation of such shallow and muddy lagoonlike water body immediately preceding a sandy beach is a serious hindrance to swimmers. Also the entrance of the thicket of reeds becomes considerably more intense, penetrating directly to the sandy shore. From the boundary between Männikäbi and Mändjala camping towards Nasva in the north we cannot find any sandy beach that would be open to the sea. There is abundant reed growth on the shore and in nearshore shallowsea practically in the whole area up to Nasva harbour. The bushes of young reed (for the time being yet temporary) can be found at places near Mändjala camping territory even within the longshore bar area.

## Determining the amount of sand in active motion

In order to solve rationally several vital applicable issues, especially the ones related directly to beaches and beach facilities and to pass scientifically proven decisions, the results of the research that was conducted directly in the nature and the conclusions drawn on the basis of the results of the shore evolution, incl. the quantitative nature of the beach sediment dynamics, are relevant. Namely such data provides us with a basis to yield a realistic prognose concerning the harbour congestion and further beach development related issues and enables us to plan the measures to prevent the damage in time. The following is a short overview on such research in the given area.

As the earlier research of the author and the colleagues (Lutt, Mäss, Orviku 1991) demonstrated, the sandy scarp formed in the Järve dune sands receded in January-February of a warm ice-free winter of 1990 due to cumulative effect of severe storms and high water level on an approximately 4 kilometer stretch at places up to 4-5 meters towards the land (photo 4). When comparing the repetitive measurements also the quantitative side of the erosion processes was determined in the given area. It was found out that in average 6500 $m^3$ of sand sediments was transported from one linear kilometer, with ca 2/3 of the transported material attributed to the sandy scarp. It amounts to ca 6 500 $m^3$ of sand per one kilometer subjected to erosion and in intensely damaged high dunes of Järve even amounting almost up to 9 000 $m^3$. The storms of 1990 destroyed extensively also the coastal dunes in the

**Photo 4.** Extensive storm damage at the Järve–Keskranna lifeguard station in the February storm of 1990. (Photo – K.Orviku, 1990).

**Photo 5.** The beach of Järve Keskranna at the former lifeguard station in 2004. An earlier formed bluff in dune sands (see photo 4) has been covered by talus. (Photo – K.Orviku, 2004).

backshore, where the earlier formed sand bluff receded at places up to 4-5 meters towards the land.

During the following years after the storms of 1990 the waves did not reach as far as to damage the foot of scarp nor carry all the eroded sand away. During the 9-10 years after the storm of 1990 a distinct erosion scarp has formed, the foot of its sandy scarp covered especially at the expense of the sand falling off from the edge of bluff. Intensive growth has begun at the already formed natural sandy talus. During the storms of the winter of 1999 – 2000 a part of sandy surface layer of the beach was carried away at places and the surface

**Photo 6.** Järve Keskranna beach at the former life guard station (the location that was on photos 4 and 5) after the January storm of 2005. An earlier formed talus has disappeared and scarp line has receded 4–5 meters. Several ancient trees have fallen to the bluff foot of storm waves. (Photo – K.Orviku, 2005).

**Photo 7.** In January storm of 2005 a sandy scarp shore of Järve–Mändjala receded at places again up to 5 meters. (Photo – K.Orviku, 2005).

of the beach was covered by gravel and pebbles. The sandy beach has been restored to a great degree with the storms of 2000/2001 that were not too intense.

The last storm of January, 2005 caused again severe damage in an observed coastal area. The sandy talus (Photo 5), formed during the calmer years in between was predominantly washed away and the crests of storm surge destroyed again the coastal dunes on the backshore, forming into it a brand new vertical bluff (Photo 6). At places the scarp line receded again several meters towards the land (Photo 7 and Fig 2).

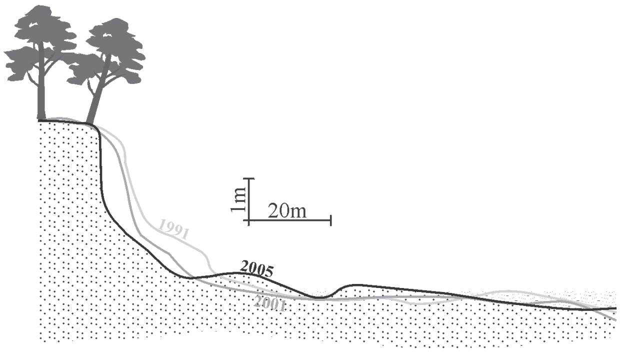


**Figure 2.** Cross-sections of a levelled shore near the former Järve–Keskranna life guard station (see fig. 1) cross sections of the shore levelled in 1991–2005. The range of sandy bluff that receded during the January storm of 2005 is particularly clearly visible, being up to 5 meters and the accumulated beach sand in front of bluff foot on the beach and on the nearshore. (Compiled by H. Tõnisson).

**Photo 8.** The January storm of 2005 damaged Järve–Mändjala sandy scarp to the extent of inclining the 32 kW poles of overhead line, providing the Sõrve peninsula with electrical energy. (Photo – K.Orviku, 2005).

A high voltage transmission line, built directly to the pine wood in the dunes and partially immediately to the preliminary dunes, providing Sõrve peninsula with electricity, suffered from extremely severe damage. In some sections of the line the poles were slanted (Photo 8). The issues regarding the deteriorated condition of the given transmission line and a need to remove it from the actively receding shore and pine wood that is under nature protection were raised already after the storm of 1990. By the present day the future stay of the 32 kW line is the issue of “numbered days”. The above mentioned refers distinctly to the cyclical nature of intense processes, occurring on the shores that are relatively closely connected with the climatic changes of the past decades (K. Orviku et al 2005).

When comparing the data of repetitive surveys conducted in 2001 in the close vicinity of the harbour and the sea channel by Merin Ltd. (Merin assignment no 336) it was found out that the most intensive sand accumulation that time period had occurred in the pier section of the sea channel and stretched up to 500-600 m towards the open sea.

All the sediment accumulation calculations were done for one kilometer long and about 200 m wide (100 m both sides of harbour entrance leading line ) section of the sea channel measuring zone by 200 meter stretches. Thus it covered ca 40 000 $m^2$ of changed area. In total the accumulation of sediments within the measuring area, covering about 200 000 $m^2$ (5 polygons amounting to 40 000 $m^2$) amounted to ~ 48 000 $m^3$ that had accumulated approximately in the past 2 years. There is every reason to suggest that most of this amount has been amassed at the period of severe storms of 1999 or basically during one autumn/winter storm period.

The accession of sediments to the channel has not been uniform, considering its overall length. The numerical data of absolute accession within the first 200 yd./m from the harbour approach is negligible or even negative. But the analysis of channel cross profile measurement data reveals that such a 6”0” balance does not reflect the actual dynamics of sediments. The profile analysis demonstrates clearly that an intensive accumulation of sediments has also occurred in nearshore bottom directly south of channel where the thickness of sedimentary layer has diminished at places to 0.5 m. At the same time almost a similar amount of sediments has accumulated into the channel, prevalently to its southern edge. Therefore also at the immediate beginning of the sea channel, in front of the harbour approach there has been intensive migration of sediments and their accumulation to the sea channel that has resulted in noticeably greater shelving and essentially lower cross section of the channel!

The measuring results within the following polygones located further away from the harbours (200 to 400 m and 400 to 600 m distances) display that the accumulation of sediments is more even within the sea channel. Also the majority of the acceded sediments fall into this measurement category, i.e. ca 65% of the total volume. Considering also the above mentioned sediment accumulation in the immediate vicinity of the harbour approach, the prevailing majority of the about 50 000 $m^3$ of sediments has accumulated to the channel and near that.

What has been said confirms again the fact that in connection with the accession of the longshore bar formed to the western side to the end of the mole, creating basically a new shoreline, the sediments drift now along the concave shelving shoreline and end up directly in sea channel. Or in another words, from the Männikäbi area to Nasva harbour a new shoreline (photo 3 and fig. 2) has begun to develop, initially not yet a permanent one, but with decisive value from the perspective of the longshore sediment drift.

There is a certain controversy in the numerical data concerning the erosion of sand from the scarp area and sand accumulation to the Nasva harbour sea channel that has been caused by varying lengths of measuring periods and these calculations have not been done on the basis of synchroneous surveys (time spans of research/surveys in erosione and accumulation areas differ). Irrespective of that the obtained estimates of sedimentary volumes yield a realistic idea on the intensity of shore processes. At the same time it should be also remarked that considering especially the mutual big distance between the erosion and accumulative area, the sand sediments forming in the course of shore erosion can not even make it to the accumulation area during the simultaneously occuring storm. There is a temporal shift in nature, especially in case of short term storms. It means in its turn that the longshore sand drift formed as a result of intense erosion during a certain storm does not arrive to the accumulative area and will remain stuck in the so-called intermediate transit area, widening and lowering the latter.

In case of several natural experiments that have been conducted in shore polygons in Poland and Bolgaria the movement of sands along the shoreline in the form of shelving sand headlands of different sizes were observed. Evidently also a similar phenomenon occurred in close vicinity of the Nasva harbour approach where the lowering of nearshore seabottom was observed (Fig. 2), for the loose sand formed by the previous storm and carried along the shore had not yet reached there. Naturally, this is a rather simplified approach to the migration of sediment drift along the shoreline, especially in harbour and estuary areas, where the cumulative effect of several natural processes and technical agents needs to be considered (02;N: et al 1987) (Pavliuk et al 1987).

It is evident with no further explanation that in order to obtain a realistic idea on beach sediment dynamics in each specific area several years long observation measurement rows are needed in a stationary test area, that would reflect the observation periods of different hydrodynamic intensity. At the moment the prospect of conducting such stationary research with the scarce possibilities of our republic seems not too probable, for there is also no direct need for that and very often quite a few practical solutions at practical usage of shores will be realized at the so-called trial and attempt method.

## In conclusion

The morpho-lithodynamic changes occurring within the range of sandy shores and the intensification of these processes is a natural course of events, characterizing the hydrological conditions of previous years (Orviku 1992 1993 etc.). Determination of mutual connections between the natural processes and hydrotechnical facilities like harbour piers, breakwaters etc. requires long term geological-geomorphological observations-measurements (relief of the shore and nearshore bottom, grain size distribution, texture and lithology of shore sediments, etc.), but also simultaneous hydrological-hydrodynamical research (wind, waves, alteration of sea level, sea ice etc.) (Martin et al 1988).

Tehumardi – Järve-Mändjala – Nasva abrasion - accumulation system is a splendid example of the formation of such morpho-lithodynamic systems (Orviku et al 1998; Raukas et al. 1994 etc.). With the simultaneous activation of severe storms also the development of accumulative shore formations has become quicker and more intense.

Sedimented material formed at the erosion of Tehumardi – Järve scarp shore by waves and currents moves intensively along the shoreline towards Nasva harbour that is practically located from the perspective of sediment movement in the area of their final accumulation. For decades (hundreds of years) beach has accumulated in front of the mole built in the estuary of Nasva river (west of pier), filling in the corner between the shoreline and mole.

Due to the frequency of storms and intensification of erosion in Järve erosion area, this corner has been filled in and sedimented material moves around the mole, congesting both the approach channel and entrance of harbour. At present the sand is obtained from the accumulated area in the south side of the west mole of Nasva harbour – the so-called preventive dredging process. The removed fine beach sand can be used in future at building sites as filling.

Part of the finer grained material moves even further - east, towards the Loode headland and has closed due to accumulation the approach of an old waterway leading to the Tori harbourharbour, located near the city of Kuressaare. For similar reasons also several other harbourharbours like Rinksu at Ruhnu, Läätsa at Sõrve, Mahu at the coast of the Gulf of Finland etc. are in a deteriorated condition due to their intense accumulation of sandy sediments. The harbour are not to be blamed for coastal damage, but the harbour suffers from intense clogging , caused by the intensification of natural processes.

At the same time as e.g. seen near the Lehtmaa harbour in Hiiumaa that has been built in the way of intense longshore movement of beach sands, the harbour itself suffers indeed from intense accumulation, but there is intense coastal damage south of harbour, i.e. downstream from sediment drift. The sand moving along the shore, remains predominantly accumulated behind the protective mole north of harbour. But south of harbour the deficit of beach sediments intensifies and due to that the shoreline has receded over 30 meters in the Tõrvanina area in the past decades. Such phenomena would require also in future a special approach. .

Long term research of mutual interaction of beach sediments and hydrotechnical constructions require the existence of stationary research ground and research team, but its formation, founding and conducting the research are not possible in the conditions of economic lack in small Estonia. Considering the former utterance and taking into account the level of our research and data, this work should be limited mainly by the issuance of suggestive data. The modeling of processes does not also yield better results, for irrespective also of the smartest models that could be used, there is a lack of sufficient initial data and long temporal lines of required data. The results obtained by modeling in such conditions can at best be only used to solve very limited tasks or are meant mainly for data processing.

## References

**Bird, E. C. F. 1985.** Coastline Changes. Wiley Interscience. New York. 219 p.

**Bird, E. C. F. 1990.** Coastline Changes. (in Russian) Hüdrometizdat. Leningrad. 255 pp.

**Jaagus, J**. 1998. Climatic fluctuations and trends in Estonia in the 20th century and possible climate change scenarios. – In: Kallaste, T. and Kuldna, P. (ed.), Climate Change Studies in Estonia. Stockholm Environment Institute, Tallinn, pp. 7–12.

**Jaagus, J**. 2003 Climatic change tendencies in Estonia at the 2nd half of the 20th century related to changes in the atmospheric circulation. Research on Estonian climate. – Publ. Inst. Geogr. Univ. Tartuensis 93. pp. 62–79.

**Martin, E. and Orviku, K.** 1988. Artificial structures and shoreline of Estonian SSR. - Artificial Structures and Shorelines. Kluver Academic Publishers. pp. 53-57.

**Orviku, Kaarel. 1992.** Characterization and Evolution of Estonian Seashores. Doctoral thesis at Tartu University. Tartu, 20 p.

**Orviku, K. 1993**. The present time shore. Geology of Estonian shelf. Tallinn. 29-39.

**Orviku, K. ja Palginõmm, V.** 1998. About the relations of nature and harbours on Liivi Bay shore. – Ed. Kukk, T. XXI Estonian Naturalists Day. SW Estonian nature. Estonian Naturalists' Society, Tartu-Tallinn, pp. 15–29.

**Orviku, K. 2004**. Estonian shore and its developmental tendencies. – Estonia Maritima. 6. 27 – 44.

**Orviku, K., Jaagus. J., Kont, A., Ratas, U., Rivis. R., Tõnisson. H. 2005.** Ties between the shore processes and climatic change in Estonia. Yearbook of Estonian Geographical Society 34 k. Ed. O. Kurss. EE Publishing House. Tallinn. 75-100.

**Павлюк, К.; Орвику, К. 1978.** Изменения состава поверхностных осадков прибрежной зоны в течение одного цикла волнения. В сборн.: Береговые процессы бесприливного моря. Редактор: Р. Зайдлер. Гданск. 317-332. (Changes in the composition of surface sediments in coastal zone in a single wave cycle. In a collection: Shore processes in a non-tidal sea), Ed. R. Zaidler, Gdansk. 317-332.)

**Raukas, A., Bird, E.D. and Orviku, K.** 1994. The provenance of beaches on the Estonian islands of Hiiumaa and Saaremaa. Proceedings, Estonian Academy of Sciences, Geology, 43 (2): 81–92.

## Järve – Mändjala – Nasva rannapiirkonna arenguprobleemid

### Resümee

Liivarandade piires esinevad litoloogilis-morfoloogilised muutused ja rannaprotsesside ägenemine on valdavalt looduslik protsess ja iseloomustab erinevate aastate hüdroloogilisi tingimusi (Orviku 1992 1993 jt). Looduslike protsesside ja hüdrotehniliste rajatiste nagu sadamamuulid, lainemurdjad jne omavaheliste seoste määratlemine nõuab pikaajalisi geoloogilis-geomorfoloogilisi vaatlusi-mõõtmisi (ranna- ja rannalähedase merepõhja reljeef, rannasetete lõimis ja litoloogia, jne.) aga ka samaaegseid hüdroloogilis-hüdrodünaamilisi (tuul, lainetus, meretaseme muutused, merejää jt.) uuringuid (Martin *et al* 1988).

Heaks näiteks aktiivselt arenevate seotud süsteemide arengus ongi Tehumardi – Järve – Mändjala – Nasva kulutus-kuhjesüsteemi areng (Orviku *et al*. 1998; Raukas *et al.* 1994 jt). Samaaegselt randade murrutuse aktiviseerumisega on kiiremaks ja intensiivsemaks muutunud ka kuhjeliste rannavormide areng. Nii liigub Tehumardi – Järve rannaastangute murrutusel moodustuv liivane rannasete lainetuse ja hoovuste toimel intensiivselt piki rannajoont Nasva sadama suunas, milline asub setete pikiranda rände seisukohalt nende lõpliku kuhjumise piirkonnas. Aastakümnete (-sadade) jooksul on kuhjuv rannaliiv moodustanud ulatusliku kuhjelise liivakeha – rannabarri Nasva jõe suudmesse rajatud sadamamuuli ette (lääne poole muuli), täites liivaga rannajoone ja muuli vahelist nurka.

Tänu tormide sagenemisele ja toiteala murrutuse intensiivistumisele on see nurk üha enam liivaga täitunud ning settematerjal liigub ümber muuli, ummistades nii sadama sissesõidukanalit kui ka sadamasuuet. Samadel põhjustel on intensiivse setetega ummistumise tõttu halvas seisukorras paljud teisedki sadamad nagu Rinksu Ruhnul, Läätsa Sõrves, Mahu Soome lahe rannikul jt. Mitte sadamad pole süüdi rannapurustustes, vaid sadam ise kannatab looduslike protsesside ägenemise tõttu intensiivse ummistumise all.

Samal ajal näiteks Lehtmaa sadama ümbruses Hiiumaal, mille muulid on ehitatud rannaliivade intensiivse liikumise teele ette, kannatab sadam ise intensiivse ummistumise all. Ka siin jääb pikiranda liikuv liiv valdavalt pidama sadamast põhja pool kaitsemuuli taha. Sadamast lõuna poole aga liivasetted ei jõua, ning seal süveneb rannasetete defitsiit. Liivaranna intensiivse kahanemise tõttu sadamast lõuna pool on rannajoon Tõrvanina piirkonnas taganenud viimastel aastakümnetel üle 30 meetri. Selles piirkonnas, vastupidiselt Nasva sadamale, on sadamarajatised seega süüdi intensiivsetes rannapurustustes.

Reaalse pildi saamiseks rannasetete dünaamikast ja tehiskonstruktsioonide omavahelistest suhetest igas konkreetses piirkonnas on vajalikud aastatepikkused vaatlus-mõõtmisread, mis kajastavad erineva hüdrodünaamilise intensiivsusega perioode.

# Environmental impact assessment of offshore sand mining in Estonian coastal sea

**ANDRES KASK[1], JÜRI KASK[1], TARMO SOOMERE[2]**

[1] Marine Systems Institute at Tallinn University of Technology , Akadeemia tee 21, 12618 Tallinn andres.kask@phys.sea.ee; jyri.kask@phys.sea.ee

[2] Institute of Cybernetics at Tallinn University of Technology, Akadeemia tee 21, 12618 Tallinn soomere@cs.ioc.ee

## Introduction

In recent years the intensity of various development activities on the Estonian shore has largely increased. Ports are constantly renovated, extended and constructed. Development of new ports has often been accompanied by the extension of port areas towards the sea, requiring a vast volume of landfill material. For example, approximately 3 mio $m^3$ of landfill material was required for the construction of a coal terminal, NW of Muuga Harbor. For this purpose the options to transport sand from the mainland deposits, the use of flotation sand, transporting the limestone from the Maardu quarry, acquisition and use of possible sand amount from the sea were considered. The first three options were left aside after economic and environmental assessments. Due to a need for such a volume of landfill material a geological research was immediately launched in the area of marine sand deposits (*Kask, Suuroja et al. 2002; Kask et al. 2003; Kask 2004*). Based on the research results the resources of Prangli and Naissaar sand deposits were confirmed.

In order to extract sand from the sea the developer has apply for the extraction permit and obtain a permit for special use of water. In order to get the permit a preliminary environment impact assessment (EIA) must be conducted (*§ 3 item 1 and § 7 item 2 and 3 of the Environmental Impact Assessment and Environmental Management System Act*). According to the Estonian legislation also the EIA of general geological surveys has to be conducted (*§ 8 section 3 item 9 of May 26, 2005 decree no 44 by the Minister of Environment "The procedure of general geological survey and exploration of natural Resources" and § 3 item 1 and § 7 item 3 of the Environmental Impact Assessment and Nature Management System Act*) although the assessment of marine geological research is not always grounded, for research causes no essential impact on the environment. EIA has by now been conducted for the mining sites of Prangli and Naissaar sand deposits. The mining operations in the above sites have also been launched. The present article sums up the results of the environmental impact of mining of sand from the sea.

## Prangli and Naissaar sand deposits

Prangli sand deposit is located about 1 km south of the Prangli Island in the range of 6-20 m isobaths (*Figure 1 and 2*). Its area is 77.4 ha and the resources of sand amount to 1 195 000 $m^3$. Naissaar sand deposit is located about 1 km south of the Naissaar Island in the range of 6-30 m isobaths (*Figure 1 and 3*). The Naissaar sand deposit covers 235 ha and has a reserve of 4 303 000 $m^3$.

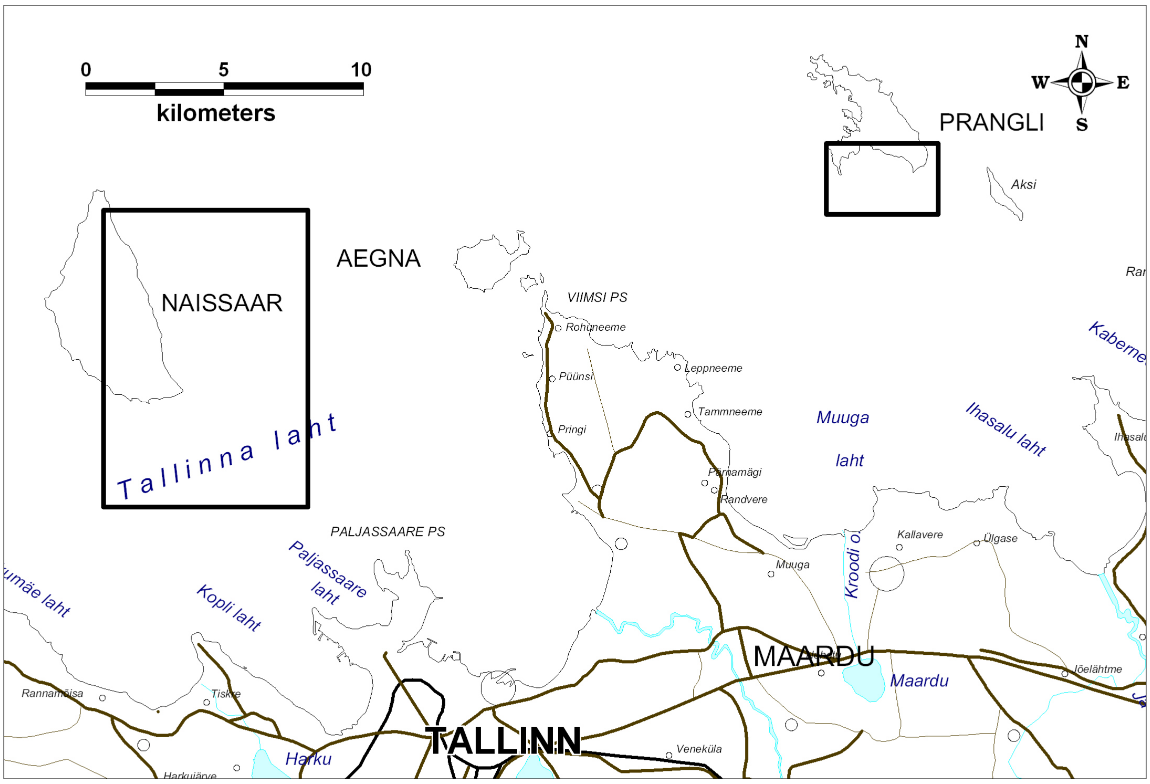


**Figure 1.** Investigation area.

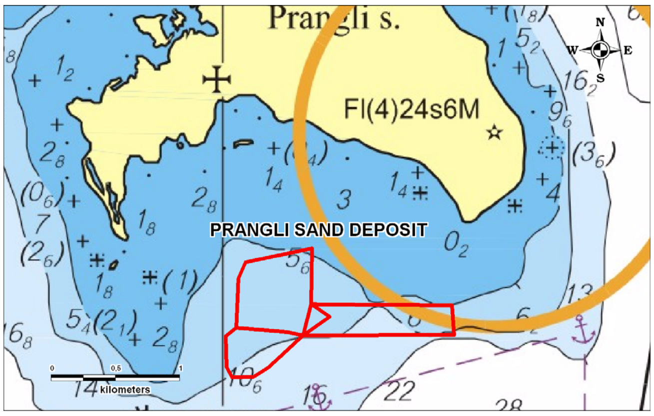


**Figure 2.** Prangi sand deposit.

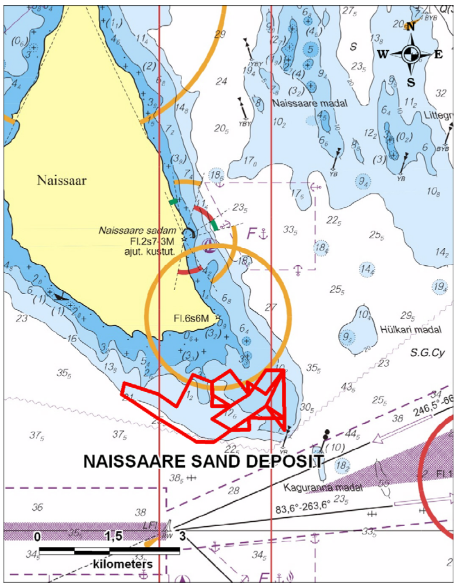


**Figure 3.** Naissaare sand deposit.

**Photo 1.** Beach on the south coast of island Prangli. Photo by Andres Kask.

**Photo 2.** Beach on the souht coast of island Naissaar. Photo by Andres Kask.

The formation of both deposits is related to the formation of the coastal zone of the islands located north of the deposits. Most of sand has accumulated due to the abrasion of coastal area sediments (*Photo 1 and 2*). The abraded material was due to waves and currents sorted according to grain size and transported to the deposits' area, where it overlies the glacio-lacustrine and glacial deposits.

## Environmental impact assessment

Environmental impact assessment has a crucial role in the planning of mining. Physical and biological impacts of mining of mineral resources in the coastal sea have been researched extensively worldwide (*Birklund et. al. 2005, Newell et. al. 1998, Boyd et. al. 2003*). In Europe the

Guidelines for Environmental Impact Assessment elaborated by the International Marine Research Council (*ICES 2003*) have been used for EIA planning. The general guidelines have been published also in Estonia (*Randmer et al., 2002*). The article by Lapimaa and Soomere (*2006*) included in the present collection gives an overview of the EIAs of development activities in Estonian coastal waters.

The alteration of seafloor relief during mining destructs literally the whole seafloor ecosystem and disturbs the natural balance for years. Therefore underwater mining exerts generally a significant environmental impact and EIA has to be conducted according to the *Environmental Impact Assessment and Nature Management System Act*. The primary goal of EIA is to minimize the impact of human interference in natural processes. Ignorant mining of natural resources can cause additionally to essential damage to the seafloor of the mined area (it is impossible to guarantee the preservation of the latter) also devastation of the biological communities in its vicinity, fish species and the nearby coastline. Environmental impact can be relatively long-lasting and can be manifested within several years. In order to identify and monitor a possible long-term impact, environmental monitoring is usually conducted prior to launching, during and also for several years after of mining operations.

Environmental impact needs to be assessed comparing the latter before the onset of activities with the current state of the environment (*John et al. 2000*). Prior to mining the condition of the environment should be described in detail in order to provide an opportunity to monitor the later changes and to apply the measures to alleviate the environmental impact if needed. The description should include more general aspects of environment. Usually a general description of hydrometeorologic conditions in the location of the deposit and in adjacent sea areas is given first. Mapping of the seafloor relief before and after mining is always obligatory. It provides the overview on seafloor relief changes, which in turn influence the hydrodynamic processes. Data regarding the adjacent coasts shall be presented (geological setting of the shore, distance of the shore from the deposit). In case the shore is more than 2 km closer to the site, a detailed relief mapping of the coastal zone should be carried out before mining (in a scale min. 1:500).

Based on the geological research of the deposit, EIA report must also outline its geological setting, discussing the origin of sand, its grain-size distribution and volume, transport of sedimentary material and properties of underlying sediments. Also hydrodynamic environment and its components (wind, waves and currents) and the motion of sediments impacted by the latter should be highlighted there. The annual average storm day count is often used as a feature characterizing the motion of sediments in mining area and its vicinity.

Prior to EIA also the chemical analyses of the material to be mined should be made. According to the recommendations of the Helsinki convention (HELCOM recommendation 13/1) the content of heavy metals and oil products within seafloor sediments will be determined. The count of sediment samples is determined according to the mining volume. In the deposit's area also the content of suspended matter in water will be measured. It provides an opportunity to compare the amount of suspended matter generated in the process of mining with its background content.

The description of marine biological environment includes also the composition of the species of benthic fauna and flora at the mining site and in its probable impact areas, considering the short- and long-term variability. The location of fishing areas, spawning areas and migration paths shall be presented. The feeding conditions of fishes according to benthic organisms located in their digestive tract are usually considered separately. Ecologically vulnerable areas located in mining area are treated separately (Natura areas, nature reserves, marine parks, nature parks etc.).

The descriptions should be based on scientific research conducted before mining.

## Assessing the environmental impact of mining operations

The nature of environmental impact depends greatly on the technology of sand mining. In Estonian coastal waters sand was mined by surface suction dredgers (SSD). A SSD leaves at slow motion to the seafloor a 1-2 m wide and 20-50 cm deep trace. In the process of mining the SSD mixes sand with water and the resulting pulp is pumped to a sedimentary basin aboard a ship. This process usually results in injection of large amounts of finer sediment fractions into nearby water masses in the form of suspended matter. Suspended matter is also brought to the near-surface water layer by the overflow from the sedimentary basin. The overflowing water always contains a part of finer fractions that have been washed out of sand. Sedimentary basin of SSDs is also often used for enriching, washing out by recurrent flushing the finer sedimentary particles from sand, which will be removed by overflow. Unfortunately in Estonia there is no detailed and independent surveillance of mining and suggestions presented in EIA report are often ignored or even abused (Rooväli 2004).

Alteration of seafloor relief and releasing of suspended matter are the most essential factors of environmental impact of sand mining. Due to the alteration of seafloor relief the intensity of water movement in the deposit's area and in its vicinity will be changed. Extensive mining can noticeably modify the properties of waves in shore sections at the lee side of the deposit and cause acceleration of coastal processes and damage the shore. In the process of relief alteration also the phytobenthos and fauna shall be removed. Suspended matter generated in the process of mining may influence the development of benthic flora, fauna and fish in comparatively remote sea areas.

## Impact on phytobenthos

Phytobenthos is usually comparatively sparse at sand deposits. Phytobenthos communities are therefore most of all influenced by suspended matter (*Photo 3*) that can be transported to adjacent marine areas with relatively dense phytobenthos (Martin 2003). Suspended matter can be transported by waves and currents to a considerable distance from the mining area, influencing the development of phytobenthos. When mining is intensive and suspended matter is constantly

**Photo 3.** Sediment plume distribution near the south coast of island Prangli. Photo by Andres Kask.

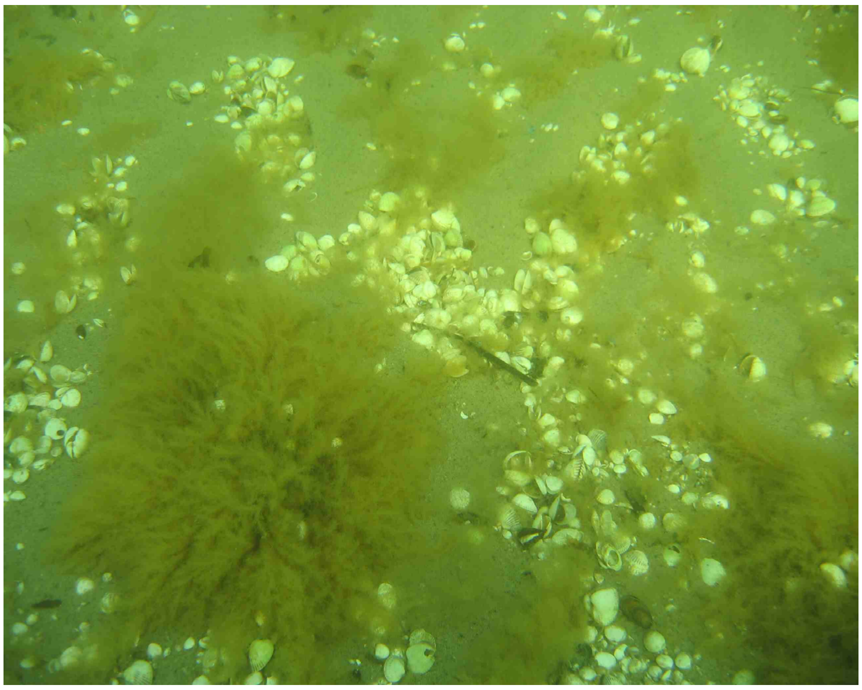

**Photo 4.** Benthic community on the seabed at water depth 4,5 m north from Prangli sand deposit. Photo by Georg Martin.

generated, the decrease in transparency of water can impede the growth of phytobenthos. The transparency of water in the Baltic Sea is moderate and primary production will usually cease at the depth of 15-18 m. Extensive plumes of suspended matter can cause noticeable decrease in this depth limit.

Ecologic factors limiting the vertical and horizontal distribution of phytobenthos communities in littoral zone are generally similar in all water bodies. In brackish water bodies and areas affected by human activity the role of various ecological factors may be different as compared to the natural environment in Estonian coastal sea. In the specific brackish environment of the Gulf of Finland the salinity of seawater is relatively small, determining the species composition of phytobenthos. According to G. Martin (2003) the species composition of phytobenthos in the surroundings of Naissaar is influenced by the effluents reaching this sea area from Tallinn Bay and Kopli Bay. This process can influence the eutrophication of several portions of the Tallinn Bay, but probably is negligible in Naissaar area.

Neare the coast of Naissaar sand deposits form a substrate suitable for phytobenthos, in particular, on seafloor in the northern section of the deposit (Martin 2003). In this area the phytobenthos community with relatively large biomass was found at the depth of 5 m with brown and green alga as dominating species. The kelp zone reaches up to a depth of 8 m in this area. Besides the kelp also brown alga *Sphacellaria arctica* was registered in the given area. In shallow coastal sea (depth 2 m) the phytobenthos is dominated by green alga *Cladophora glomerata.*

From 2004 to 2005 a detailed research of phytobenthos was conducted in the coastal sea south of Naissaar to find out the impact of mining. The results reveal that extraction of sand from Naissaar deposit has not caused any noticeable changes in the phytobenthos of Naissaar area (Martin 2005). In the process of the research conducted prior to mining (Martin 2003) between the Prangli Island and the deposits, the communities of kelp and other algae were found, with big biomass and variety of species. On sandy seafloor (deeper than 2 m) there was practically no seafloor vegetation. In more shallow water (up to 2 m) there were also communities of pondweed and spiked water milfoil.

In the coastal waters of Prangli Island there is also a community of eelgrass (*Zostera marina*) (*Photo 4*) which is sensitive to the decrease in transparency of water. For example the density and biomass of eelgrass formations decreased due to long term and extensive dredging operations in Oresund (*Oresundskonsortiet 2000*).

Therefore it can be concluded that in the process of mining the mineral resources from the sea, as well as dredging and dumping operations it is important to visually monitor the state of phytobenthos during the above operations and after their completion. The most important factors influencing the state of phytobenthos were gluing of clay particles from the suspended matter to phytobenthos, as well as the alteration of underwater light field. If these are short-term processes, then natural balance of the phytobenthos ecosystem will not undergo a drastic change.

## Impact on zoobenthos

Research regarding the impact of mining on zoobenthos reveals (*Boyd S.E., Rees H.L. 2003; Kotta, I. and Kotta, J. 1997*) that littoral seafloor formations are most of all influenced by suspended matter dumped into water during the mining. If the material is not polluted by toxic substances, the impact of suspended matter will become evident first of all in the deterioration of light conditions and increase in trophic level. In case of toxic pollution the impact on zoobenthos is usually more complicated and long-term.

Mining can also have a positive impact on certain groups of organisms. Organic particles released from the sediments serve as food for the zoobenthos. Therefore the alteration of zoobenthos habitats and composition of species, as well as their increase in number and biomass may accompany mining. Several researches have displayed that reasonable concentration of suspended matter can improve the living conditions of edible common mussels (*Mytilus edulis*), compared to water that is free from suspended matter (*Kiorboe et al. 1980; Navarro et.al. 1996; DHI, VKI & Geografisk Institut 1993*).

The impact of suspended matter on zoobenthos communities can be identifed also several years after the completion of the operations (*Kotta, I. and Kotta, J. 1997*). Zoobenthos can fully recover on a sandy substrate approximately 4 years after the end of the mining operations (*Newell et al. 2004*). Research conducted in Estonian coastal sea shows that on a sandy substrate zoobenthos may recover even in 2-3 years (*Kotta, I. and Kotta, J. 2003*). Suspended matter can be carried by waves and currents also to the wider sea areas. Therefore also the neighboring vulnerable areas should be taken into consideration. It takes longer for the finer particles of suspended matter to deposit. The impact of suspended matter depends on the duration of mining: longer mining period generates more significant impact. The finer fraction of suspended matter frequently contains organic matter and serves as food for zoobenthos. The change in the composition of zoobenthos in relation to the improvement of their feeding habits is most distinct at the depth of 5-30 m (*Kotta, I. and Kotta, J. 2003*). At these depths the number of zoobenthos and biomass will increase after mining due to massive development of filtering species (i.e. feeding from suspended matter found in water) *Mytilus edulis, Mya arenaria, Hediste diversicolor, Balanus improvisus* and detritophagous organisms (i.e. feeding from organic matter found in sediments and upon the latter) *Macoma balthica*.

Alterations in the structure of communities disturb biological balance. Therefore it is possible that zoobenthos could be dominated once by a certain species and then again by another ones. Such fluctuations may be accompanied by drastic changes in the number and biomass of zoobenthos. The impact of additional suspended matter to zoobenthos communities can be observed even for 2-3 years after mining. Then the number of fauna and biomass will stabilize.

## Impact on fish fauna

Mining can cause adverse impact on environmental conditions and existing ecologic connections. The impact exerted on fish depends on water body, composition of fish fauna, nature, volume and timing of operations and duration of the work period, as well as hydrometeorologic conditions during this period. The impact can be revealed directly as perishing of fish (especially roe and larvae), deterioration of their general state and the resulting spread of diseases, or indirectly throughdestruction of spawning areas and decrease of food basis, bringing along the decrease in reproduction potential and hindrance of their growth (*Järvik 2003*).

The above has shown that mining operations are usually accompanied by an increase in suspended matter in the water column and particularly near seafloor within a certain period. Suspended matter created at mining has generally natural origin and only its excessive concentration at certain time and place can cause problems. Transport of a vast quantity of suspended matter in spawning areas of fish, at an unfavorable time will cause extensive damage to fish stock reproduction. Deposition of suspended matter to roe in spawning areas is implicitly dangerous to roe. Even a very thin layer of fine-grained sediments is dangerous to the development of already spawned roe, because it does not allow the roe to use oxygen and can result in the destruction of the developing roe (*Järvik 2003*). Also, clay particles in suspended matter can glue to phytobenthos, thus impeding the attachment of roe in the spawning areas of fish.

The increase in concentration of suspended matter in seawater can have a harmful effect on the respiratory organs of fish (especially larvae), but can also damage food basis of fish species feeding from plankton. As a rule, such an impact is directly exerted in industrial areas when the concentration of suspended matter several times exceeds the natural background (*Alabaster and Loyd 1984; ICES 2001*). Thus, mining the mineral resources from the sea can not be conducted during the spawning period of fish which in Estonian coastal sea normally lasts from the beginning of April to the end of June. This requirement has been now also prescribed in all special permits for use of water.

The research of fish fauna conducted after the completion of mining from the Naissaar sand deposit (*Saat et al. 2005*) demonstrates that compared to 2004, in 2005 the number of fish species and their productivity have been lower in the area of the sand deposit than in comparison area. The difference in abundance of species and productivity in the area of sand deposit and comparison area has increased. These differences are probably caused by changed feeding habits of fish in the deposit's area.

## Impact on waves

Prangli and Naissaar sand deposits are located in comparatively shallow water. A new seafloor relief has been formed by mining, influencing the waves. With the increase of depth in deposit's area the wave regime in leeward areas can undergo a certain change, especially in case of longer wave components.

Two kinds of changes are possible. First the waves in deposit area can attenuate less and due to that a greater amount of wave energy can arrive to certain sections of coasts compared to present conditions. Second the wave propagation direction can change due to the alteration of intensity of topographic refraction. Topographic refraction in coastal area is one of the main factors, causing essential differences of wave load in relatively close coastal sections. Alterations in seabed relief can create a condition where storm waves start to influence the coastal areas where the present wave activity is relatively small. This may lead to essential acceleration of coastal processes in certain sections. It is not easy to forecast the relevant changes, for the intensity of topographic refraction depends on length and height of waves.

The complicated structure of potential changes in wave properties requests that the models reproducing correctly the basic wave properties in realistic conditions need to be used for their analysis (e.g. *Byrnes et al., 2004*). The described EIAs used the modification of WAM wave model fine-tuned to the Baltic Sea conditions with enlarged spatial and directional resolution (*Soomere 2005*).

In the process of EIA on Naissaar and Prangli sand deposits also the probable changes in wave patterns in the vicinity of the coastal sections near the deposits were analyzed for the first time in Estonia (*Soomere et al 2003; Kask et al. 2003*). In both cases the direction of dominating wind causes high waves to propagate generally over the deposit area to the open marine areas. In typical wind conditions the change of wave propagation direction caused by the increase in depth amounts to a few degrees only, being smaller than the natural variability of wind conditions.

In case of both deposits, wave modelling revealed that no acceleration or substantial changes of sediment transport processes at coasts near the deposit area was expected provided that an even 1-2 m deep sand layer was going to be removed by mining. The bathymetric changes caused by mining do not cause practically any impact on the wave regime in Naissaar coastal zone adjacent to the deposit site where the wave intensity decreases instead. In case of Prangli mineral deposit it was forecast that the wave activity should increase slightly (max. 10 %) in some sections of Aksi Island but does not change or slightly decreases at coasts of Prangli. For the shore in the given area such small changes in wave characteristics are negligible. Wave height can increase maximum 7-8 % at sea area leeward from the mineral deposit site. In case of prevailing wind directions and typical storms it means insignificant changes in wave intensity and propagation in the open parts of Tallinn and Muuga Bay.

As the intensity of topographic refraction is approximately proportional with the relative change in depth, the alteration of the existing nature of bottom topography should be avoided. It is especially vital to preserve the shallow sandy or moraine areas (sandy headlands in SW and SE part of Prangli Island, Kaguranna shallow near Naissaar Island), for considerable changes of sea bottom can drastically change the wave propagation conditions.

## Impact on currents

The changes in bathymetry owing to mining necessarily influence the properties of currents. When mining hollow is created, the speed of water flow in its cross section will decrease. This leads to a more intense sedimentation of coarser fractions of suspended matter as compared to original current intensity. Relative changes of currects compared to the current corresponding to the present relief are manifested more in deeper marine areas than in the shallow sea. The biggest changes of currents will occur with southern and south-eastern wind. A bit smaller, but still considerable (a few dozens per cent) changes correspond with the eastern and north-eastern wind. In other cases the changes are smaller, remaining under 10%.

Depending on the hydrometeorologic conditions, the edges of the hollow formed in the process of sand mining will flatten due to the material (sand) in near surroundings already in a few months. Some material will remain on sea bottom between the hollows, that was also accounted for when issuing the mining volume permits. It contributes also to the filling of hollow border areas and recovering the general structure of the bottom towards the pre-mining situation. Modelling of sediment transport in the vicinity of Prangli sand deposits made by Corson LCC revealed that there will be no extensive transfer of sediments. Thus the hollow can remain detectable in this area for years and its filling with the material from sandy Liivsääre headland *(cf. Orviku 2005)* is unlikely.

## Conclusions

When assessing the environmental impact of mining it is important to forecast as precisely as possible the probable environmental changes during and after the mining. In Estonia sand has been mined from the sea only in 2003 and 2004, therefore there is no long-term practice in the given field. But EIA conducted already before the onset of mining, was carried out according to worldwide practice and experience gained in other areas (*Byrnes et al. 2004; Morris and Therivel 2001* ).

In the process of conducting EIAs more attention has been paid to hydrodynamical aspects and especially to modelling the wave-related processes, for changes in the hydrodynamics in turn influence several processes in marine environment such as transport of suspended matter and sediments, and intensity of coastal processes. Until now the development of seafloor communities near the mining area has not been fully understood, because vulnerable marine areas have not yet been accurately mapped. Usually the phytobenthos in sand deposit sites is missing or sparse. Benthic fauna will be removed in the process of mining, but environmental monitoring demonstrates its relatively fast recovery at sandy substrate.

The release of suspended matter into marine environment causes relatively short-term changes of the underwater light field. Forecasting the sedimentation areas of suspended matter (both intermediate and final deposition) is a problematic issue to-day. The basic hope is that most of the material is fine–grained and therefore it finally it will be deposited in a deeper sea area where the benthic communities are either absent or poorly represented. The intermediate sedimentation may cause certain substantial problems but it apparently has no crucial effect on a long-term balance of benthos in shallow sea.

In case of minor changes in the ecological system it is difficult to distinguish whether they have been generated by natural or anthropogenic processes. Therefore a longer research period should precede the mining, which would enable to more accurately describe the situation prior to the anthropogenic impact. This also places the scientists under an obligation to elaborate the parameters that would enable to describe the changes in ecosystem (*SANDPIT 2003, 2004; Lapimaa and Soomere 2006*).

Till now in Estonia the monitoring system for the underwater mining activities is quite sparse although there is clear need for a more elaborated practice and regulations. There is also practically no supervision of dredging vessel operations (*cf. also Lapimaa and Soomere, 2006*). Therefore the limitations presented in environmental and working permit are moral rather than legal.

## References

**Alabaster, G., Loyd, R.** 1984. Water quality criteria for freshwater fish. Moskva, Ljekgaja ja Pists. Prom., 344 pp. (in Russian).

**Birklund, J., Wijsman, J. W. M.** 2005. Aggregate extraction: A review on the effect on ecological functions. DHI Water & Environment. WL Delft Hydraulics.

**Boyd, S. E., Rees, H. L.** 2003. An examination of the spatial scale of impacts on the marine benthos from aggregate extraction in the central English Channel. Estuarine, Coastal and Shelf Science 57, 1-16.

**Byrnes, M. R., Hammer, R. M., Thibaut, T. D., Snyder, D. B**. 2004. Physical and biological effects of sand mining offshore Alabama, USA. Journal of Coastal Research, 20, 1, 6-24.

DHI, VKI & Geografisk Institut. 1993. Environmental impact assessment of planned deepening of the access channel to the harbour of Esbjerg in the Danish Wadden Sea. Report to Harbour Authority of Esbjerg (in Danish).

ICES 2001. Effects of extraction of marine sediments on the marine ecosystem. Cooperative Research Report No. 247.

**John, S. A., Challinor, S. L., Simpson, M., Burt, M., Spearman, J.** 2000. Scoping the assessment of sediment plumes from dredging. Construction Industry Research and Information Association. 188.

**Järvik, A.** 2003. Impact of mining on fish. In: EIA of Naissaar sand deposits (leader of expert group J. Kask). Manuscript. TTU Marine Systems Institute, Tallinn, 61 pp.

**Kask, A., Kask, J., Kornejev, V., Dzilna, I**. 2005. Geological research of sand deposit SE of Naissaar Island. Manuscript. TUT Marine Systems Institute.

**Kask, J.** (leader of expert group ), **Järvik, A., Kask, A., Kotta, J., Kõuts, T., Martin, G., Raudsepp, U., Soomere, T.** 2003. EIA of mining from Naissaar sand deposit (4 photos, figures, 39 pp, 2 charts). Manuscript. TTU Marine Systems Institute, Tallinn, 61 pp.

**Kask, J., Kask, A.** 2003. Geological research of sand deposit south of Naissaar Island. Manuscript. TTU Marine Systems Institute.

**Kask, J., Kask, A.** 2004. Geological research of Naissaar and Littegrund bank. Manuscript. TUT Marine Systems Institute.

**Kask, J., Suuroja, S., Talpas, A., Kask, A., Sinisalu, R.** 2003. Geological research of the extension of Prangli construction sand deposit. Geological Survey of Estonia.

**Kiorboe, T., Mohlenberg, F., Nohr, O.** 1980. Feeding, particle selection and carbon adsorption in Mytilus edulis in different mixtures of algae and resuspended bottom material. Ophelia 19: pp. 193-205.

**Kotta, J., Kotta, I.** 2003. The impact of mining on zoobenthos. In: EIA of mining from Naissaar sand deposit (leader of expert group J. Kask). Manuscript. TTU Marine Systems Institute, Tallinn, 61 pp.

**Lapimaa, T., Soomere T.** 2006. Some observations of EIAs in Estonian coastal waters. Proc. Estonian Marine Academy 3, pp. 77-92.

**Martin, G.** 2003. Impact of mining on phytobenthos. In: EIA of mining from Naissaar sand deposit (leader of expert group J. Kask). Manuscript. TTU Marine Systems Institute, Tallinn, 61 pp.

**Martin, G.** 2005. Monitoring of phytobenthos. Environmental monitoring following the mining from Naissaar sand deposit. 2005. a. Volume I (leader of expert group J. Kask). Manuscript. TUT Marine Systems Institute, Tallinn, 23 pp.

**Morris, P., Therivel, R.** (Eds.) 2001. Methods of Environmental Impact Assessment. 2nd ed. UK: Spon Press.

**Navarro, E., Iglesias, J. I. P., Camacho, A. P., Labarta, U.** 1996. The effect of diet of phytoplankton and suspended bottom material on feeding and adsorption of raft mussels (Mytilus galloprovincialis Lmk). Journal of Experimental Marine Biology and Ecology. 198: pp. 175-189.

**Newell, R. C., Seiderer, L. J., Hitchcock, D. R.** 1998. The impact of dredging operations in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology. An Annual Review 36, pp. 127-178.

**Newell, R. C., Seiderer, J. E, Robinson, J. E., Simpson, N. M., Pearce, B., Reeds, K. A.** Impacts of overboard screening on seabed and associated benthic biological community structure in relation to marine aggregate extraction. Technical report to the Office of the Deputy Prime Minister (ODPM) and Minerals Industry Research Organisation (MIRO). Project No SAMP.1.022. Marine Ecological Surveys Limited, St. Ives. Cornwall. pp. 152.

Oresundskonsortiet. 2000. Environmental Impact of the Construction of the Oresund Fixed Link.

**Orviku, K.** 2005. Rational usage of coastal areas, *Proceedings of Estonian Maritime Academy*, 2, 42–61

**Randmer, A., Ruut, J., Põder, T.** 2002. *Environmental Impact Assessment.* Handbook. Ministry of Environment, KIK. Tallinn.

**Rooväli, K.** 2004. Dredged sea erodes the sandy shore of Prangli island. *(The Postman) Postimees* 23.11.2004.

**Saat, T., Eschbaum, R., Verliin, A., Vetemaa, M., Kesler, M.** 2005. Monitoring of fishes. In: Follow-up environmental monitoring of Naissaar sand deposit mining. 2005, Volume I (executive performer J. Kask). Manuscript. TUT Marine Systems Institute, Tallinn, 23 pp.

SANDPIT. 2003. Scientific report of SANDPIT project April 2002 - April 2003 (year 1) EC Fifth framework project no. EVK3-2001-00056.

SANDPIT. 2004. Scientific report of SANDPIT project April 2003 - April 2004 (year 2) EC Fifth framework project no. EVK3-2001-00056.

**Soomere, T.** 2005. Wind wave statistics in Tallinn Bay, Boreal Environment Research, 10, 2, 103-118.

**Soomere, T., Elken, J., Kõuts, T.** 2003. Hydrodynamics. In: EIA of geological research and mining from sand deposit in shallow sea near the southern shore of Prangli island. Manuscript. TTU Marine Systems Institute, Tallinn.

# Merest liiva kaevandamise keskkonnamõju hindamine Eesti rannikumere näitel

## Resümee

Kaevandamise keskkonnamõju hindamisel on oluline prognoosida võimalikult täpselt keskkonnamuutuseid kaevandamise ajal ja kaevandamise järgsel perioodil. Eestis on merest liiva kaevandamine toimunud vaid 2003-ndal ja 2004-ndal aastal mistõttu selles valdkonnas puudub pikaajaline praktika. Kuid juba kaevandamise eel teostatud keskkonnamõju hindamine viidi läbi arvestades maailma praktikat ning teistes piirkondades saadud kogemusi (*Morris and Therivel 2001*).

Suuremat tähelepanu on pööratud keskkonnamõju hindamiste käigus hüdrodünaamika ning eriti lainetusega seotud protsesside modelleerimisele, sest vee liikumine mõjutab omakorda paljusid protsesse merekeskkonnas (heljumi ja setete liikumine, rannaprotsessid). Senini ei ole täpselt prognoositud merepõhja koosluste arengut kaevandamise lähipiirkonnas, sest ei ole teostatud tundlike meralade täpsemat kaardistamist. Tavaliselt põhjataimestik liiva maardla alal puudub või on hõre. Põhjaloomastik kaevandamisel eemaldatakse, kuid keskkonnaseire näitab selle suhteliselt kiiret (2 kuni 3 aastat) taastumist liivasel substraadil.

Kaevandamise käigus tekkinud heljumi liikumisel merekeskkonnas muutub veealune valgusväli kuid see on lühiajalise iseloomuga. Probleem on heljumi nn. vahepealsete settimispiirkondade prognoosimine. Kuna tegemist on peeneteralise materjaliga, siis lõppkokkuvõttes toimub selle settimine mere sügavamas osas, kus põhjakooslused tavaliselt puuduvad või on vähe esindatud. Seega ei ole liiva kaevandamisel tekkiva heljumi settimisel olulist mõju põhjaelustiku pikaajalisele tasakaalule madalmeres.

Väikeste muutuste korral ökosüsteemis on raske eristada neid põhjustanud looduslikke ja antropogeenseid protsesse.

Senini on Eestis välja töötamata kaevandamise aegse seire süsteem, mis annaks võimaluse kaevandamise vahetus läheduses keskkonna jälgimiseks. Puudub ka järelvalve süvenduslaeva tegevuse üle. Seetõttu on keskkonna- ja tegevusloas esitatud piirangud rohkem moraalsed kui juriidilised.

# Analysis of hydrometeorological conditions for environmental impact assessment of reconstruction of Rohuküla and Heltermaa harbors

**TAAVI LIBLIK, URMAS LIPS**

Estonian Maritime Academy, Department of Hydrography, Mustakivi 25, 13912, Tallinn
Corresponding author: Taavi Liblik, e-mail: taavi.liblik@emara.ee

## 1. Introduction

Rohuküla and Heltermaa are the main harbors linking the Estonian mainland and Hiiumaa Island. Some problems of ferry operations related to the present state of harbors and occasionally appearing severe hydrometeorological conditions are the main reasons for the initiation of reconstruction of these harbors. In addition, more yachts and pleasure boats could be expected to visit the harbors in future.

After taking into account all the possible interests of different stakeholders (local population, ferry connection, cargo ships, yachts and pleasure boats etc.) a new design of both harbors was suggested (Saarte Liinid Ltd, 2005). According to this plan both existing breakwaters will be dismantled, a new breakwater and a new harbor office will be built and up to 150 000 $m^3$ of materials will be dredged (and dumped) at Rohuküla. At Heltermaa a breakwater will be built, two piers will be reconstructed, the ship manoeuvring area will be extended, a new basin for 32 small boats will be established and up to 110 000 $m^3$ of materials will be dredged (and dumped).

There are four different official dumping areas in the northern part of the Väinameri region. However only one in the Hullo Bay (off the Vormsi Island) was used during the last 10 years. According to preliminary plans, the latter was supposed to be used in case of planned reconstruction of Rohuküla and Heltermaa harbors as well.

The main aim of the present paper is to analyze the hydrometeorological conditions at Rohuküla and Heltermaa harbors. Based upon this analysis some suggestions are presented to minimize the environmental impact of reconstruction activities. Special attention is paid to describe the distribution of suspended matter from the dredging areas and from the dumping area. One of the conclusions is that taking into account the amount of dredged materials the dumping area should be located in more open sea areas and not in the Hullo Bay or anywhere in the inner part of the Väinameri region.

## 2. Material and methods

Hydrometeorological conditions in the area are characterized using data from the Estonian Meteorological and Hydrological Institute (EMHI). In addition to the data from the closest stations in Rohuküla and Heltermaa, data sets collected at other meteorological or coastal stations in the region – Virtsu, Vilsandi, Ristna, Pakri and Kärdla – are used. Table 1 gives an overview which data from what station is taken for the analysis.

**Table 1.** Meteorological stations and data sets used in the analysis.

| Station/Parameter | Rohuküla | Heltermaa | Virtsu | Vilsandi | Ristna | Pakri | Kärdla |
|---|---|---|---|---|---|---|---|
| Wind speed and direction | x | | x | | | | |
| Sea level | x | x | | | | | |
| Air temperature | | | x | | | x | x |
| Water temperature | x | | | | | | |
| Precipitation | | | x | x | x | x | |
| Ice conditions | x | x | | | | | |

Wind speed and direction are recorded as 10-minute-average values at the Rohuküla meteorological station twice a day. Wind direction is registered with the accuracy of 22,5° and speed with the accuracy of 1 m/s. Data set used contains the measurement results from 1995-2004. Sea level measurements are carried out 3 times a day and data set used contains data obtained in 1981-2003. Ice observation results are available from 1961-1990 (the same is valid for the Heltermaa meteorological station). Water temperature is recorded twice a day and data set contains measurement results from 1995-2004. To characterize precipitation, fog and air temperature in the harbor area and in the adjacent region the data on average and extreme values available at the EMHI home page at (http://www.emhi.ee/) are used.

Wave characteristics are calculated using simple empirical equations derived for conditions when wind is blowing from certain direction for a long time and taking into account the fetch or water depth. Calculations are carried out for 5 different locations along the Rohuküla-Heltermaa ferry route (Fig. 1). Current fields in the areas under consideration

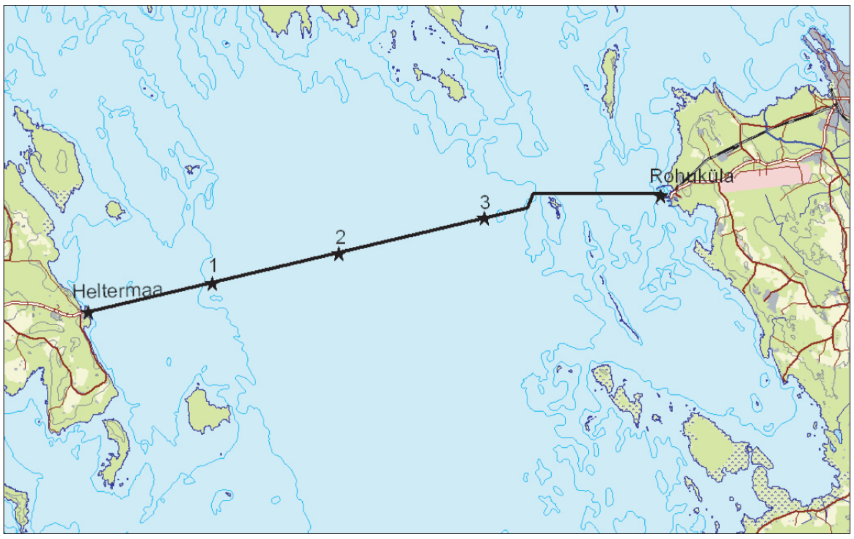


**Figure 1.** Location of harbors, ferry route and points between Rohuküla and Heltermaa for which the significant wave height is estimated.

are described using the published modelling results (Kullas et al., 2000; Suursaar et al., 2001). Conclusions about the transport of suspended matter are made taking into account the prevailing wind conditions and related current schemes as well as roughly estimated sedimentation rates of dredged materials.

## 3. Hydrometeorological conditions

### *Wind conditions*

Distribution of wind directions is relatively even if all measurements are taken into account. If records with wind speed higher than 5 m/s are considered then easterly directions are observed remarkably less frequently than other directions. For winds with speed higher than 10 m/s, a distinct dominance of two directions – from north-west and from south – south-west – is demonstrated (Fig. 2). In addition, wind directions fall between 67.5º-112.5º only in 1.5 % of measurements. Prevailing directions for strong winds are from south-west and south in summer, autumn and winter (also north-westerly winds are frequent). At the same time north-west is the most dominating direction in spring. Thus most of the strong winds are directed across the ferry route between Hiiumaa and mainland.

Monthly average wind speed varies during various months relatively little. Maximum monthly average wind speed is observed in February (7.4 m/s) and minimum in April (6.1 m/s). Seasonal variation is more marked, considering the average number of days with strong winds (wind speed over 10 m/s). Maximum number of stormy days is observed in February (5-6 days), minimum in March-April and June-August (3-4 days, see Fig. 3). Most frequently observed wind speed is 4 m/s, followed by 5 m/s and 3 m/s.

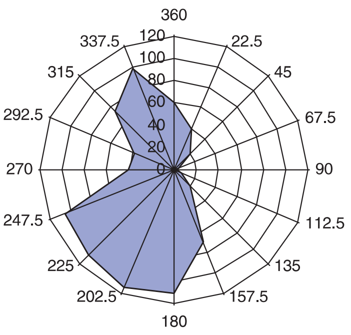


**Figure 2.** Wind rose, Rohuküla, 1995-2004 (wind speed over 10 m/s).

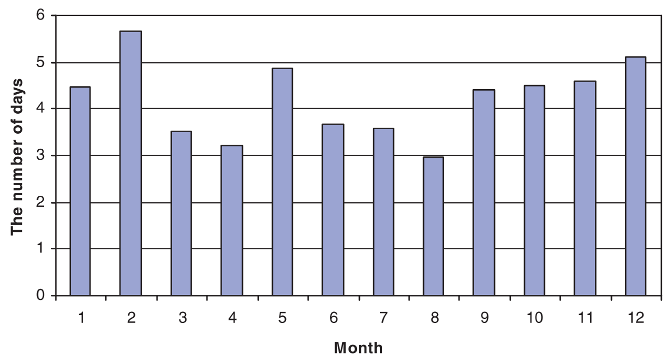


**Figure 3.** Monthly average number of days with strong winds (>10 m/s) in Rohuküla, 1995-2004.

### *Waves*

Wave characteristics depend on wind speed, duration, fetch and water depth. There are different methods to estimate the wave height. For instance, in the shallow sea area a method introduced by Krylov and Rzheplinski can be used (Абузяров. З. В.; Шармаев, Ю. И. 1974). The average wave height ($h$) is calculated on the basis of wind speed ($v$) and water depth ($H$) as:

$$h = \left(\frac{gH}{v^2}\right)^{0,6} \frac{v^2}{g}\ 0,07 \qquad (1)$$

where $g$ is gravity acceleration.

In this method fetch is not taken into account, thus it is considered to be long enough. At the same time near the Heltermaa harbor the fetch is very short for directions 180º-320º and much longer for easterly winds (11-17 Nm). In addition, duration of the wind is assumed to be long enough to get a developed wave field. To get significant wave height estimates the result obtained by using (1) has to be multiplied by 1.6.

In the frames of an experimental study in the North Sea area (JONSWAP) another method for estimating significant wave height ($h_s$) was introduced (Elken, J; Geophysical Fluid Dynamics):

$$h_s = 0.0016\, V_W \sqrt{\frac{F}{g}}\,, \qquad (2)$$

where $V_W$ is wind speed and $g$ – gravity acceleration. This method does not take into account wind duration (it is assumed to be long enough) and water depth (it should be applied in relatively deep sea areas). In the present study we estimated significant wave height using formula 2 and replaced the result by the estimate obtained using formula 1 (where water depth was a significant parameter) if the latter was less than the former.

The highest waves develop in the area close to Heltermaa harbor in case of easterly winds (Fig. 4) and in Rohuküla harbor in case of south-westerly winds (Fig. 5). If the wind speed is 20 m/s, then significant wave height is 1.7 m in both above mentioned situations. Howevere in most cases the significant wave height is below 1 m due to short wind fetch and shallow water (Fig. 6).

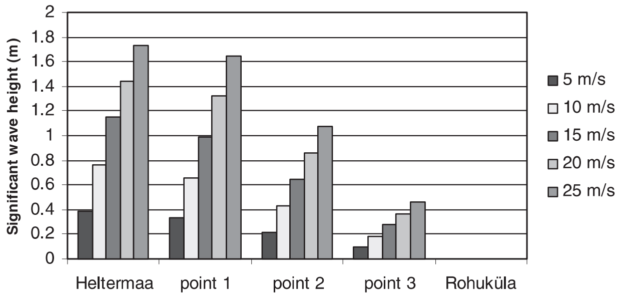


**Figure 4.** Significant wave heights for easterly winds.

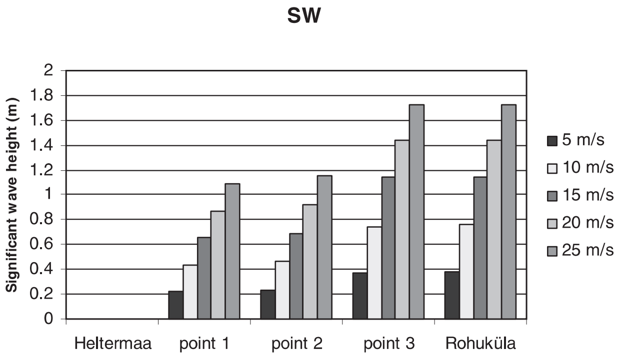


**Figure 5.** Significant wave heights for south-westerly winds.

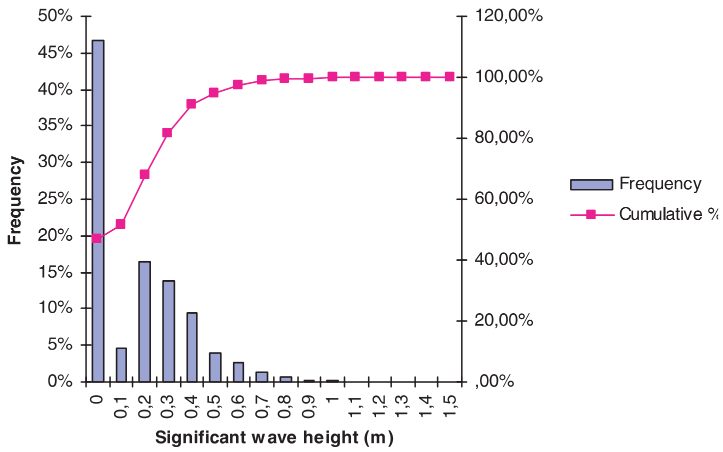


**Figure 6.** Histogram of significant wave height near the Heltermaa harbor.

### *Currents*

Mainly wind and water level differences of adjacent basins (Gulf of Riga and northern Baltic Proper) drive the currents in the Väinameri (Moonsund) area. Current velocity and direction are quite variable in time in the area, depending on wind direction and speed. Sea area between the Suur Strait and the Hari Strait could be considered as a channel and therefore current velocity is inversely proportional to the cross-section area. In the straits the velocities are higher than in the wider Väinameri area.

Water exchange (ca 80-90% of it) in the Väinameri area is governed by currents flowing forth and back in this channel-like system (Estonian Geological Survey LCC, 2000). An average current velocity in the Heltermaa-Rohuküla ferry route is about 12-16 cm/s, maximum velocities could reach 60-80 cm/s. Such strong currents develop during storms with south-westerly and north-westerly winds. Strong winds from above mentioned directions are prevailing in the area (see sub-chapter *wind*). South-westerly winds cause northward currents and north-westerly winds cause southward currents (Kullas et al., 2000; Suursaar et al., 2001).

Since currents are mainly related to the winds, similarly to the local wind regime, seasonal variations in current velocities may be expected. In spring and summer current velocities are lower, but in autumn, when there is a high probability of stormy weather, current velocities are higher.

### *Sea level*

Long-term variations of sea level are similar in all sea areas, including the Väinameri region in Estonian coastal sea. Temporary low or high sea levels are caused by local wind peculiarities and influenced by topography of the area under consideration.

Maximum sea level observed in Heltermaa in 1981-2004 (Fig. 7) is 92 cm and in Rohuküla 136 cm (zero sea level in Kronstadt is taken as the reference). Minimum sea level observed in Heltermaa in 1981-2004 was –69 cm and in Rohuküla –77 cm. Such extreme values are quite rare and in 91% of recordings the sea level stayed within –40 cm to +40 cm. Due to the shallow sea area along most of Rohuküla-Heltermaa ferry route, the low water situa-

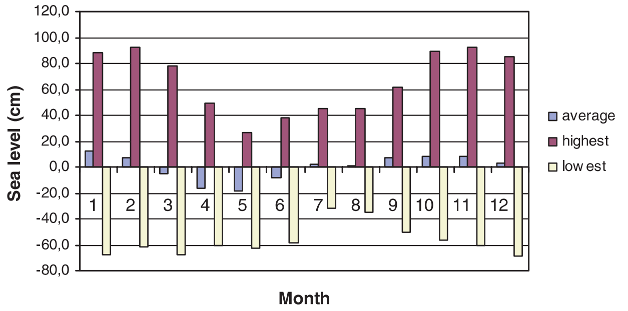


**Figure 7.** Monthly mean, minimum and maximum sea level observed in Heltermaa in 1981-2004.

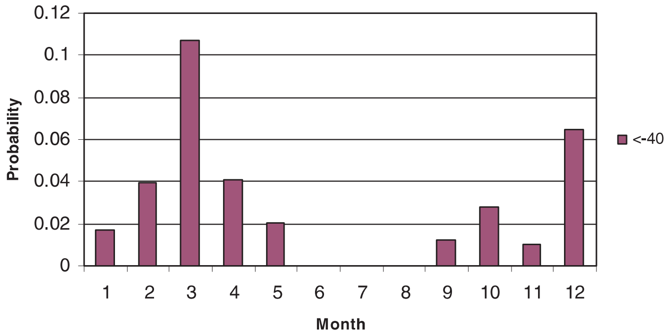


**Figure 8.** Probability of low water level (below –40 cm) in Heltermaa according to data of 1981-2004.

tion (sea level below –40 cm) could be dangerous for navigation. Such conditions are observed with a 2.9 % probability. Most often very low water level is observed in February-March (probability is 11 %). During the summer months such a low water level was not observed in 1981-2004 (Fig. 8).

The amplitude of water level fluctuations within one month is the lowest in May-August – difference between minimum and maximum values was 77-96 cm. Fluctuations are the biggest in October-March, reaching up to 145-156 cm. The same seasonal pattern is demonstrated, considering the monthly mean sea level. Sea level is below the Kronstadt zero reference in March-June (the lowest monthly mean sea level occurs in May). During the rest of the year the monthly mean sea level is above the reference level with maximum in January – +13 cm.

## *Water exchange*

Water exchange and renewal in the Väinameri area is mainly related to inflows-outflows through the Suur Strait and Hari Strait (80-90 %). Due to prevailing south-westerly winds the northward flow occurs more often than the southward flow. Amount of water flowing annually into Väinameri through the Hari Kurk is 147 $km^3$ and out of Väinameri into the northern Baltic Proper – 203 $km^3$ (Estonian Geological Survey LCC, 2000). Annual water flux through the Suur Strait into Väinameri is 164 $km^3$ and out of Väinameri into the Gulf of Riga - 124 $km^3$. An average annual inflow into Väinameri through the Soela Strait is 37 $km^3$ and outflow 20 $km^3$ (Fig. 9). The only fresh water inflow to the area that could be taken into account - the Kasari River with its annual run-off about 0.95 $km^3$, is too small in comparison with flow rates through the straits.


**Figure 9.** Scheme of the average annual water exchange through the main straits in the Väinameri area (Suur Strait, Hari Strait and Soela Strait).

Since Heltermaa is situated close to the Hari Strait, we can conclude that relatively intensive water exchange is expected in the area under consideration. Currents and water exchange in the areas close to Rohuküla and Hullo Bay are more complicated – in addition to the described channel-like flow they are influenced by flow through the Voosi Kurk and inflows-outflows to and from the Haapsalu Bay.

## *Ice conditions*

Ice conditions in a coastal area depend on the openness of the area, water depth and salinity but most of all on weather conditions in a particular winter. It means that ice conditions in one place could vary a lot in different years. Considering the salinity, the freezing point of water in Väinameri is about –0.4º C (it could be closer to 0º C in river mouths). Ice was observed in Heltermaa and Rohuküla harbor basins every year (only 1992 was recorded as an ice-free winter in Rohuküla). Average ice period was 122 days (median 131 days) and 123 days (median 133 days) in Heltermaa and Rohuküla, respectively. The longest ice period in Heltermaa was observed in 1966 when the basin was covered by ice during 173 days and in Rohuküla in 1965 when the basin had ice cover for 174 days.

## *Precipitation, fog*

Precipitation rate is the highest in July-November when monthly average lays between 62 and 72 mm. Low precipitation rates from 31 to 33 mm were obtained from February to May. Annual precipitation rate in Heltermaa-Rohuküla region is estimated to amount to 603 mm. Maximum daily precipitation rate is observed in July-August (66 mm). At the same time in January-March the maximum values of daily precipitation rates do not exceed 17-19 mm.

Average number of fog days estimated by linear interpolation is 44. Most foggy months were March-May when 5-7 fog days occurred. The lowest probability of fog existed in August when on average about 1.5 fog days was observed.

### *Air and water temperature*

Seasonal variation of air temperature in Heltermaa and Rohuküla area is similar to that of other coastal areas in Estonia. Compared to the inland meteorological stations the maximum air temperature in summer is lower and minimum air temperature in winter is higher at the coastal stations than at the inland stations. Annual average air temperature in Heltermaa was found to be 5.6º C. Maximum and minimum air temperature for the period 1961-1990 was estimated to amount to 31.0º C and –33.0º C, respectively.

Water temperature is characterized on the basis of measurements at Rohuküla coastal station. Mean water temperature was estimated to be 8.2º C. Water temperature reaches its maximum in July-August (monthly average was 19.3º-19,4º C) and the minimum is observed from December to March (monthly average 0.8º-0º C). Maximum values until 25º C can be measured in July-August. Usually (except long periods of calm weather) the water column in the sea area is not stratified.

### *Salinity*

Salinity of water in the research area depends to a large extent on current direction. If flow is directed from north to south, then saltier water from the northern Baltic Proper and if flow is directed from south to north, then less saline water from the Gulf of Riga appears in the area. Salinity stays usually between 5.5 and 6.5 psu. Due to the shallowness of the area the water column is almost always vertically not stratified by salinity.

## 4. Distribution of suspended matter

Sedimentation rate and distribution of suspended matter depends on different factors, like size and density of particles, current velocities and wave characteristics. The latter is especially important in the shallow Väinameri region where waves reach the seabed and are able to re-suspend newly settled sediments. For instance a wind wave with a 1 meter wave height in a sea area with about 4 m depth causes an about 0.5 m/s near-bottom current velocity. Water circulation caused by waves and currents can then transport the suspended matter far away from dredging or dumping area.

The extension of plume of suspended matter depends mainly on weather conditions during the period of dredging operations. As it was described above, prevailing winds from south-west and north-west cause northward or southward flow, respectively. The settling velocity of particles during calm weather depends on particle size and density. If we take an average particle size of 0.01 mm, then settling velocity could be estimated as 0.04 mm/s. For average current velocity of 12-16 cm/s (Estonian Geological Survey LCC, 2000) in the area, the extension of the plume could range up to 10 km.

Water depth south and south-west of Rohuküla is mostly less than 3 m and south and south-east of Heltermaa about 2-6 m. Thus, in case of stormy weather conditions, recurrent suspension is a common feature there. Southward distribution of suspended matter from the Rohuküla or Heltermaa area is expected in case of northerly, north-westerly and north-easterly winds. We can suggest that suspended matter could reach the mouth area of the Matsalu Bay or spread to the Kassari Bay only if strong north-westerly or northerly winds will prevail there for a long enough period.

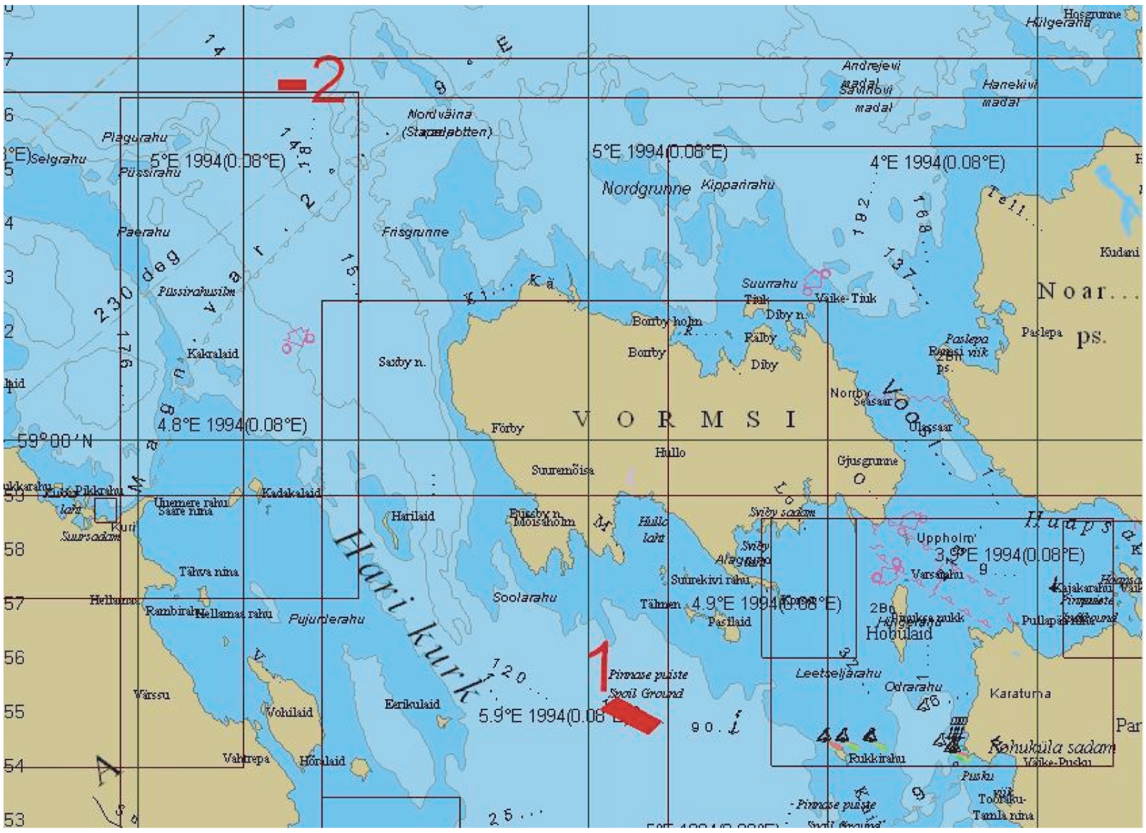


**Figure 10.** Dumping areas. 1- Spoil Ground in the Hullo Bay, 2- New dumping area.

In case of prevailing strong south-westerly, southerly or south-easterly winds, suspended matter can spread northward through the Hari Strait or Voosi Strait (the latter is valid for the Rohuküla dredging area and dumping area in the Hullo Bay). In this case part of the suspended matter could settle in the shallow areas close to Noa-Rootsi peninsula (mainly from the dredging area at Rohuküla) or the coast of Vormsi island (mainly from the dumping area). If suspended matter reaches the open sea (in case it spreads through the Hari Kurk) it is unlikely that it spreads further due to the relatively deep basin (20 m or deeper) and low current velocities.

Since Rohuküla harbor is not well sheltered from strong westerly winds, Heltermaa harbor is relatively open to south-easterly and north-westerly winds and dumping area is open to southerly winds, recurrent suspension of settled material and its further transport away from the working areas are critical factors to be considered. Although, if the material is not contaminated, the effects are similar to those occurring in stormy weather conditions when the water turbidity is high - then the amount of suspended matter released during dredging and dumping operations needs to be considered.

Locations of dredging areas are fixed, but it is possible to suggest another dumping area. In total up to 260 000 $m^3$ of dredged spoils is planned to dump in the Hullo Bay. As analyzed above quite a lot of resultant suspended matter (directly during the reconstruction period or afterwards in case of stormy weather conditions) could reach the shallow coastal areas of Vormsi Island or Noa-Rootsi peninsula. Therefore, dumping area should be situated outside of Väinameri in the deeper areas.

The present study supports the suggestion of (BCEOM and Aavo and Riina Raig, 2005) to establish a new dumping area outside the Väinameri region with coordinates: 59º 06.6N, 23º 01.0E; 59º 06.4N, 23º 01.0E; 59º 06.4N, 23º 02.0E; 59º 06.6N, 23º 02.0E. Water depth is more than 20 m there and it almost rules out recurrent suspension of dumped materials (see Fig. 10).

## 5. Conclusions

The present analysis of hydrometeorological conditions in the Rohuküla-Heltermaa region yielded the following results:

– South-west and south in summer, autumn and winter are prevailing directions for strong winds (also north-westerly winds are frequent). At the same time north-west is the most dominating direction in spring. Thus most of the strong winds are directed across the ferry route between Hiiumaa and mainland.

– The highest waves develop in the area close to the the Heltermaa harbor in case of easterly winds and in Rohuküla harbor in case of south-westerly winds. If the wind speed is 20 m/s, then significant wave height is 1.7 m for both above mentioned cases.

– An average current velocity at the Heltermaa-Rohuküla ferry route is about 12-16 cm/s, maximum velocities could reach 60-80 cm/s. South-westerly winds cause northward currents and north-westerly winds - southward currents.

– The low water condition (sea level below –40 cm) is observed with the probability of 2.9 %. Most often very low water level is observed in February-March (probability is 11 %).

– An average ice period was 122 days (median 131 days) and 123 days (median 133 days) in Heltermaa and Rohuküla, respectively. The longest ice period was in Heltermaa in 173 days and in Rohuküla - 174 days.

– An average number of fog days is 44 and most foggy months are March-May when 5-7 fog days may occur.

Taking into account the average current speed in the area, the extension of the plume of suspended matter (from working area) can range up to 10 km. Since Rohuküla harbor is not well sheltered from strong westerly winds, Heltermaa harbor is relatively open for south-easterly and north-westerly winds and dumping area is open for southerly winds, there is a very high probability of recurrent suspension of settled material and its further transfer from the working areas. Impact from the Heltermaa harbor area can be observed mostly in coastal areas close to the port. Impact from the Rohuküla harbor area can be observed also close to the port. However, if strong south-westerly winds dominate, then suspended matter can be transported to the coastal areas of Noa-Rootsi peninsula and if strong north-westerly winds dominate for a long period, then suspended matter can reach the mouth of the Matsalu Bay.

To minimize the impact of dredging it is recommended to stop the dredging activities in case of strong north-westerly and westerly winds with their speed higher than 15 m/s at both harbors. To minimize the risk of impact on Vormsi and Noa-Rootsi coastal areas and Haapsalu Bay it is recommended to stop dredging at Rohuküla in case of strong south-westerly and southerly winds (> 10…15 m/s). Monitoring is recommended considering also the fact that Väinameri belongs to Natura 2000 network. Since the planned dredging activities are relatively voluminous (150000 and 110000 m³), it is recommended to monitor the distribution of suspended matter: 1 day before dredging (to map background conditions) and 2-3 days during both periods of dredging operations.

Since the total amount of dredged spoils to be dumped is up to 260 000 $m^3$, it is recommended that the dumping area should be situated outside of the Väinameri in deeper areas. The present study supports the suggestion to establish a new dumping area 5,5 Nm north-west from the Saxby lighthouse.

## References


Saarte Liinid Ltd, 2005. Preliminary Design.and Feasibility Study Report.

**Kullas, T., Otsmann, M. and Suursaar, Ü.,** 2000. Comparative calculation of flows in the straits of the Gulf of Riga and the Väinameri. Proc.Estonian.Acad.Sci.Eng., 6, 284-294.

**Suursaar, Ü., Kullas, T. and Otsmann, M.,** 2001. Hydrodynamic modelling of sea levels in the Väinameri and Pärnu Bay. Proc.Estonian.Acad.Sci.Eng., 3, 222-234.

Estonian Meteorological and Hydrological Institute, home page at http://www.emhi.ee

Estonian Geological Survey LCC, 2000. Environmental Impact Assessment of dredging of Rohuküla-Heltermaa waterway.

Estonian Maritime Academy, 2003. Monitoring of distribution of suspended matter during dredging in Virtsu harbor.

**Elken, J.** Geophysical Fluid Dynamics.

**Абузяров, З. В.; Шармаев, Ю. И.** 1974, Морские гидроличесие информации и прогнозы. Ленинград Гидрометеоиздат. (Marine hydrologic information and prognoses).

# Hüdrometeoroloogiliste tingimuste analüüs Rohuküla ja Heltermaa sadamate rekonstrueerimise keskkonnamõjude hindamiseks

## Resümee

Käesoleva töö peamiseks eesmärgiks on analüüsida hüdrometeoroloogilisi tingimusi Rohuküla ja Heltermaa sadamate piirkonnas ja teha ettepanekuid nimetatud sadamate rekonstrueerimisega seotud (eriti heljumi leviku tagajärjel tekkiva) keskkonnamõju vähendamiseks. Analüüsiks on kasutatud Eesti Meteoroloogia ja Hüdroloogia Instituudi (EMHI) andmeid Rohukülast ja Heltermaalt, aga ka teistest piirkonna meteojaamadest ja EMHI koduleheküljelt. Peamised analüüsi tulemused ja ettepanekud võib kokku võtta alljärgnevalt:

– Kuna süvendusmaht on kuni 260000 m³, siis on vajalik kasutada kaadamispaika väljaspool Väinamerd, mitte esialgselt planeeritud kaadamispaika Hullo lahes. Antud süvendustöödel teisaldatav materjal on soovitatav kaadata 5,5 meremiili Saxby tuletornist loodes.

– Võttes arvesse keskmisi hoovuskiiruseid peaks heljumi esialgne levimiskaugus süvendus- ja kaadamistööde piirkonnast jääma 10 km piiresse.

– Heljumi resuspensiooni tõenäosus on Rohukülas suurem läänetuultega ning Heltermaal kagu- ja loodetuultega. Välja pakutud kaadamispiirkonnas on settinud heljumi resuspensioon suuremate sügavuste tõttu vähem tõenäoline.

– Heljum mõjutab kõige enam Rohuküla ja Heltermaa sadama vahetus läheduses asuvat rannikut. Tugevate edelatuulte domineerimise korral võib heljum levida Noa-Rootsi poolsaare lähistele. Pikaajaliste tugevate loodetuultega võib heljum jõuda Matsalu lahe suudmealale.

– Heljumi mõju vähendamiseks on soovitatav süvendustööd peatada tugevate (>15 m/s) loode ja läänetuulte korral. Heljumi levimise riski vähendamiseks Vormsi saare ja Noa-Rootsi poolsaare rannikule ning Haapsalu lahte on soovitatav süvendustööd peatada Rohuküla sadamas edela- ja lõunatuultega (>10 m/s).

– Kuna Väinameri tervikuna kuulub Natura 2000 võrgustikku, siis on vaja teha heljumi leviku seiret. Tulenevalt süvendustööde mahust (150000 ja 110000 m³) peaks heljumi leviku seiret tegema 3-4 päeval, sealhulgas kord enne süvendustööde alustamist (heljumi loodusliku fooni määramiseks).

# Changes of fish communities and fishery in Muuga Bay in 1994-2002: possible impact of Muuga Harbor

**AHTO JÄRVIK[1&2], TENNO DREVS[1], LEILI JÄRV[1], TIIT RAID[1], ANDRES JAANUS[1]**

[1] Estonian Marine Institute of University of Tartu, Mäealuse 10a, 12816 Tallinn, Estonia

[2] Estonian Maritime Academy, Mustakivi 25, 13912, Tallinn
Corresponding author: Ahto Järvik, e-mail: ahto.jarvik@emara.ee

## Introduction

Muuga Harbor is located in the middle of the West coast of the Muuga Bay in the central part of the Gulf of Finland. Muuga Harbor is relatively new, operational since the beginning of 1980s, but rapidly growing, being the second biggest port in the Baltic Sea in 2002 with an about 40 million tons of annual trade capacity.

Muuga Bay ecosystem has been suffering from severe anthropogenic pressure by inflow of the wastewaters of the Maardu Chemical Factory during 1950-1980s. Since the closure of the factory in early 1990s no other significant pollution sources except for Muuga Harbor and its infrastructure are located in the Muuga Bay.

The ecosystem investigations in the Muuga Bay, including the survey of fish communities, date back to the 1950s (Järvekülg, 1969). The intensity of those investigations increased at the end of the 1970s and in the beginning of the 1980s in the period of planning and building a new deepwater port. Special attention has been paid to the investigations of water chemistry and sedimentology as well as the plankton and benthos research (Kotta & Kotta, 1997; Lumberg & Ojaveer, 1997). Concerning fish, the main attention in earlier studies was paid to the examination of possible impacts on the reproduction conditions of herring *(Clupea harengus membras)* as the most important commercial fish of the area. Effect of suspended materials and secondary pollution risk on the distribution pattern of herring spawning grounds and larvae were studied and analyzed (Palm, 1985; Raid, 1985). In 1995 new large scale dredging operations in Muuga Harbor were initiated and as a part of the process of the Environmental Impact Assessment (EIA) it was agreed between the Port of Tallinn Corp. (the owner of Muuga Harbor) administration, Ministry of the Environment, and Estonian Marine Institute to establish the continuous marine environment monitoring program. The monitoring program includes measurements of hydrological aspects (currents, waves, and optics), hydrobiology (bottom communities), fish, and fishery (started already in 1994). In some years, also the sea sediment dynamics and pollution rate have been monitored.

The aim of this paper is the assessment of the impact of Muuga Harbor on the fish communities (diversity, age and size composition, distribution pattern) and fishery (catch composition, fishing efficiency) in Muuga Bay during the period of active development of the Muuga Harbor within a certain area in 1994 - 2002. The dynamics of fish stocks by themselves is not the objective of the present survey, and therefore, has not been discussed here, because it is impossible to determine the local stock areas of freshwater species as the distribution areas of the stocks of marine and migratory species are considerably bigger than Muuga Bay (Vitinsh, 1976; Mikelsaar, 1984; Nissling, Westin, & Hjerne, 2002). However, seasonal migration and general abundance tendencies of the more frequent commercial species in the Gulf of Finland are taken into account as well as cyanobacterial blooms and more important hydrological changes (salinity in deeper water layers) (Drevs et al., 2003).

In 2003 a new phase of the enlargement of Muuga Harbor begun. New coal terminal in Tahkumäe Peninsula was built in 2003-2004 and the area west of the new terminal up to existing berths of Muuga Harbor will be completed during 2005-2007. As a result, in 2003-2004 significant changes in fish communities (biodiversity, spawning grounds etc.) were found, but they should be the object of special studies and publication.

The need for updated program and methods for monitoring activities in case of further enlargement of Muuga Harbor, including the building of a new coal berth and two breakwaters served as another principle underlying the present paper.

Financing of monitoring was fully assured by the Port of Tallinn Corp., as it is the owner of the Muuga Harbor.

## Materials and Methods

Fish monitoring was carried out in three sites in the Muuga Bay (Fig. 1). The analysis of the dynamics of fish catch statistics in Muuga, Ihasalu, and Tallinn bays were used to separate the impact of Muuga Harbor activities from the one exerted by natural and other sources on the fish communities. Tallinn Bay is under relatively high anthropogenic pressure, while the Ihasalu Bay is not.

### *Area 1, Northwest from the Port (Fig.1.)*

Monitoring, carried out by semi-professional fishermen using gill nets and trap nets, started in 1994. The used gill nets had mesh sizes between 90 – 110 mm, thread 0.2 mm, length by headline 50 m. Nets were soaked in one fleet (4 – 5 gears) all the year round depending on weather conditions. The following parameters were monitored: species composition, CPUE (catch per unit of effort), and length-weight composition by species. Monitoring trap net (used in 1994-2000) had mesh size in cod end 24 mm and mouth opening 4 m. The length of leader net was 100 m. The period of trap net fishing lasted usually from April to September. The parameters monitored were as follows: species composition, CPUE, and length composition by species.

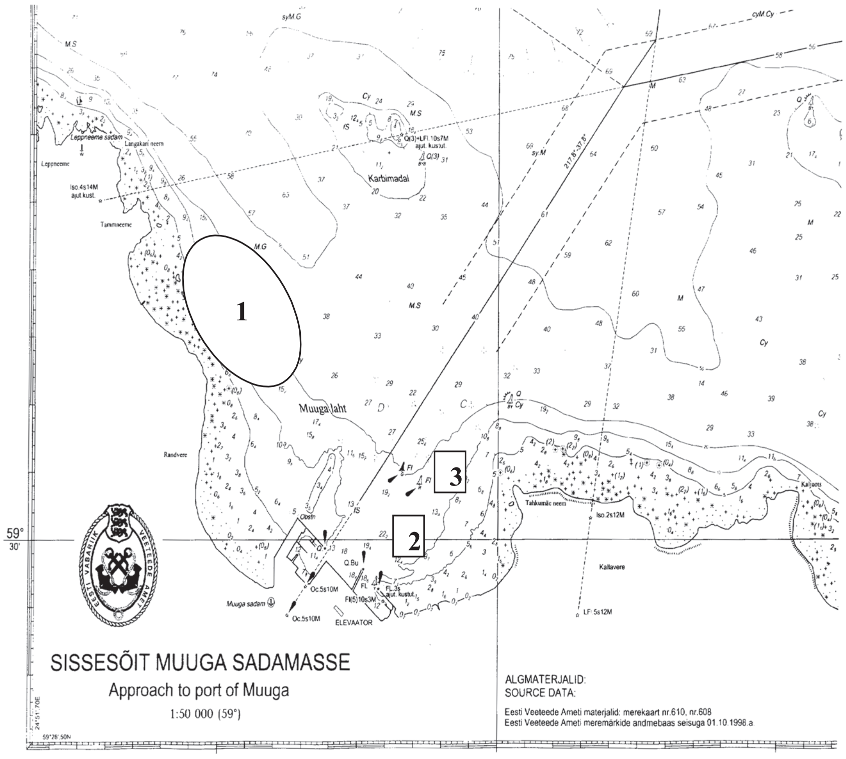


**Figure 1.** Scheme of fish monitoring sites in Muuga Bay: 1 (NW); 2 and 3 (SE).

### *Areas 2, and 3, Southeast from the Harbor (Fig. 1)*

Monitoring started in autumn 1998. Randomly positioned standard fleet monitoring gill nets with mesh sizes of 32, 44, 60, 72, 80, 92, 100, and 120 mm were used. The specified length of float line of the nets was 27.8 m, the length of lead line 33 m, and the height 1.8 m. The hanging ratio was 0.46 by headline. Nets were manufactured from the grey monofilament twine with specified thickness of 0.17 mm in nets with mesh size between 44 - 92 mm and that of 0.20 mm in nets with mesh 100 and 120 mm. Two separate fleets of those gillnets were deployed on ground during each set: the first set nearby the Harbor at the depths between 7 -15 meters and the second one more distant from the Harbor at the depths of 4-7 meters (Fig. 1, areas 2 and 3). The directions of both fleets were perpendicular to the coastline. Soaking lasted for 9-14 hours (from the evening until early morning) depending on the darkness hours. However, the fishing time was practically equal in both fleets (+/- 30-40 minutes) for all sets.

The following parameters were measured: species composition of catches; total length (L, mm) of all specimens of all species, caught by net with given mesh size; age and maturity stage of all specimens of flounder *(Platichthys flesus)*, turbot (*Scophthalmus maximus*), perch (*Perca fluviatilis*), smelt (*Osmerus eperlanus*)**,** and whitefish (*Coregonus lavaretus*) caught, if the total catch in numbers was not very high, or in sub-sample in case of big catch (above 100 specimens) total number and weight of species caught by each particular net.

The exception was herring, when it was presented in large numbers per catch. In this case 100 specimens of herring were measured. The specimens were distributed into length groups by 10 mm, e.g. $L_{20}$ include all specimens from L = 200 mm to L = 209 mm. All specimens in the catch were examined at least in one net of each mesh size category studied. A non-parametric test was used to reveal the trend of the changes in total number of fish species (Parring et al., 1997).

The effect of tanker ALAMBRA oil disaster on September, 16, 2000 on fish communities was specially monitored. The regular soak monitoring SE of Harbor was conducted shortly before this accident on September, 13-14 and after the accident an extra soak monitoring was carried out on September, 25-26.

To estimate the impact of this oil disaster on the fish, Fulton's coefficient, characterizing the body condition and often used as proxy indicator of feeding conditions of fish and other organisms (Dutil, Lambert & Chabot, 2003; Dadikjan, 1967; Nikolski, 1963; Anon., 1990), was employed. Fulton's coefficient **(CF)** was found separately for males and females as follows:

$$\mathbf{CF = w \times 100/Sl^3} \qquad (1),$$

where w is weight (g) and Sl is body length (cm) of without caudal fin (Mikelsaar, 1984).

The values of Fulton's coefficient follow certain seasonal dynamics. Therefore, in order to reveal any possible effect of ALAMBRA oil spill on feeding conditions of flounder, the coefficients observed during 10 days after the disaster were compared to those found during the same season in other years. All observed data of Fulton's coefficients were compared with theoretically calculated normal distribution using Pearson's chi-squared test (Campbell, 1989). Analysis of variance was used to compare the averages of samples, which were obtained in September in different years. Scheffe's test was used to reveal significance of the difference of Fulton's coefficients 10 days after the oil pollution in comparison with all the other samples in September (Parring et al., 1997). Using Bartlett's test the homogeneity of variances of Fulton's coefficient was tested. The Student's t-test for unequal variances was used as additional method to reveal the significance of mean differences of Fulton's coefficient on September, 13-14, 2000 and September, 25-26, 2000 as well as samples on September, 25-26, 2000 and October, 23, 2000.

The specific selectivity of species of gill nets as well as their dependence on the spatial and temporal peculiarities of the fishing process is well-known (Holst et al., 1999; Baranov 1948). As result, the selectivity of gill nets has an effect on the length and age composition of the catch. Commonly the selectivity curves of gill nets have a configuration of Gauss curve or close to it (Baranov, 1948; Hamley, 1975). However, some authors found insufficient adequacy of character of actual selectivity curve of gill nets flatfish fishing to Gauss one (Madsen et al., 1999; Treshchev, 1974). In our monitoring the last opinion was proven. Therefore, on the basis of the experimental data, collected during current monitoring, a modified method for the calculation of selectivity parameters of gill nets was implemented. The evidence, that for each length group $\mathbf{l_j}$ of flounder, there exists a certain mesh size $\mathbf{A_j}$ where the retaining efficiency is equal to the possible maximum limit in current case, should be acceptable. The retention rate of length class $\mathbf{l_i}$ for mesh size $\mathbf{A_j}$, was set equal to one. Relative retention rate of fish within length class $\mathbf{l_i}$ in other gill nets (with different mesh sizes) used in the monitoring fleet were then calculated as share to one. The following formula was used:

$$\mathbf{C_{liAj} = n_{jli} / n_{jli} \max} \qquad (2),$$

where: **C** $_{l_iA_j}$ - relative retention rate of the specimens in length-group $\mathbf{l_i}$ by net with mesh size $\mathbf{A_j}$;

**n** $_{jl_i}$ - actual number of specimens in length-group $\mathbf{l_i}$ caught by net with mesh size $\mathbf{A_j}$;

**n** $_{jl_i}$ **max** - maximum number of specimens in length group $\mathbf{l_i}$ caught by net with any certain mesh size $\mathbf{A_j}$ (probably maximum possible catch of flounder in length group $\mathbf{l_i}$ by net with any particular mesh size during single set).

Using the results of the calculations by Formula 2, the empirical selectivity curves were fitted. To adjust those curves, the polynomial regression analysis was used. The selectivity parameters of the "left size of selection curves" L25% (25% retention rate), L50% (50% retention rate), and L75% (75% retention rate) were then found for each mesh size by polynomial regression curves.

### *Fishery monitoring*

On the basis of monthly catch report from professional and semi-professional fishermen the catch database was created for three national fishing rectangles: 130 (Ihasalu Bay), 134 (Muuga Bay), and 138 (Tallinn Bay). The annual catches and catch per unit of effort (CPUE) dynamics by species were estimated separately for each of those three rectangles and by gears used. Differences of CPUE values between bays were analyzed.

## Results and discussion

### *Fish Communities*

Overall 29 marine, freshwater, and brackish water fish species were caught during monitoring (Table 1).

Annually observed number of species in both monitoring sites (NW and SE from Harbor) is given in Fig. 2 and the annual catch compositions in Fig. 3 and 4.

Quite well pronounced negative temporal trend in the number of fish species caught in the area was observed in NW monitoring area in 1994-1998. However, only slight negative trend could be revealed for the whole series, probably due to some increase in species diversity in most recent years (Fig. 2). According to non-parametric test a statistically sig-

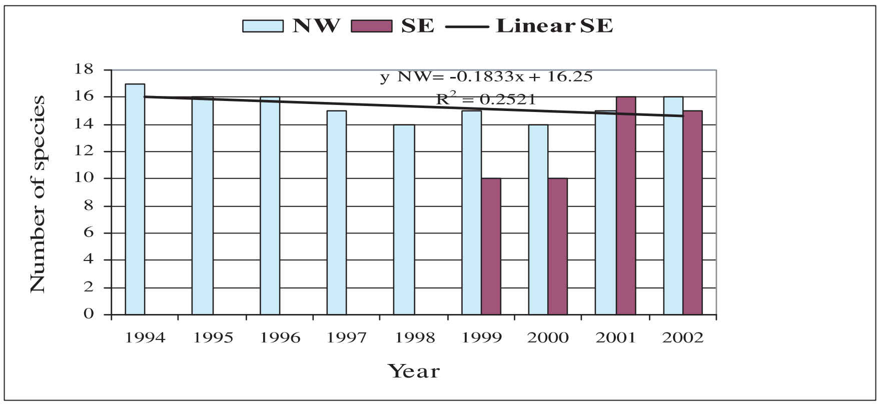


**Figure 2.** Number of species in monitoring gill net catches in NW (Randvere) and SE (Tahkumäe) of Muuga Harbor.

**Table 1.** List of the species caught during experimental catches in Muuga Bay.

| Marine species | Fresh and brackish water species | Migratory species |
|---|---|---|
| Flounder *Platichthys flesus* (Linnaeus, 1758), | Perch *Perca fluviatilis* (Linnaeus, 1758), | Sea trout *Salmo trutta trutta* (Linnaeus, 1758), |
| Turbot *Scophthalmus maximus* (Linnaeus, 1758), | Pikeperch *Lucioperca lucioperca* (Linnaeus, 1758), | Rainbow trout *Oncorhynchus mykiss*, |
| Baltic herring *Clupea harengus membras* (Linnaeus, 1761), | Pike *Esox lucius* (Linnaeus, 1758), | Whitefish *Coregonus lavaretus lavaretus* (Linnaeus, 1758), |
| Smelt *Osmerus eperlanus eperlanus* (Linnaeus, 1758), | Roach *Rutilus rutilus rutilus* (Linnaeus, 1758), | Vimba bream *Vimba vimba vimba* (Linnaeus, 1758), |
| Baltic sprat *Sprattus sprattus balticus* (Schneider, 1904), | Bleak *Alburnus alburnus* (Linnaeus, 1758), | Eel *Anguilla anguilla* (Linnaeus,1758). |
| Garfish *Belone belone belone* (Linnaeus, 1758), | Ruff *Acerina cernua* (Linnaeus, 1758), | |
| Eelpout *Zoarces viviparous* (Linnaeus, 1758), | Silver bream *Blicca bjoerkna bjoerkna* (Linnaeus, 1758), | |
| Baltic cod *Gadus morhua callarias* (Linnaeus, 1758), | Tench *Tinca tinca* (Linnaeus, 1758), | |
| Sandeel *Ammodytes tobianus* (Linnaeus, 1758), | Bream *Abramis brama* (Linnaeus, 1758). | |
| Lumpsucker *Cyclopterus lumpus* (Linnaeus, 1758), | | |
| Four-horn sculpin *Triglopsis-quadricornis quadricornis* (Linnaeus, 1758), | | |
| Bull-rout *Myoxocephalus scorpius scorpius* (Linnaeus, 1758), | | |
| Sea scorpion *Taurulus bubalis* (Euphrasen, 1786), | | |
| Stickleback *Gasterosteus aculeatus* (Linnaeus, 1758), | | |
| Straight nosed pipefish *Nerophis ophidon ophidian* (Linnaeus, 1758). | | |

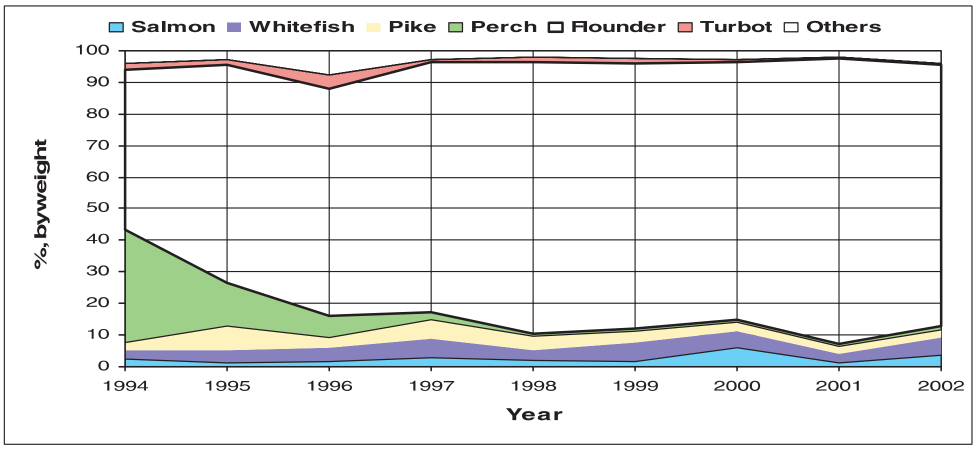


**Figure 3.** Catch composition of monitoring gill nets in NW (Randvere) in 1994-2002.

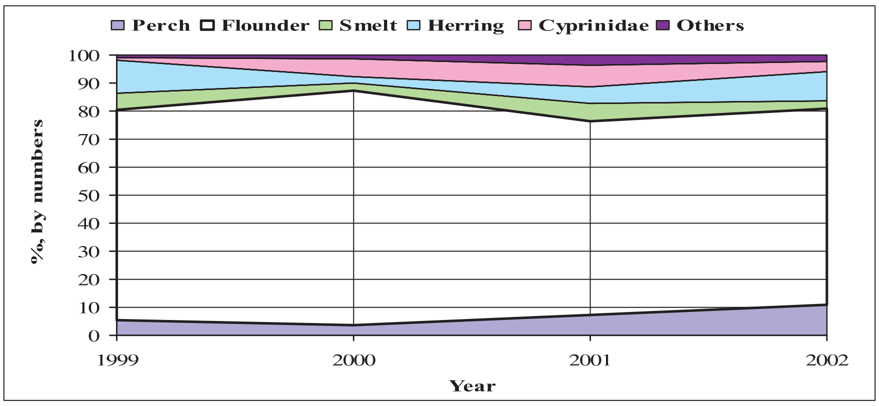


**Figure 4.** Catch composition of monitoring gill nets in SE (Tahkumäe) in 1999-2002.

nificant tendency in the number of species in 1994-2002 in Muuga Bay was not found. The monitoring period in SE monitoring site is far too short to estimate any tendency. In both NW and SE sites flounder was a highly dominant species, followed by perch and whitefish in NW, and by herring, perch, and smelt in SE (Fig. 3 and 4).

Slight increase in the occurrence of cyprinids (roach, bleak) in both sites of monitoring should be pointed out. Increase in cyprinid abundance has usually been an indicator of increasing trophyc status of water in the particular sea area (HELCOM., 1993; Neuman et al., 1988).

On the other hand, the occurrence of such marine species as lumpsucker, four-horn sculpin, bull-rout, and sea scorpion, known as clean water species, in monitoring catches allow to conclude that the environment conditions in the Bay of Muuga are not yet threatened by high pollution rate.

### *ALAMBRA case study*

Catch composition (except flounder) of both monitoring sites in SE of Muuga Harbor before and after the oil disaster in September and October 2000 are presented in Table 2.

**Table 2.** Changes of catch composition of monitoring gill nets (number of individuals per fleet) in SE Harbor before and after the ALAMBRA oil disaster on September, 16, 2000.

| Species/Date | Sept., 13-14 | | Sept., 26-27 | | Oct., 5-6 | | Oct., 23-24 | |
|---|---|---|---|---|---|---|---|---|
| | Area 2 | Area3 | Area 2 | Area3 | Area 2 | Area3 | Area 2 | Area3 |
| Perch | 12 | 7 | 21 | 8 | 8 | 3 | 9 | 1 |
| Vimba bream | 1 | 0 | 3 | 0 | 2 | 0 | 0 | 0 |
| Whitefish | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 |
| Smelt | 0 | 2 | 0 | 6 | 1 | 15 | 15 | 8 |
| Bleak | 0 | 0 | 23 | 0 | 1 | 0 | 0 | 0 |
| Roach | 0 | 0 | 72 | 2 | 4 | 0 | 3 | 0 |
| Ruff | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

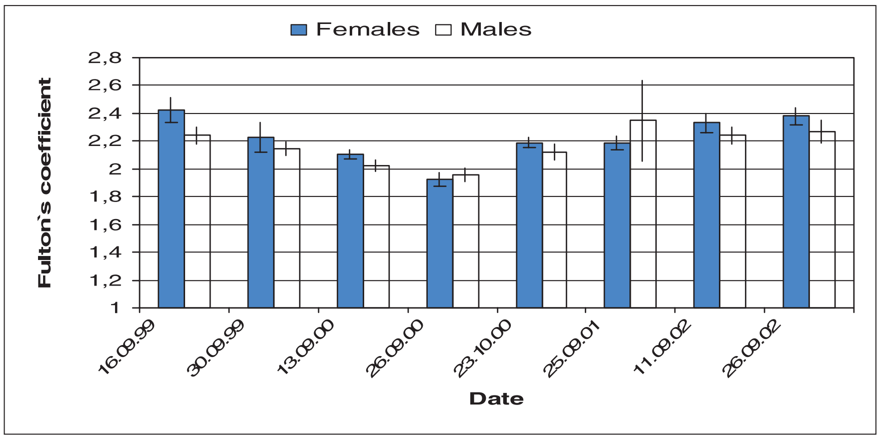


**Figure 5.** Fulton's coefficient (condition index) and 95% confidence intervals of flounder in Muuga Bay SE from Muuga Harbor in September 1999-2002 and October 2000.

The rapid increase in the abundance of bleak, a typical Harbor species, was observed after the oil disaster, particularly in the catches of monitoring fleet, located at about 500 meters from the south-eastern piers of Muuga Harbor (Fig. 1). Even more, the amount of roach was unexpectedly high. Later, in October, both bleak and roach numbers decreased again and became close to zero by the end of the month (Table 2). Therefore the very high amount of bleak and roach in monitoring catches within Site 2 immediately after the ALAMBRA accident can be explained as after-effect of oil pollution mainly. Obviously, the fish left the area where water was covered by oil.

The Fulton's coefficients of flounder with 95% confidence intervals in September and October 2000, compared with the respective values of September 1999, 2001, and 2002 are presented in Fig. 5. The lowest Fulton's coefficient for the whole monitoring period (1999-2002) in September was observed 10 days after the ALAMBRA accident. The difference was statistically significant for female flounders but not for male flounders (Scheffe test, $p < 0.05$) (Fig.5). Student's t-test revealed significant decrease of Fulton's coefficient in males as well as in females 10 days after oil pollution in comparison with the analysis on the September, 13-14, 2000, before the pollution.

As a result of special monitoring, obtained 10 days after the ALAMBRA disaster in Muuga Bay, remarkable changes in zoobenthos communities within the area close to Harbor and in SE direction up to about 2 kilometres were observed: the share of species more tolerant to pollution (*Hediste diversicolor* and *Corophium volutator*) increased noticeably in comparison with the standard monitoring data during 1999-2000 (Martin et al., 2001). However, these species are not important prey for flounder preferring the mussels *Macoma balthica* and *Mytilus edulis* (Shshukina, 1970).

The Fulton's coefficients of both male and female flounders increased significantly according to t-test and achieved values close to the "normal" level before the end of October 2000 (Fig. 5).

However, these changes in fish communities, mentioned above, could be influenced also by some natural processes in the unmonitored ecosystem of Muuga Bay in September 2000, such as: concentration of $O_2$, N and P, salinity etc. So, it should be concluded that despite the reactions of fish communities described above, no explicit immediate injurious effect of tanker ALAMBRA oil disaster in Muuga Harbor on fish communities was demonstrated.

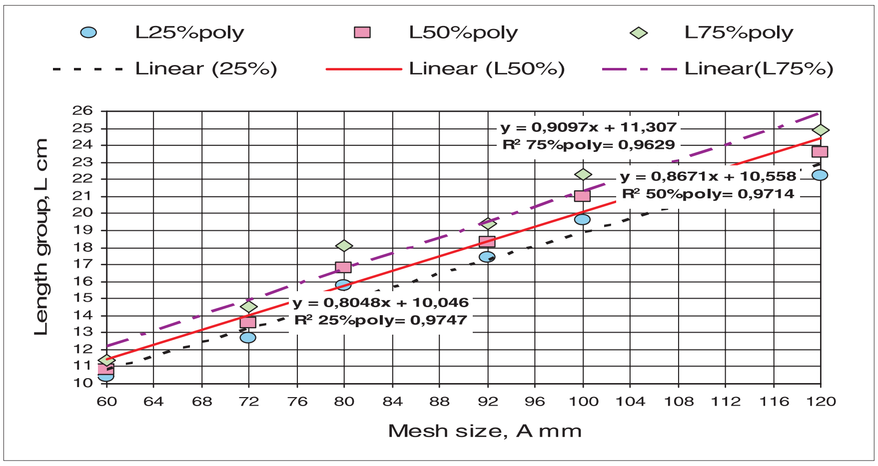


**Figure 6.** Linear regression curves of L25%, L50%, and L75% retention of flounder in gill nets, method modified by polynomial regression of experimental data.

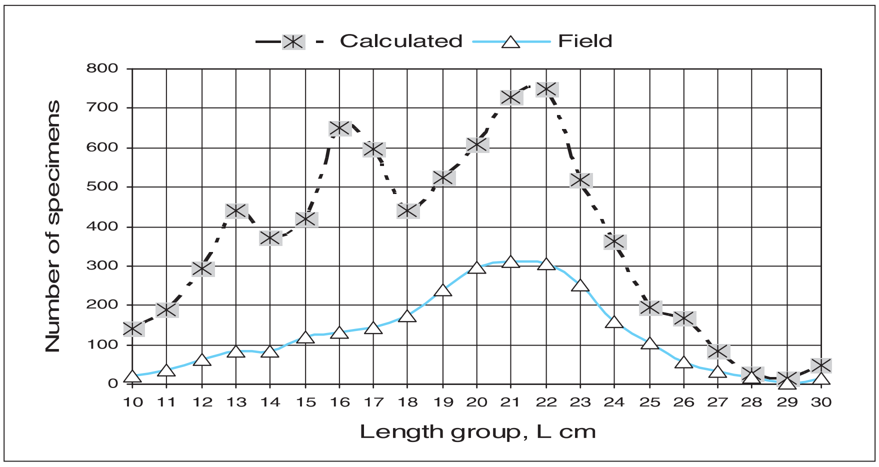


**Figure 7.** Total observed catch composition of flounder (field) and calculated number of specimens, actually contacted with all monitoring fleets in 1999-2001.

## *Impact of gill net selectivity*

Established relative selectivity parameters for flounder, the used monitoring gill nets of L25%, L50% and L75% mesh size are presented in Fig. 6.

The calculated length composition of flounder contacting the monitoring gill nets was significantly different ($p < 0.01$, F-test) from the registered catches by number of fishes within each length group. Furthermore, the distribution pattern of length groups was considerably different, it would be assigned in particular to the smallest ones with TL 10 – 18 cm corresponding to 1 and 2 year old flounder (Fig. 7). Thus, neglect of the selectivity of monitoring gears may be a serious source of errors in interpretation of gill net monitoring data.

## *Changes in commercial fishery*

The efficiency of fishing (CPUE) by both gill nets and traps in Tallinn, Muuga and Ihasalu bays are presented in Fig. 8 and 9. Similar to the monitoring gill nets in Muuga Bay, flounder was the predominant species in gill net catches in all the bays inspected. Herring and flounder were dominating in trap net fishery.

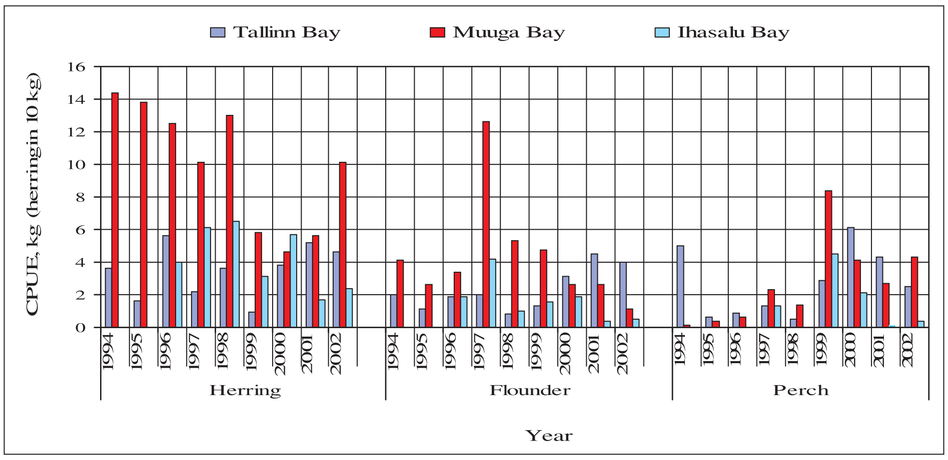


**Figure 8.** CPUE dynamics of commercial trap nets in Bay of Tallinn, Bay of Muuga, and Bay of Ihasalu in 1994-2002.

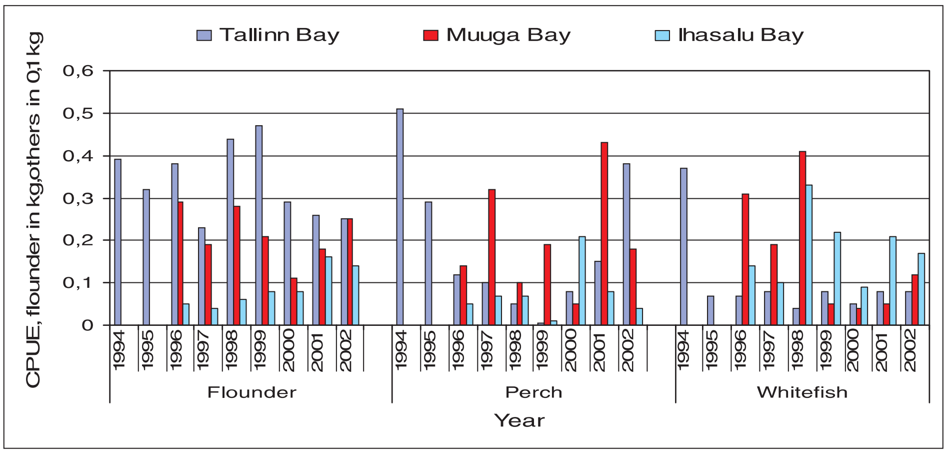


**Figure 9.** CPUE dynamics of commercial gill net fishery in the Bay of Tallinn, Bay of Muuga and Bay of Ihasalu in 1994-2002.

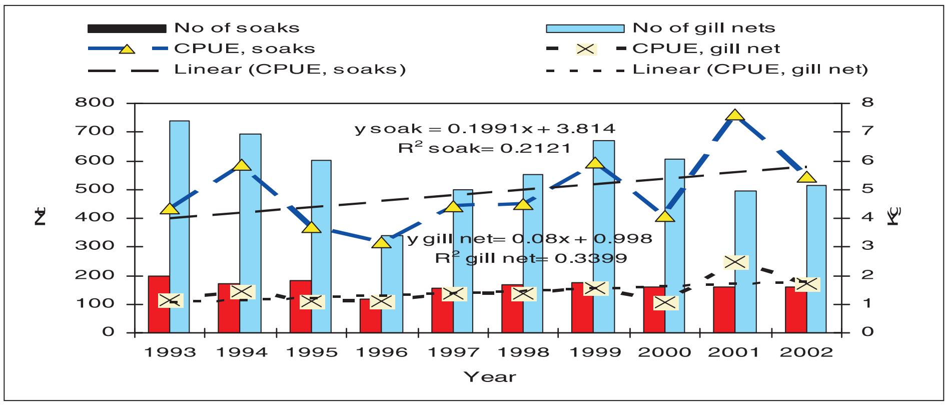


**Figure 10.** Intensity (number of soaks and gill nets) and efficiency (CPUE) of monitoring gill nets in NW of Muuga Harbor in 1994-2002.

The annual catch of both gill and trap nets fluctuated widely in all the three bays studied, but no clear trends were revealed. Furthermore, the same conclusion can be drawn in case of efficiency of the commercial fishery (Fig. 8 and 9). The total CPUE as well as the CPUE by species also fluctuated without any clear trend.

Exceptionally, some increase of flounder CPUE in gill net catches can be observed in Muuga and Ihasalu Bays. However, it may be the result of increase in flounder abundance in the Gulf of Finland, due to increased salinity (Nissling et al., 2001; Anon., 2003). The slight positive trend established for monitoring gill nets in NW site (monitoring area 1) for both catch per soak and catch per one gill net, is mainly caused by the increasing number of flounders in catches, also (Fig. 10).

The all-round similarity of fluctuations of commercial catches in Muuga Bay and Tallinn Bay, both suffering from a high impact of human activities and remarkably less affected Ihasalu Bay indicated during the last decade, that the impact of Muuga Harbor on fishery in Muuga Bay can not be clearly defined (yet).

### *Special remarks*

Investigations of bottom algae communities, carried out parallel to fish monitoring, showed a clearly decreasing trend in the number of taxes represented in the area close to the Harbor (Fig. 11) (Martin et al., 2001). It allows to assume that the reproduction conditions for many fish species, especially for herring, using the bottom algae as spawning substrate (Raid, 1985); have been seriously damaged since 1995 in this area. This effect on herring reproduction conditions has a long-term character and may become evident in the future years. Probably, the changes in bottom algae communities mentioned above are results of the overall eutrophication of Muuga Bay (Martin et al., 2001).

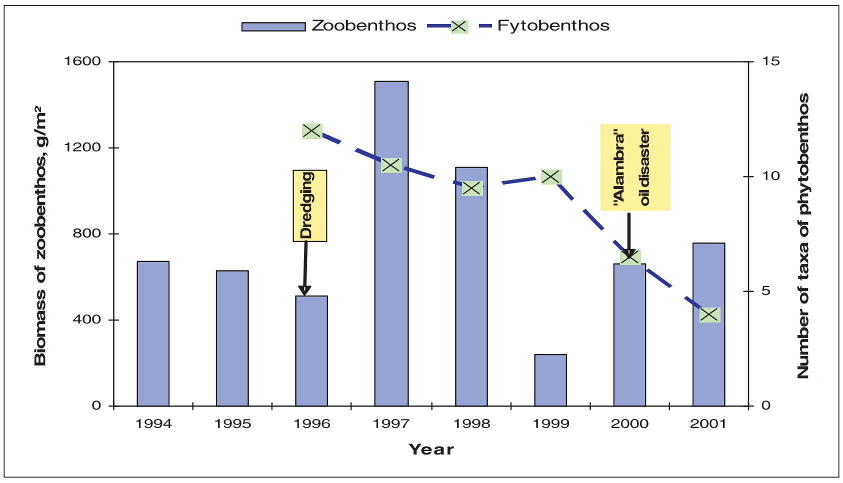


**Figure 11.** Changes of zoobenthos biomass (1994-2001) and phytobenthos species diversity (1996-2001) in Muuga Bay close to Muuga Harbor (by Martin et. al, 2001).

## Conclusions

Slightly increasing trend in the share of cyprinids (eutrophication indicators) like roach (*Rutilus rutilus*) and bleak (*Alburnus alburnus*) can be observed in the vicinity of the Muuga Harbor area. However, no direct and clearly defined impacts of Muuga Harbor on the composition of fish communities were revealed up to 2002.

The commercial catches in Muuga Bay fluctuated greatly in 1994 – 2002, but no clear differences with comparative catches in neighbouring bays were found, which could be explained by the activity of Muuga Harbor.

The slight positive trend in both the average catch per soak and in average catch per monitoring gill net in NW of Muuga Harbor was observed in 1994 – 2002, caused by increase in the abundance of flounder in the Gulf of Finland.

The lowest Fulton's coefficient of flounder, rapid increase in the abundance of roach and bleak was observed immediately after the oil spill due to ALAMBRA oil disaster.

The requirement to pay attention to the size-species selectivity of monitoring gear in further fish monitoring in Muuga Bay should be highlighted.

It is obvious that the effect of the vast sea Ports on the ecosystem is a long-term process and requires also continuous long-term monitoring. Therefore it is not surprising that the results of the present relatively short (less then 10 years) monitoring did not allow to draw solid conclusions concerning clear, and/or potential effects of Muuga Harbor.

However, the results clearly indicate that the overall monitoring program of Muuga Harbor impact on marine ecosystem should be continued and updated (i.e. water chemistry should be included), particularly in the light of the significant enlargement of the Harbor in 2003-2007.

## Acknowledgements

The authors are extremely grateful to Port of Tallinn Corp. and Muuga Harbor for financing the monitoring and technical support in 1995-2002.

We also thank all the participants in this monitoring: colleagues from MSI Prof. J. Elken, D. Sci. H. Arst, Ph. D. T. Kõuts & others, as well as colleagues from Estonian Marine Institute Ph. D. G. Martin, Ph. D. J. Kotta, Ph.D. I. Kotta and other marine biologists and also fishery biologists and technicians Ph. D. M. Kangur, Ms. V. Kasak**,** Ph. D. V. Kadakas, and Ms K. Grauziniene.

## References

**Anon.**, 2003. The condition of internationally regulated fish stocks in the Baltic Sea in 2002, the prognosis of fish stocks and suggestions to administrate the fish stocks in 2003; acoustic estimating of fish stocks. Research report no211-14/446 (27.07.2002). TU Estonian Marine Institute, Tallinn.

**Baranov, F. I.** 1948. Theory and assessment of fishing gear. Pishchepromizdat, Moscow, (in Russian).

**Campbell, R.C.** 1989. *Statistics for biologists*. Press Syndicate of the University of Cambridge, Cambridge.

**Dadikjan, M.G.** 1967. On food availability and nutrition coefficient as a criterion. *Journal of Ichthyology***, 7**, no **2(43)**, 338-347 (in Russian).

**Drevs, T., Jaanus, A., Vahtmäe, E.** 2003. On the effect of cyanobacterial blooms on the flounder stock in the Gulf of Finland. ICES CM 2003/**S:01**.

**Dutil, J.-D., Lambert, Y. & Chabot, D.** 2003. Winter and spring changes in condition factor and energy reserves of wild cod compared with changes observed during fooddeprivation in the laboratory. *ICES Journal of Marine Science,* **60**, 780-786.

**Hamley, J. M.** 1975. Review of gillnet selectivity. *J. Fish. Res. Board*. Can., **32,** 1943-1969.

HELCOM, 1993. First Assessment of the State of the Coastal Waters of the Baltic Sea. In *Baltic Sea Environ. Proc.* No **54**.

**Holst R., Wileman, D, Tschernij, V. & Madsen, N.** 2000. Statistical Modelling And Analysis Of Gill Net Size Selectivity Data. In Selectivity research in the Baltic Sea area (Thulin, J., ed.), pp.149-188. Meddelande Fran Havsfiskelaboratoriet, Lysekil.

**Järvekülg, A.** 1969. The influence of sewage water to the development of zoobenthos and capacity for self-purification in the bays of the Baltic Sea. In XIV Conference of the water-bodies of inner Baltic Sea (Andrusaitis, G.P., Katsalova, O.L., Kumsare, A.J., Laganovskaja, P.J., Leinerte, M.P., Matisone, M.N. & Salna, L.J., eds.), pp.57-62. Zinatne, Riga (in Russian).

**Kotta, I. & Kotta, J.** 1997. Changes in Zoobenthic Communities in Estonian Waters Between the 1970s and 1990s. An Example from the Southern coast of Saaremaa and Muuga Bay. In Proc. of the 14th Baltic Marine Biologists Symposium (Ojaveer, E., ed.) pp.70-80. Estonian Academy Publishers, Tallinn.

**Lumberg, A. & Ojaveer, H.** 1997. Zooplankton dynamics in Muuga and Kolga Bays in 1975-1992 with particular emphasis on the summer aspect. In Proc. of the 14th Baltic Marine Biologists Symposium (Ojaveer, E., ed.), pp.59-75. Estonian Academy Publishers, Tallinn.

**Madsen, N., Holst, R., Wileman, D. & Moth-Poulsen, T.** 1999. Size selectivity of sole gill nets fished in the North Sea. *Fish. Res*., **44**, 59-75.

**Martin, G, Kotta,I, Kotta, J., & Orav-Kotta, H.** 2001. Monitoring of seabottom composition. In Environmental Monitoring of Muuga Harbor, 2001. Report of contractual research for the Estonian Marine Institute no L20/01. TU Estonian Marine Institute, Tallinn.

**Mikelsaar, N.** 1958. Flounder of the Eastern Baltic Sea. Doctoral Thesis. Academy of Sciences of Estonian SSR, Tartu (in Russian).

**Mikelsaar, N.** 1984. Fish of Estonian SSR. Valgus, Tallinn.

**Neuman, E., Sandström, O. & Olsson, M.** 1988. Some aspects of the influence of pollution on the quantity and quality of the Baltic Sea fishery resources*. ICES, BAL*/No **28**, 1-8

**Nikolski, G. V.** 1963. *Fish Ecology.* Vyshaja shkola, Moscow (in Russian).

**Nissling, A., Westin, L., & Hjerne, O.** 2002. Reproductive success in relation to salinity for three flatfish species, dab (Limanda limanda), plaice (Pleuronectes platessa), and flounder (Pleuronectes flesus), in the brackish water Baltic Sea. *ICES Journal of Marine Science***, 59**, 93-108.

**Palm, T.** 1985. The potential impact of heavy metal concentrations in the waters of southern Gulf of Finland on Baltic herring stocks. Finn. Fish. Research, **6**, 71-76.

**Parring, A.-M., Vähi, M. & Käärik, E.** 1997. Principles of statistic data processing*.* Tartu University Library, Tartu.

**Raid, T.** 1985. The reproduction areas and ecology of Baltic herring in the early stages of development found in the Soviet zone of the Gulf of Finland. Finn. Fish. Research, **6**, 20-34.

**Shchukina, I. N.** 1970. Feeding and migration of flounder (*Pleuronectes flesus trachurus* Dunker). In Trudy Baltijskogo Nautchno-Issledovatelskogo Instituta Rybnogo Hozjajstva **IV** (Veldre, I, Lishev, M., Malikova, E., Polyakov, M., Pozhogina, P. & Shlimovich, B eds.), pp.361-378. Zvaigzne, Riga (in Russian).

**Treshchev, A. I.** 1974*. Fundamentals of selective fishery*. Pishchevaja promyshlennost, Moscow (in Russian).

**Vitinsh, M.A.** 1976. Some regularity of Flounder (*Platichthys flesus* L.) distribution and migrations in the Eastern and North-Eastern Baltic. *Fischerei-Forschung,* **14**, 39-48.

# Muutused kalakooslustes ja kalapüügis Muuga lahes 1994-2002. a. Seos võimalike Muuga sadama mõjudega.

## Resümee

Selgitamaks võimalikke Muuga sadama mõjusid kalakooslustele ja kalapüügile Muuga lahes teostati 1994-2002 seirepüüke mõrraga ja nakkevõrkudega sadamast loodes ja nakkevõrkudega sadamast kagus ning analüüsiti tööndusllike püüniste saake Muuga lahes ning võrdluseks ka Tallinna ja Ihasalu lahes.

Seirepüükide tulemuste põhjal hinnati muutusi saakides esinenud liikide koguarvus ning erinevate liikide suhtarvudes ja levikus. Samuti analüüsiti kalavarude dünaamikat kalaliikide kaupa toetudes seire- ja tööndusllike püüniste saagikuse (CPUE) andmetele.

Kuigi Muuga sadamast kagus võis seirepüükides täheldada teatud trendi karplaste osakaalu suurenemisele seirepüükides ja sadamast loodes avaldus vähemärgatav seirevõrkude saagikuse tõusu tendents, ei saa nimetatud muutusi otseselt seostada sadama tegevuse mõjuga.

Spetsiaalselt uuriti 16. septembril 2000.a. Muuga sadamas toimunud tanker ALAMRA naftareostuse mõju. Määratleti statistiliselt usaldatav tüsedusindeksi Fultoni koefitsiendi vähenemine lestal ning järsk särje ja viidika arvukse tõus seirevõrkude saagis 10 päeva pärast reostust, võrreldes reostusele vahetult eelneva seirepüügiga ja ka püükidega 1999, 2001 ning 2002.a. septembris. Mõlemad näitajad taandusid normaalsele tasemel 2000.a. oktoobri lõpuks.

Leiti, et püütavate kalakoondiste liigilise ja pikkuselise koosseisu määramisel võivad tekkida märgatavad ebatäpsused juhul, kui ei arvestata seirevõrkude selektiivsulikke omadusi sõltuvalt võrgu silmasuurusest.

# Environmental aspects requiring consideration in port building construction

**GABRIELA KOTSULIM & TARMO SÖÖT**

Estonian Maritime Academy, Mustakivi 25, 13 912 Tallinn, Estonia
Corresponding author: tarmo.soot@emara.ee

## Introduction

The economic development in Estonia has geared the establishment of new ports and extended the existant ones to increase their ability to transit goods or even handle entirely new cargoes. For example a new coal terminal was established at Muuga, Paldiski South Port started receiving tankers etc. Besides the major ports an increasingly bigger number of small ports will get to their feet. As setting up the ports includes a lot of work and big investments, their planning should be done with full seriousness and "homework" should be done properly to prevent later similar and as important issues. It means that also preliminary research should be conducted with no economy in mind, and it should be performed with sufficient profoundness. This research includes: ports and port constructions; loads influencing the port facilities and their research; modeling the port; hydrographic surveying; geodetic surveying; geotechnical research; research of shore processes; procedure of assessing the environmental impact of constructing the port facilities.

In order to plan the port constructions correctly one has to know the loads influencing them, the relief of sea bottom and mainland in the given area, geology and coastal processes, all that has been also researched in the given paper.

## Discussion

Port constructions include further below wharves, piers and breakwaters. As the port constructions can not be researched without any knowledge about their type and principles of planning their construction, the first chapter gives an overview on the classification of ports and port constructions, describing also the general principles of port projecting and operations related to port construction.

The use of different defensive buildings depends on various factors: purpose of the building, natural conditions, availability of local building materials, material base of carrying out the construction work, methods of realizing the work operations etc. Defensive building can also be designed only to protect the port from the waves or it is also at the inside edge of water basin as a mooring wharf.

In the process of constructing defensive buildings of the port it should be considered that they would protect the port maximally from waves and would also be at minimal cost. It is

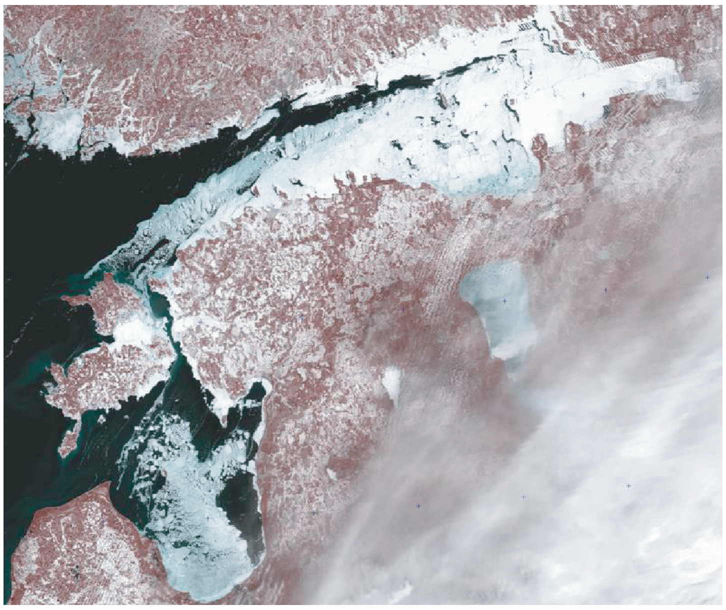

**Figure 1.** Satellite photo of ice conditions on 06.04.2003, in winter rarely occurring north-easterly storm has freed the Pärnu bay, and northern section of the Liivi Gulf and Gulf of Finland, as well as the central part of Väinamere. The formed pack ice hinders vessel traffic at the southern shore of the Gulf of Finland and in the center of the Liivi Gulf [Estonian Maritime Administration,2003].

advised to set up defensive buildings in the shortest possible time, so that unforeseen nature conditions would not damage them in the construction phase[Liiv, 2004].

The main natural loads influencing the port buildings are impact of waves, currents and ice. From the port construction perspective it is important that port facilities would not run into ice pressure. Wind and the accompanying waves dictate the primary demands on the placement of breakwaters and quays. Waves are also a vital agent in the transfer of bottom sediments and influence also the precision of hydrographic bottom relief research.


**Figure 2.** Icebreaker Tarmo

**Figure 3.** Obtaining a drilling core for ice thickness measurements.

**Ice.** At port building planning it is expedient to have an overview on ice conditions in a given location, which can be obtained from Pilot books, research data of specific relevant institutions, from earlier research data etc. Ice conditions are in direct dependence on seawater temperature and therefore also on the atmospheric temperature regime.

Depending on the wind direction, drift ice fills at certain times the bays, then drifts out of them or accumulates (becomes pack ice) in some sections of the bay or at the shore.

Ice research consists of measurements of ice and snow thickness, ice and water temperature, porosity, thickness of pack ice and snow layer covering the ice.

**Waves**. An overview on wave patterns can be obtained by the data of the nearest observation station. It is based on preferably twice a day conducted visual observations during the longest possible time period. A longer temporal progression is more reliable. Obtained data will be specified by direct measurements and modelling. In order to conduct the research on port building, it is necessary to know the maximum wave heights, formed in storm conditions. In order to assess the maximum height of waves in a given area it is expedient to know about the local extreme winds as well as global wind patterns[Estonian Marine Institute, 2000].

In case of wave research the following equipment can be used: pressure transducer that allows to measure only the height and period of wave. There are also buoys that will add the direction. Both methods provide wave characteristics in a single location. In order to obtain the wave field in a bay or a bigger seatract, e.g. within a range of 10 km, radars are used, that are divided into analogous and digital radars.

Then the waves will also be captured nowadays by satellite, especially by radar satellites like JASON, TOPEX POSEIDON etc. Yet the latter functions successfully mainly in the ocean. In the Baltic Sea it has been applied rather rarely, for it is a costly method.

Modelling that can not be conducted without a quality field research is used as one stage of planning the port location and placement of port buildings. In meteorology (wind patterns, air temperature, humidity, visibility, fog, precipitation) an analysis will be made based upon the data of the meteorological station, located nearest to the place, whereby measurements must have been conducted at least for 10 years. The longest time span (50-100 years) is of course better, but it all depends on the duration of the planned exploitation time of the building. Water level regime is also determined based on measurements, whereby it is important to know the extreme water levels and how long the water remains above (or sometimes also below) a certain level [Estonian Maritime Administration, 2003].

This crucial water level amounts e.g. in case of Tallinn Vanasadam to + 80cm, the absolute maximum at the same time being + 152cm and minimum - 95cm.

Modelling is basically done with a computer, that is cheaper, but also physical modelling has been used. Physical and mathematical port models are important aids that enable the projector to:

– determine wave heights in a port;

– elect the best location for water constructions, that they would provide sufficient protection from waves;

– reckon with unusual waves and currents in entrance channel;

– elect the best and safest location for port entrance route;

– plan the protection of port entrance route from sediments;

– observe flood and ice conditions;

– reckon with sediments carried by river current;

choose the optimal constructional solution for the best kind of port protection at minimal cost[Coastal Engineering Manual, 2002].

Physical modelling yields excellent results in the solution process, but it is expensive and time consuming, for it presumes testing the physical model built in a certain scale. Physical model is used when mathematical models yield controversial or too aberrant results (fig. 3.1). Usually mathematical modelling and comparison of the results with the actual natural condition will be adequate enough.

In the process of planning the port buildings it is especially vital to know the relief of seabottom and Chapter 4 gives a detailed outline on the hydrographic surveying of seabottom.

There are no special precision normative for the hydrographic surveying operations conducted as part of water construction research. Therefore the normative of surveying operations conducted for navigational purposes should be adjusted. But generally it should be considered that these surveys are made in ports and at smaller depths, thus special class surveying should be resorted to.

Surveying norms proceed first of all from the intensity of navigation in the surveyed area and its relevance; size and draught of the used vessels, depth of seabottom, intricacy of relief and potential danger. The whole data processing is done only in digital form to avoid subjective errors. Proceeding from these fundamental principles there are four precision classes or survey data with four different quality levels.

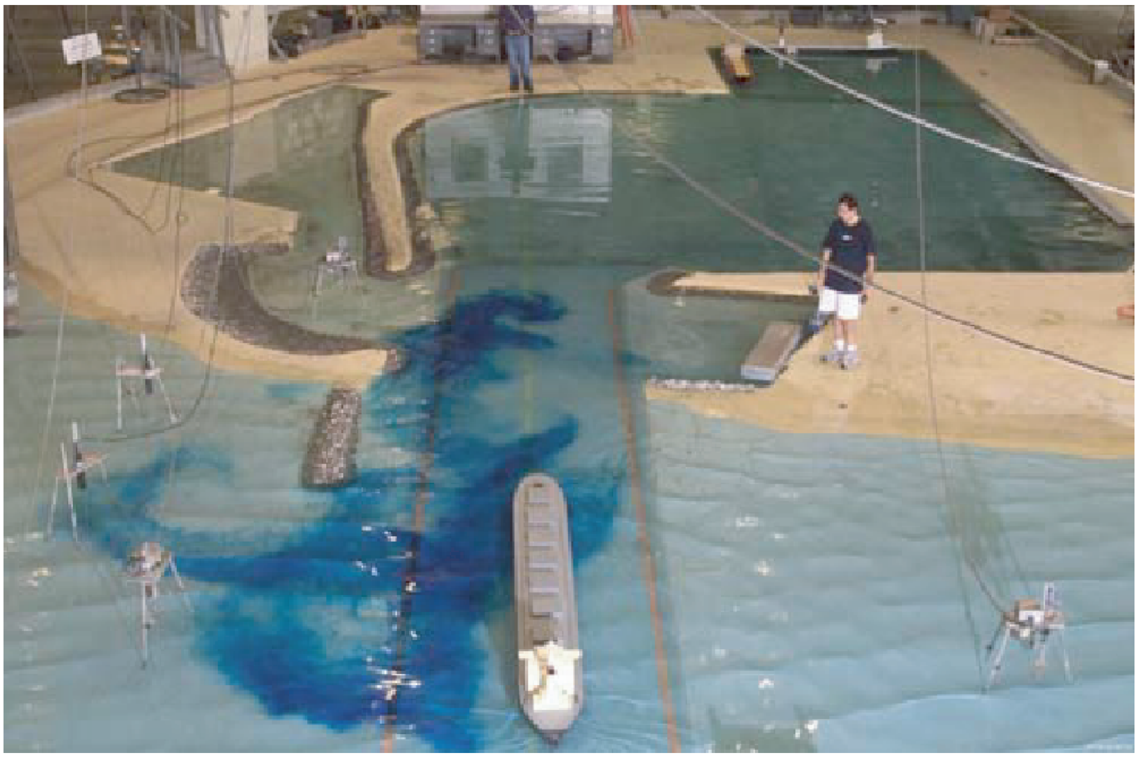

**Figure 4.** Three dimensional physical modelling, two ship models are used [Coastal Engineering Manual, 2002].

In case of fairways with intense navigation, harbor basins or anchorages, and after dredging operations a full or continual survey of seabottom is required. Port basins, port entrances, busy fairways where the draught of vessels has minimum difference from fairway depths and most relevant anchorages, should be surveyed according to the higher, i.d. special class precision requirements. Sound travel velocity measurements conducted several times per every measuring day and respective depth data adjustment are mandatory. It is advisable to use first of all DGPS or RTK GPS devices for obtaining position fixes, but in offshore shallow water also precise electrontachymeters and self-regulating Polartrack-type (distance-azimuth) devices are used. In recently dredged areas the research of sediments is a must. A heave-roll-pitch – HRP of a vessel and gyrocompass are used as additional devices[Vaher, 2001].

If there is anything doubtful after hydrographic surveying, diver research is used to obtain precise results.

Based upon the survey results it is possible to draw a large scale plan of the port area where the locations of buildings will be planned and required dredging volumes will be calculated. To obtain correct results for crucial hydrographic surveys, also diver research will be resorted to.

Besides the hydrographic surveys also a geodetic survey of land area that is described in Chapter 5, must be conducted. Geodetic operations are performed to make the topographic and hydrographic plans. This includes also tracing the approach railways and roads, electric and transmission lines, underground engineering networks and other line erections. For water construction research also the following geodetic operations can be conducted and may be deemed necessary: elaborating the mapping material of the port location and solving the issue of connecting roads, establishment of planned and altitudinal basic network and its securing, topographic surveying to obtain the projecting base for the port land area, tracing the final versions of connecting roads, observations of deformations during construction and exploitation.

Geotechnical research is vital for the choice of port building construction. The goal of geotechnical operations is to obtain source data for projecting and building the jetty/breakwaters/pier in the form of geologic data and surface qualities and finding out about the conditions for sea channel dredging.

Geotechnical research will ascertain the density, thickness, boundaries and depths of various layers. The possibility to dredge a certain area is researched and it will be also ascertained which technology to adopt to conduct dredging, i.e. whether pumping, digging or pyrotechnical operations.

The research is conducted on a chosen area and it consists of several stages: planning of operations, study and analysis of the existent material, engineering-geological field research, geophysical operations, field tests of surfaces, stationary observations, laboratory research, writing the report and passing the final engineering-geological decision.

In case of need also diver research will be resorted to.

The activity of shore processes influences the stability of port constructions and the choice of their location from the perspective of the shore processes is described briefly in Chapter 7.

The research of coastal processes is essential, for filling in may cause the sedimentation of the area in front of port building, that may give rise to annual vast dredging costs. Shore processes should be also researched to guarantee the stability of shore buildings, to adopt the measures against the outflow of bottom material from beneath the building.

Procedure of assessing environmental impacts should be conducted in the course of erecting every new port building. Chapter 8 gives a brief description of that.

In order to find out about the impact of building operations on the environment, the range of this impact and adopt the opportunity to avoid or alleviate these impacts and the best solution option for realizing the planned activities, environmental impact assessment needs to be carried out. Port building projection and environmental impact assessment interact and if environmental impact is unacceptable, there may be a need to change the project[http://www.sisemin.gov.ee].

In the course of port building and exploitation the risk regarding vulnerable environment increases essentially by the following factors:

Risk to environmental balance within the port construction process, including:

– Dredging and filling operations at building the hydrotechnical constructions, that may cause considerable extensive distribution of sediments and finer fractions of filling materials.
– Specific noise at the construction stage (blasts, constructing the foundations of wharves and breakwaters) and the related disturbance to fishes, birds and seals.
– Possible entrance of environmentally extraneous materials (cement, asphalt, immersion and finishing materials etc.) into vulnerable environment.

– Probable alteration of current circulation and wave impact and resultant disruption of the dynamic balance of shore sediments.
– Disruption of land flora balance in the process of establishing the connection roads.

Risk to environment during port exploitation, including:

– Danger of probable oil pollution due to incidents occurring both in the fairway and near the port (damage, leak of tankers, illegal pumping of bilge water to the sea etc.).
– Noise created by vessels and impact of fast ferry generated waves to fairway and shores near the port that may be manifested as quickening the coastal erosion and also disturbance to nesting birds. The impact is particularly big in coastal sections that are hidden from the natural waves.
– Pollution of seawater by sewage from vessels and the port.

Disrupting the local groundwater regime (incl. drying the wells and smaller water bodies, penetration of seawater to groundwater reservoir etc.) due to the establishment of the required water reaches[Estonian Marine Institute, 2002. E-Consult Co, 2003. http://www.sisemin.gov.ee].

Considering all the above mentioned issues, there is a need to obtain already at the research stage exhaustive topographic, hydrographic, geologic and hydrometeorologic materials and plot all the required information (e.g. habitats of seafloor flora, invertebrate fishes, birds and sea mammals) to the topographic maps and hydrographic charts. Periodic monitoring of groundwater should be conducted during building and after it and monitoring of erosion process should be arranged.

In conclusion it can be stated that several problems related to port buildings are caused namely by faulty analysis and estimation of their location. With no proper consideration of the planned site of port facilities it is impossible to set up a modern port and use it effectively. Therefore extensive research should be conducted already in the process of choosing the proper location for the port.

## References

Coastal Engineering Manual. 2002. Part II. Harbor Hydrodynamics. USA.

E – Consult Co. 2003. Environmental assessment of the construction of hydrotechnical buildings - Sillamäe port pier and wharf. Assignment no E885.

Estonian Maritime Administration. 2003. Estonian Pilot Book

Estonian Marine Institute. 2000. Hydrodynamic and geologic research of probable locations of the Saaremaa deep draught port. Scienctific-technical report.

Estonian Marine Institute, 2002. Assessment of environmental impacts of dredging operations in Rohuneeme pilot port.

**Vahter, K.** 2001 Surveying with multi-channel echo sounder at Hobulaiu. Diploma paper.

**Liiv, U.** 2004. Hydrotechnical marine constructions. Lecture notes.

http://www.sisemin.gov.ee/atp/failid/keskkmoj_hindamine.rtf

http://www.envir.ee/keskkonnakorraldus/hindamine.html

## Arvestamist vajavad keskkonnaaspektid sadamaehitiste projekteerimisel


## Resümee

Sadamaehitise projekteerimine ja keskkonnamõjude hindamine mõjutavad üksteist ja kui keskkonnamõjud on vastuvõetamatud, võib osutuda vajalikuks projekti muuta.

Sadama ehituse ja ekspluatatsiooni käigus suureneb oluliselt risk tundlikule keskkonnale järgmiste tegurite kaudu:

– Süvendus- ja täitmistööd hüdrotehniliste ehituste rajamisel, mille tulemusena setete ja täitematerjalide peenemad fraktsioonid võivad levida ehituspaigast märkimisväärsele kaugusele.

– Spetsiifiline müra ehitus- ja ekspluatatsiooni järgus ning sellega seotud kalade, lindude ja hüljeste häirimine.

– Kasutatavate keskkonnale võõraste materjalide võimalik sattumine tundlikku keskkonda.

– Hoovuste tsirkulatsiooni ja lainete mõju võimalik muutumine ning sellest tingitud rannasetete dünaamilise tasakaalu rikkumine.

– Maapealse taimestiku tasakaalu rikkumine ühendusteede rajamise käigus.

– Võimaliku õlireostuse leviku oht nii laevateel kui ka sadama lähistel aset leidvate intsidentide tagajärjel.

– Merevee reostamine laevade ja sadama heitvetega.

– Kohaliku põhjavee režiimi rikkumine sadama veevarustuseks vajalike veehaarete rajamise tagajärjel.

Arvestades kõiki eeltoodud küsimusi tuleb juba uurimistööde staadiumis hankida ammendavad topograafilised, hüdrograafilised, geoloogilised, hüdrometeoroloogilised materjalid ja kanda topograafilistele ja hüdrograafilistele kaartidele kogu vajalik info.

Selleks et selgitada välja ehitustegevuse mõju keskkonnale, selle mõju ulatus ning võtta kasutusele nende mõjude vältimise või leevendamise võimalus ja sobivaim lahendusvariant kavandatava tegevuse elluviimiseks, tuleb läbi viia keskkonnamõjude hindamise protsess. Sadamaehitise projekteerimine ja keskkonnamõjude hindamine mõjutavad teineteist.

Ehituse käigus ja peale ehituse lõppu tuleks teostada põhjavete perioodilist seiret ning korraldada erosiooniprotsessi seiret.

Kokkuvõtteks võib öelda, paljude probleemide põhjusteks sadamaehitistel on just puudulik asukoha keskkonna iseloomu analüüsimine ja sellega arvestamine. Arvestamata õigesti kuhu sadamarajatised kavandatakse, ei ole võimalik rajada ja efektiivselt kasutada kaasaegset sadamat. Seetõttu tuleb juba sadama asukoha valimisel läbi viia laiaulatuslikud uuringud.

# Project of Kuivastu Yacht Port approach route

**TARMO SÖÖT[1], MARINA ABOLTÕN[2]**

[1] Estonian Maritime Academy, Mustakivi 25, 13912 Tallinn, tarmo.soot@gmail.com
[2] Graduate hydrography student of Estonian Maritime Academy (2005)

## 1. Introduction

Estonia is a rapidly developing marine country. Multitude of ports create favorable prerequisites for the development of marine industry, fishing industry and various accompanying fields (marine transport, ship- and boatbuilding and repair, marine tourism, processing of marine products etc.).

Marine tourism is a field that has merited increasing attention. In recent years the demand on sailing services has essentially increased, both because of hobby mariners and marine tourists. Also the number of yacht clubs (in Tallinn, Pärnu, Haapsalu, Saaremaa etc.) increased constantly and they have been operated efficiently.

Unfortunately also the disasters with pleasure boats have become more frequent in Estonian coastal sea and ports. Although the disasters with small craft do not include as a rule extensive marine pollution, local environmental damages can still be noticeable. Especially in cases when disaster occurs in such a marine area like Väinameri that is fully covered by two Natura 2000 areas: SPA Väinameri (code EE0040001) and pSCI Väinameri (code EE004002) (RTL 2004,111,1758).

At present the yachts and other small craft sailing in Suure-Väina region have no opportunity to shelter in case of storm at a refuge harbor that would meet the present-days requirements. Entrance and stay of yachts in Virtsu and especially Kuivastu ports at the present level of marine safety in these ports has been related to certain heightened navigational risks.

Therefore there is a plan to set up a yacht port with 50 berths at Kuivastu port, at the island of Muhu, that should first of all justify itself namely as refuge harbor of yachts. The consortium BCEOM & Aavo and Riina Raig Project Ltd. (BCEOM &Aavo and Riina Raig 2005) drew up a draft project of the refuge harbor (figure 1). At present the technical preparation of operations continues. In the process of preparatory works a petition to the European Commission Communion Fund is made to finance the construction works. The construction works are going to begin at the earliest in 2006.

The purpose of present research is to project the approach of the above mentioned yacht harbor and its navigational marking, proceeding from the draft project. It was considered that there is a Natura 2000 area and the realization of a project should not cause an essential impact on the wholeness, key species and purposes of both above mentioned Natura 2000 areas (EC Environment DG, 2001).

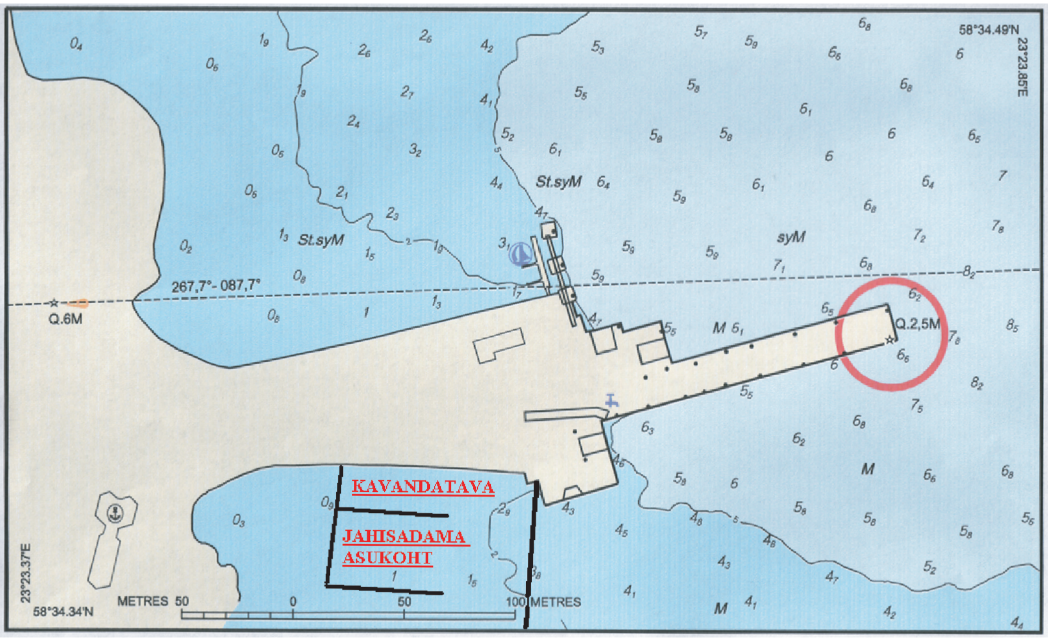


**Figure 1.** Site of the planned yacht harbor.

## 2. General characterization of project area

Kuivastu port is located 3.4 nautical miles (M) SSW of the southern coast of islnad Kessulaiu, on the eastern coast of Muhu island. Today the main task of the port is to serve the ferries and passengers and load the cargoes, including also serving the pleasure craft mariners and marine tourists when weather conditions allow it. The port consists of a 310 m long pier, stretching in an eastward direction with 4 jetties attached to it with the total length of 328 m. Kuivastu port has a ferry connection with Virtsu.

Ferry traffic is year-round, the traffic of cargo and pleasure boats depending on ice conditions in the Gulf of Riga and Väinamere, lasting predominantly from the second decade of April to the end of November. The parameters of the biggest vessel that can be received are:100×20×4,5m. The port in its present form is only protected from the westerlies winds. Therefore Kuivastu port can□t be used for the mooring of ferries with northern winds above 18 m/s and southern winds above 15 m/s (Saarte Liinid Ltd., 2004).

No regular hydrometeorologic observations have been conducted in Kuivastu port. In the nearest stationary observation site – Virtsu hydrometeorologic station, meteorological observations have been conducted over 40 years and ice conditions have been observed already since the winter of 1929/30. Besides, researchers from various scientific institutes have conducted episodic observations near the Kuivastu port (Suursaar 2001).

Therefore the data of Virtsu hydrometeorologic station was used to characterize the winds of Kuivastu port. It demonstrated that during the whole observation period and basically namely during winter months southerlies winds prevailed here, especially the south-westerlies (SW) winds. In spring and summer there are also often the north-westerlies (NW) winds. Wind blows the least from the north (N), north-east (NE) and east (E).

The average monthly wind speed has been equal in Suur-Väin strait area to 4.5 – 5.7 m/s. The strongest wind blows in October-November. At that time wind speed can amount up to 24 m/s. The biggest amount of calm days is from February to March, but also some days of severe wind intervene into this period (E-Consult LLC, 1997).

Although the winds of Virtsu and Kuivastu can differ diametrically, it is still evident that in case of severe wind, the data obtained in Virtsu meteorologic station can also be used to describe the winds in Kuivastu area. Regarding the Kuivastu port south-easterlies, southerlies and north-westerlies endanger navigation the most. The probability of northerlies, north-easterlies and easterlies is the highest during summer months and their speed seldom exceeds that of 15 m/s (E-Consult LCC, 1997).

There is no permanent current in the given area. The motion occurs whether in SSE or NNW direction. It can be stated based upon the results of the present measurements that the average speed of a current in Suur-Väin strait is 25 cm/s. The currents in Suur-Väin strait depend on wind direction and level of seawater in Gulf of Riga and Väinamere (E-Consult LCC, 1997). The force of currents and frequent change of their direction create rather complicated conditions for navigation in Suur-Väin strait, especially in case of port maneuvres.

The following extreme levels of seawater have been measured in the Virtsu observation site (in cm above or below the Kronstadt zero ):

max. 18.10.1967 +152 cm

min. 09.11.1959 -122 cm

The average annual fluctuations of water level are ± 40 cm.

Table 1 demonstrates the data regarding waves between the Virtsu and Kuivastu ports (E-Consult LCC, 1997).

The biggest waves reach the Suur-Väin strait during southern storms when wave height of a 1% guarantee should theoretically amount to 2.9 m. In this case high swell, spreading along relatively deep-lying level to the strait and the local wind wave join. The depth of strait (8 -10 m) limits the development of a wave, therefore the maximum observed wave height amounts to 2.5 m in the strait. North of Viirelaid waves acquire a western direction due to refraction and then move straight towards the Kuivastu port. With the decrease of

**Table 1.** Wave parameters at Virtsu – Kuivastu route.

| Wave parameter | Wind direction | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N | NE | E | SE | S | SW | W | NW |
| Wind speed V (m/s) | 21 – 24 | 18 – 20 | 14 – 17 | 18 – 20 | 18 – 20 | 18 – 20 | 18 – 20 | 18 – 20 |
| $\tau$ (s) | 3,2 | 3,2 | 3,2 | 3,2 | 3,2 | 3,2 | 3,2 | 3,2 |
| h 5% (m) | 1,6-1,8 | 1,6-1,8 | 1,6-1,8 | 1,6-1,8 | 1,9-2,1 | 1,6-1,8 | 1,6-1,8 | 1,6-1,8 |
| $\lambda$ (m) | 14-16 | 14-16 | 20 | 14-16 | 20 | 14-16 | 14-16 | 14-16 |
| prevailing h (m) | 1,0-1,4 | 1,0-1,2 | 1,0-1,2 | 1,0-1,2 | 1,0-1,5 | 0,5-0,8 | 0,5-0,8 | 1,0-1,6 |
| prevailing $\lambda$ (s) | 3,0 | 2,6 | 2,9 | 3,0 | 2,8 | 2,2 | 2,2 | 3,1 |

when: V (m/s) - wind speed;
$\tau$ (s) - average wave period;
h 5%(m) - 5 % of guaranteed wave height;
$\lambda$ (m) - wave length.

depth of the sea the wave height decreases to 1,5 – 2,0 meters. In the open Kuivastu port operations will be significantly disturbed in case of such waves (E-Consult LCC, 1997).

Considering the shallow water and narrow shape of the strait, there will be no waves of similar height from any other direction, neither will there be any from the north, for the fletch distance will be too short.

Väinameri is prevalently covered by fast ice in winter. The average thickness of ice in Suur-Väin strait is appr. 42 cm (Estonian Pilot Book, 2003).

The operation area is geologically located at the shore of Suur-Väin strait and is in the form of glacier abrasion area. Marine clay and moraine form the basic part of residual soil. Ordovician limestone lies in the floor of a seam of residual soil (E-Consult LCC, 1997).

## 3. Waterway projection

*Waterway* or fairway is understood here as navigationally safe fairway between two or more locations, of a sufficient depth and width and located whether at sea or any other water body. The technical projection of waterway consists generally of the following steps:

– determination of waterway project vessel or vessels,

– projecting the position of waterway,

– determining the width of waterway,

– determining the required reserve water/trawling depth,

– projecting the seamarks.

The term “Project vessel” refers to a maximum sized fully loaded vessel that uses the waterway on a regular basis (Waterway project...., 2002). At the present case the waterway is projected for small craft, consisting mostly of pleasure crafts, yachts and small fishing vessels and boats. The length of those vessels and boats can extend from 3.6 m to 60 m, but usually remains within the range of 9-14 m. The maximum width can amount to 4.6 m (Keskküla, 2005).

The following project vessel parameters were adopted specifically for Kuivastu yacht port.

| | |
|---|---|
| Length: | 18 m |
| Width: | 4,5 m |
| Draft: | 2,5 m |

It is a well-known fact that nagivating the vessel on waterway is the easier, more accurate and safe, the more direct the waterway is. While navigating along a direct waterway, the position of a vessel within the range of waterway can be easily regulated by means of leading lines and lights and lateral marking of waterway.

The waterway projected to Kuivastu yacht port runs entirely straight. The waterway leading to port begins from ESE, runs in a direction of 290,7º – 110,7º and is 0.6 km (0.32 nautical miles) long.

Sufficiently intense navigation takes place yearlong in Kuivastu port area and its vicinity, particularly in summer when the traffic of sailing yachts and launches will increase on waterways. In case waterway planning will be considered from this perspective, it would be reasonable to plan a two-way approach for the yacht port with 50 berths. But as the cost of the project is determined greatly namely by the volume of dredging operations that should be conducted in the given case within the full water area of the yacht port and partially also in the approach area, it is economically more cost-effective to plan a one-way waterway to Kuivastu yacht port. Also the average count of visitation of the nearby Virtsu port by small craft has been considered (~200 vessels a year).

The cross section of a one-way waterway (figure 2) is conditionally divided to stretches (Keskküla 2002)

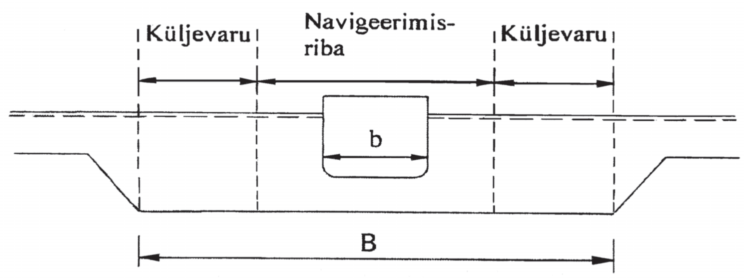


**Figure 2.** Cross section of a one-way waterway.

Navigeerimisriba **–** navigation stretch – portion of cross section, used by vessel.
Küljevaru **–** side reserve – reserve distance between the vessel and channel edge or between the vessel and shallow.

At the same time, yachts and launches should have no difficulties entering or leaving the port. Then it may be also considered that 200 m from the planned yacht port water depths are sufficiently deep enough for the yacht or launch desiring to enter the port to navigate there safely and in case of need give way to the yacht leaving the port.

The width of a one-way waterway is estimated as follows (Keskküla 2002)

$$B = b_n + 2b_l \qquad (1)$$

$$b_n = b + b_m + b_s + b_p + b_t + b_e + b_v ,$$

where b – width of project vessel [m]

$b_n$ – navigation stretch (waterway area used by vessel) [m]
$b_m$ – widening of navigation stretch, due to swapping [m]
$b_s$ – widening of navigation stretch, due to wind or current [m]
$b_p$ – widening of navigation stretch, due to rough bottom [m]
$b_t$ – widening of navigation stretch, due to lack of reserve water [m]
$b_e$ – inaccuracy of position fixing [m]
$b_v$ – widening of navigation stretch, due to dangerous cargo [m]
$b_l$ – side reserve [m]

b = 4,5 m
$b_m$ = 0,5b = 0,5 * 4,5 = 2,25 m ; navigability of vessel is average
$b_s$ = 0,5b = 0,5 * 4,5 = 2,25 m ; average wind speed is 5 – 6 m/s, drift considered up to 5°

$b_p = 0{,}1b = 0{,}1 * 4{,}5 = 0{,}45$ m ; uneven, soft bottom; water depth below 1,5 * T (vessel draft) or 1,5 * 2,5 = 3,75 m

$b_t = 0{,}2b = 0{,}2 * 4{,}5 = 0{,}9$ m ; water depth is in a range of 1,15T – 1,5T or 2,875 m – 3,75 m

$b_e = 0{,}1b = 0{,}1 * 4{,}5 = 0{,}45$ m ; navigational marking of waterway is good

$b_v = 0{,}0b = 0$ m ; only related to passengers

$b_l = 0{,}5b = 0{,}5 * 4{,}5 = 2{,}25$ m ; speed of vessel is 4 – 6 knots

$b_n = 4{,}5 + 2{,}25 + 2{,}25 + 0{,}45 + 0{,}9 + 0{,}45 = 10{,}8$ m

$B = 10{,}8 + 2 * 2{,}25 = 15{,}3$ m

Therefore, at present the width of one-way waterway, in case of a 4.5 m project vessel, amounted to 15.3 m. The required depth of waterway is estimated, proceeding from the draft and speed of project vessel, local state of the sea and the proportion of waterway and vessel cross section sizes (figure 3). If projected waterway is open to high sea impact (e.g. waves), then the minimal reserve water of a waterway is generally estimated approximately + 20% of vessel draft (Keskküla 2002). Taking as a base the 2.5 m draft of a project vessel and wave reserve (relatively open water basin) of 0.5 mm it yields 3.0 m of the minimum required depth of Kuivastu yacht port.

In addition it should also be considered that in order to maintain the navigability of a vessel and avoid bottom contact, a certain keel reserve should be left under the keel in any conditions. In case of marine waterways the size of keel reserve was estimated to be 0.5 m. Also random inaccuracies caused by surveying methods used at controlling the trawling depth are considered to be a part of keel reserve.

Therefore the final required depth of Kuivastu yacht port approach should be: vessel draft (HL) + increase in vessel draft, due to waves (HLL) + keel reserve (HK) HL+HLL+HK (2) 2,5 + 0,5 + 0,5 = 3,5 m.

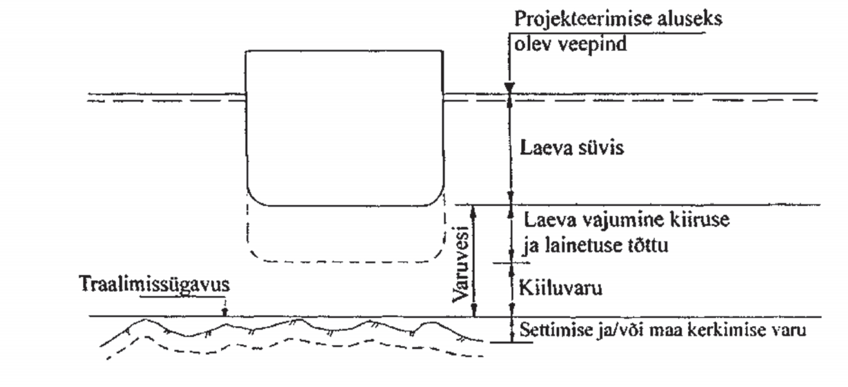


**Figure 3**. Determining the depth of waterway.

Projekteerimise aluseks olev veepind – water surface, being the projecting basis.
Laeva süvis – vessel draft.
Laeva vajumine kiiruse ja lainetuse tõttu – sinking of vessel due to speed and waves.
Traalimissügavus – trawling depth.
Varuvesi – water reserve.
Kiiluvaru – keel reserve.
Settimise ja/või maa kerkimise varu – sedimentation and/or uplift reserve.

## 4. Hydrographic surveying operations

The conducted surveying operations were divided into three parts: preliminary, field and cameral operations. Preliminary operations included composing the draft, that had to explain the general arrangement of survey realization and also determined the size of the surveyed water area. Field operations included hydrographic surveying operations, surveying equipment was tared and a hydrographic height basis to the project was created. In the course of cameral operations existent errors were eliminated and a final hydrographic survey plan was made.

In connection with the yacht port annex the whole Kuivastu inner water basin will be extended about 70 m. Thus the port water area expanse will increase from137 700 m² to 173 820 m². Therefore a post-dredging control survey of the whole port water basin and yacht port approach is required, in order to control whether the given dredging depth has been acquired by deepening and whether there will be any dangerous objects (rocks, shallows) in water areas, adandcent to the dredging area.

In areas where dredging operations take place, there is a need to conduct a 100 % head-on survey according to the higher class surveys (in the whole inside water basin of the port and partially also in the approach area) since the 5 m isoline surveys can be only conducted in accordance with the I class requirements.

Total surveys cover an area of about 187 680 m² with the approach route leading to yacht port making up 9180 m².

## 5. Dredging operations

In a projected yacht port dredging operations have to be conducted both in the inner water basin of the whole planned yacht port as well as partially also at the approach route (before entering the port at about a 200 m long stretch). The required depth of waterway was 3.5 m, as above mentioned. At the inside water basin of a yacht port it can be limited with the range of 3 meters, for waves practically do not reach there.

Due to that ~ 24 000 $m^3$ of surface material has to be removed by dredging. Dredged surface is partially soft (sand, clay) and partially semihard (sandy clay moraine, the coarse material content can partially amount to 70% of it). It presumes that the slant of channel edges should be 1:3 in order to guarantee slower filling of channel. In case of steeper edges there will be quicker filling. Thickness of the dredged layer amounts at places up to 2.7 m (Aavo and Riina Raig 2005).

During preliminary planning the research of bottom pollution was conducted in the Kuivastu port to determine the content of heavy metals and general oil products in the surface layer of bottom sediments. In order to determine the warp content and pollution indicators, samples were obtained from the mud deposit alone. Unfortunately there are still no norms concerning the pollution level of marine sediments in Estonia wherefore the normative data regarding the mainland surface, approved by the statute of the Minister of Environmental Affairs (April, 4, 2004, No 12) will be used as agreed.

Pollution parameters of the samples obtained from three locations in the area subject to dredging, are generally below the maximum value established by the above mentioned decree (peculiar reading in case of natural uncontaminated surface). Only in case of one

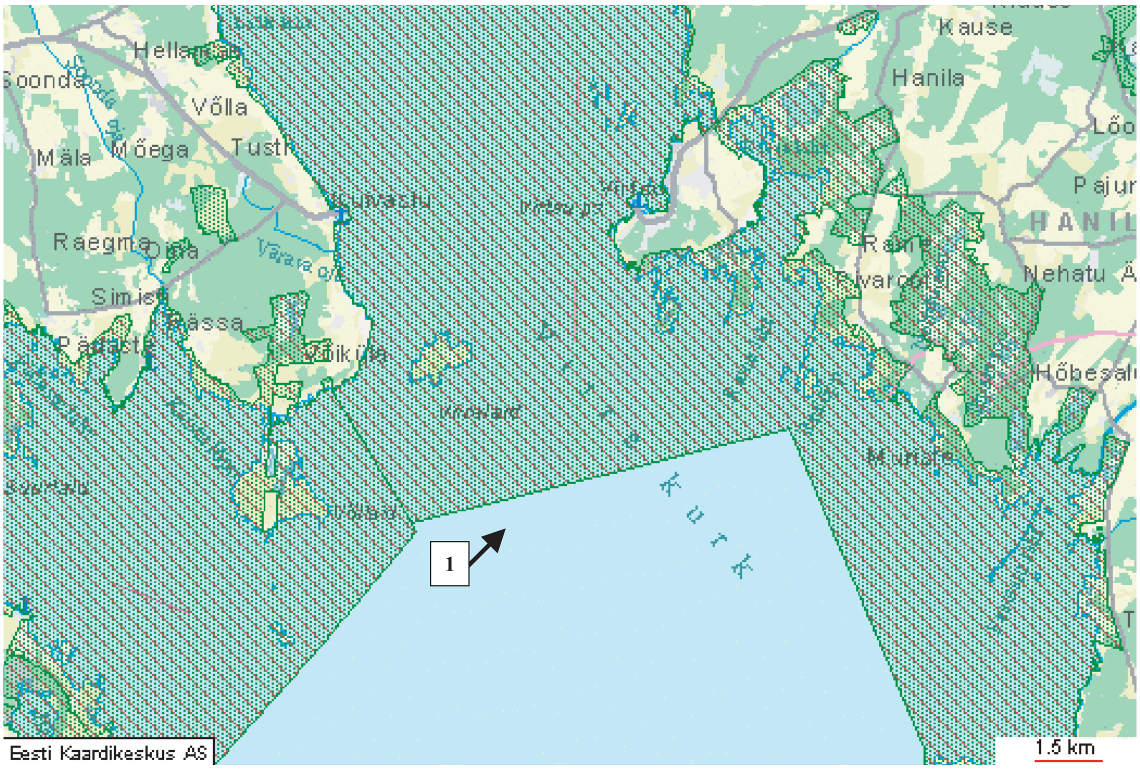


**Figure 4.** The boundaries of Natura 2000 area sites in Southern Väinameri and the recommended dumping place (K).

sample the oil product content exceeded slightly the maximum limit, but also then it remained 4 times below the established life zone maximum (Rohuküla, Heltermaa, Kui-vastu..., 2005).

As above mentioned, the whole Väinameri has been covered by two Natura 2000 sites wherefore EIA conducted for the reconstruction of Kuivastu port demonstrated that the surface extracted from Kuivastu port could not be dumped to sea in Väinamere area. EIA report advised to use a new circular marine spoil ground area outside Väinamere with a diameter of 0.5 nautical miles and its center in a geographic location with co-ordinates of 58º 30'0 N and 23º 28'5 E , i.e. ~ 5 nautical miles from Kuivastu port where dredging operations were conducted. (Figure 4).

## 7. Navigational marking of waterways

One linear leading line was planned in a project. Leading lines are projected to Kuivastu port building. The distance of the operational area of leading line is 0.71 km (0.38 nautical miles) and it is designed for 24 hour use along the 15.3 wide fairway. The width of project vessel is 4.5 m. The height of the eye of observer is 2 m. The distance of fairway sailing section from the first mark is 0.11 km (0.06 miles). The base height of the lower mark from the sea level is 2 m, the base height of the upper mark from the sea level is 3.5 m. The atmospheric transparence factor is $\tau = 0{,}74$. The characteristic of the upper and lower light of leading line is ISO W 2s (1s+1s).

The projected waterway is marked with lateral marks. The sides of waterway are determined from the sea facing the land, the spar buoys on the right hand are green and the ones on the left hand red. 3 pairs of spar buoys have been planned along the approach route, creating the so-called gate that is the best visual guide. 2 red spar buoys directing the vessels leaving the port or entering it to make the right turn, signify the end of port approach route. The paired spar buoys are placed to the edge of waterway after each 75 meters. Such placement of spar buoys should guarantee safe navigation within a dredged channel.

## 8. Conclusions

At present the Haapsalu yacht port is the biggest yacht ports in Väinamere area with its 30 berths. There is a real need in the Väinamere side of Gulf of Riga for a proper sheltering port of refuge that would meet the safety requirements. Besides, as marine tourists do not have any available yacht port at an attractive Muhu island, setting up a modern and well protected yacht port namely as a part of Kuivastu port is well justified, in spite of the fact that the port is simultaneously also located within the boundaries of two Natura 2000 areas.

Construction of the planned yacht port is only conceivable in the existent ferry port, for marine tourism is only in its initial stage in Estonia and yacht port can not be self-sufficient in its management (self-financing begins with ~ 1000 port visits in a season). Initially the port is used as a port of refuge. In about ten years it is possible that it can become unto a port of visit, but it certainly requires additional investments to set up the objects serving the yacht port.

A straight waterway with the length of 0.6 kn, depth of 3.5 m and width of 15.3 m was projected as the best option from the perspective of navigation. The approach direction is 290,7º – 110,7º. As the depth of the given fairway is not at present everywhere 3.5 m, dredging operations are required. With the required dredging in the inner water basin of yacht port the volume of dredged bottom sediments will amount to 24 000 $m^3$. In the course of the already conducted EIA it is advisable to transfer dumping of dredged surface material outside the boundaries of Väinamere Natura 2000 area.

Also a leading line was projected to the planned Kuivastu yacht port, with the height of the lower mark amounting to 2,8 m and the upper mark amounting to 3,7 m from the water level. The distance between the marks was 43 m. Also the locations for the four spar-buoys and their technical parameters were planned.

Setting up a harbor of refuge for yachts and other small craft lowers the risk of their disasters as expected and therefore there will also be a lower probability of environmental damage to the Väinamere Natura 2000 areas. Environmental impacts during the construction of yacht port are insignificant in case EIA suggestions will be applied and do not damage the wholeness, key species and goals of Natura 2000 areas.

## References

Construction and reconstruction of local state owner owned ports – BCEOM/Aavo and Riina Raig Project Ltd. 2005.

EC Environment DG, 2001.

Engineering Bureau of Geotechnics, 1997. Breakwaters of Kuivastu port and dolphins.

Estonian Maritime Administration. 2003. Estonian Pilot Book. Tallinn, 2003.

Estonian Maritime Administration, 2002.Waterway projecting guide.

Estonian Geologic Survey Ltd., 2005. Environmental research of Rohuküla, Heltermaa, Kuivastu and Virtsu port areas.

E – Consult LCC, 1997. Environmental expertise of the state of the sea in Kuivastu port.

Geo S.T. Ltd., 2002. Hydrographic surveys in Kuivastu port water basin.

Island Lines Co., 2001. Kuivastu port regulations.

**Keskküla, P.** Engineering equipment of coastal sea, lecture notes, 2005. Estonian Maritime Academy.

**Keskküla, P.,** Navigational equipment of waterways, lecture notes, 2004. Estonian Maritime Academy.

**Laigna, K., Kala, V**., Hydrography. Tallinn, 2001.

RTL 2004,111,1758.

**Suursaar, Ü., Kullas, T., Otsmann, M**. Hydrodynamic modelling of sea levels in the Väinameri and Pärnu Bay.- Proc. Estonian Acad. Sci. Eng. 2001, 7, 3, 222-234.

**Sööt T.**, Hydrographic surveying, lecture notes, 2005. Estonian Maritime Academy.

# Kuivastu jahisadama sissesõidutee projekteerimine

## Resümee

Tänase päeva seisuga on Väinamere piirkonna üheks suuremaks jahisadamaks Haapsalu 30 kohaline jahisadam. Vajadus korraliku ohutusnõuetele vastava varjusadama järele Liivi lahe Väinamere poolses osas on täiesti olemas. Lisaks, kuna mereturistidele atraktiivsel Muhu saarel ei ole seni ühtegi arvestatavat jahisadamat, on kaasaegse ja hästi kaitstud jahisadama rajamine just Kuivastu sadama juurde igati õigustatud. Seda vaatamata asjaolule, et sadam asub korraga kahe Natura 2000 ala piires.

Kavandatud jahisadama rajamine on mõeldav ainult olemasoleva parvlaeva sadama juurde, kuna mereturism on Eestis alles arengujärgus ja jahisadam iseseisvalt ei suuda ennast majandada (isemajandamine algab ~ 1000 külastusest hooajal).

Esialgu on sadam kasutatav varjusadamana. Umbes 10 aasta möödudes on võimalik, et see võib muutuda külalissadamaks, kuid selleks on kindlasti vajalikud lisainvesteeringud jahisadamat teenindavate objektide rajamiseks.

Navigatsiooniliselt parima variandina projekteeriti kogu oma ulatuses sirge laevatee, pikkusega 0,6 km, sügavusega 3.5 m ja laiusega 15,3 m. Sissesõidu suund 290,7º – 110,7º. Kuna antud laevatee sügavus ei ole praegu kõikjal 3,5 m, on vajalik süvendustööde teostamine. Koos vajaliku süvendusega jahisadama siseakvatooriumis moodustab ammutatavate põhjasetete maht 24 000 $m^3$. Teostatud KMH käigus on soovitatud ammutatud pinnase uputamine viia väljapoole Väinamere Natura 2000 alade piire.

Samuti projekteeriti rajatavale Kuivastu jahisadamale liitsiht, mille alumise märgi kõrgus merepinnast on 2,8 m ja ülemise märgil 3,7 m. Märkide vaheline kaugus on 43 m. Kavandati ka nelja paari toodrite asupaigad ja nende tehnilised parameetrid.

Jahtidele ja teistele väikelaevadele ohutu sisenemisega varjusadama rajamisega langeb oodatavalt nende avariirisk ja sellega ka tõenäosus Väinamere Natura 2000 alade keskkonnakahjustusteks. Jahisadama rajamisaegsed keskkonnamõjud on KMH soovituste rakendumisel ebaolulised ja ei kahjusta Natura 2000 alade terviklikkust, võtmeliike ning eesmärke.

# Some observations of Environmental Impact Assessments in Estonian coastal waters

**TRIIN LAPIMAA, TARMO SOOMERE**

TTU Institute of Cybernetics, Akadeemia tee 21, 12618 Tallinn
TUT Faculty of Civil Engineering, Ehitajate tee 5, 19086 Tallinn
lapimaa@cs.ioc.ee; soomere@cs.ioc.ee

## 1. Introduction

Marine and coastal resources play a major role in sustaining the economic and social development of society. About 80% of all international trade is carried out by sea. Apart from the pressure caused by industrial and transport activities, the coastal area is gradually becoming overexploited as an inhabited and recreational area. In the nearest future, by the year 2020, about 75% of the global population is expected to live within 60 km of sea coasts and estuaries (Boissonas et al., 2002, p. 29-30).

Marine transport is the major factor of anthropogenic pressure and a potential source of pollution. The turnover of Estonian ports (about 6 mio passengers and nearly 50 mio tons of cargo in 2004) has explosively increased since 1980s. Building, reconstruction works and exploitation of large harbours, e.g. dredging and/or dumping activities, are usually considered as major actions of development in the coastal zone. Apart from large harbours, infrastructure and influence which have been concentrated in a few locations, there is a severe demand for development, renovation or building of medium-size and small harbours. More than 50 small harbours belong to the relevant union and a much larger number of boat landing places are active as well.

A number of other activities exert an equally hazardous impact on the coastal environment. Extensive underwater mining activities, undertaken in Estonia since 2003, frequently influence adjacent coastal areas. Waste water from industrial enterprises, inhabited areas and tourist sites (such as Toila where the number of visitors is comparable or even exceeds the number of local inhabitants), although usually effectively handled by local communities, serves as additional source of eutrophication. Some less common actions such as installing underwater power or data cables also may adversely affect the coastal zone.

Estonian coastal line is about 3800 km (Ojaveer, 2004). This may indicate that the resources of coastal environment are virtually unlimited. This would be, however, a severely misleading opinion. In fact Estonian coastal waters, which form a part of the relatively young and fragile ecosystem of the unique brackish-water body of the Baltic Sea, are particularly vulnerable with respect to anthropogenic pressure. A large part of Estonian coastal sea is very shallow, with limited water exchange with the open sea area, and therefore especially susceptible with respect to eutrophication and pollution. The coastal zone management here must be carried out with special care.

The procedure of environmental impact assessment (EIA) has a particularly important role in sustainable use and development of coastal areas where influences from land, sea and atmosphere are combined with the anthropogenic input in an extremely complex manner (Carter, 2002). EIA report (EIAR) concentrates the results of analysis of the impacts accompanying the transformation or utilization of nature and options to prevent or minimize dangerous impacts. Based on the EIAR, the issuance of the respective environmental permit will be decided upon (Randmer et al., 2002; RTI, 06.07.2000, 54, 348; RTI, 24.03.2005, 15, 87). In international practice, many funding bodies (for example, the World Bank, Anonymous, 2003) request a relevant EIA as a precondition for raising the funds.

It has become a cliché to refer that more than 100 countries have adopted some form of environmental (impact) assessment (EA/EIA) over the last one or two decades. The wide variety of practice of EIA in those countries raises critical questions: „Is this widely adopted 'EA/EIA' indeed the same tool, or is it just a common term for different approaches used by different countries?" (Cherp, 2004). The value and features of "good practice" EIA in developed countries have been convincingly documented (e.g. Morris and Therivel, 2001). The situation with EIAs in countries of transition such as the Baltic countries is ambiguous. The common opinion is that many of those countries have "extensive environmentally significant industries regulated by rather sophisticated government and administrative apparatus, which, however, do not always meet western criteria for transparency, inclusiveness and efficiency." (Cherp, 2004).

In 1992, immediately after the collapse of the USSR, a requirement to conduct environmental expertise related to certain activities was validated in Estonia (RT, 1992, 50, 619). Environmental expertises conducted in the initial period of independence did not always meet international standards. For example, Kristoffersen and Tesli (1997) state that "in Estonia, for example, the time taken by the assessment process is limited, most statements are very short, and public participation in the decision making process is negligible."

Since then, many aspects of EIAs have been worked out properly. The national law (Environmental Impact Assessment and Environmental Auditing Act, hereafter referred to as the "old EIA act"), was enforced on January 1, 2001 (RTI, 06.07.2000, 54, 348). During the process of joining EU also the environmental legal acts were brought into congruity with EU directives. A new act on environmental impact assessment and environmental management systems (hereafter referred to as the "new EIA act"), reflecting also several EU directives and requirements, was enforced on 03 April 2005 (RTI, 24.03.2005, 15, 87).

During the period of validity of the old EIA act more than 80 EIAs on developmental activities exerting an impact on the coastal sea were conducted (Peterson and Uustal, 2005). Paist (2003) analyzed the EIAs of dredging operations planned during 2001-2003 with an aim to identify a critical volume of dredged material, exceeding of which implies an EIA. EIAs performed for underwater sand minings are discussed in (Kask et al., 2006). Some aspects of EIAs and the subsequent marine environment monitoring have been covered at the conference proceedings level (for example, Elken et al., 2004). The needs and practice of Strategic Environment Assessments in Estonia have been analysed in (Peterson, 2001, 2004).

This study is largely motivated by a need to make clear whether the EIAs conducted for various activities in the Estonian coastal sea areas during 2001-2004/2005 meet the best possible practice and the listed “western criteria”. The main aim is to position these EIAs in the light of international standards and identify positive experience and main bottlenecks. A selection of relevant EIAs are described and the quality of analysis of different factors affecting marine and coastal environment in these EIAs is estimated in Section 2. Some recommendations towards improving and unifying the quality of EIAs for the coastal areas are formulated in Section 3.

## 2. EIA reports for activities in Estonian coastal area

### *2.1 Material and method*

The study is mostly based on EIA reports archived in the department of environmental management and technology, and in the department of water of the Ministry of Environment. From this material, 38 EIA reports conducted until November 2004 were recognized as relevant to this study together with 5 EIARs from personal archives of EIA experts. A few relevant EIARs may be archived in other departments of this ministry; however, since the number of relevant EIAs is much larger, several EIARs are probably missing from the ministry archives. 31 reports were analyzed in detail (see also Lapimaa, 2005a, b). The report of one environmental expertise, conducted in 2000, was used as comparative material.

The reports were grouped according to the type of developmental activity covered in these. Then the main potential factors of environmental impact of the particular activity (hereafter called factors) were determined. The volume, expedience and quality of the analysis of all potentially important factors in all the observed EIARs were assessed according to a five grade scale suggested by Canelas et al. (2005). Based on the obtained results the quality of EIAs as well as the analysis of single factors was ranked. Finally, analogous analysis was performed for groups of EIAs belonging to different types of developmental activity. Such complex comparison enabled to establish the general level of the EIAs and solid aspects in covering single factors as well as systematic shortages.

EIAs were divided according to the object of coverage into four groups: construction works in existent ports (11 EIAs), dredging operations (10 EIAs), establishment of new ports (4 EIAs and one expertise) and other activities (6 reports). The following factors potentially influencing the environment and probable impacts of developmental activity were considered:

– problems related to oil pollution;
– issues related to the generation, transport and impact of suspended matter;
– hydrodynamic conditions (first of all waves and currents), their potential alteration and impact of respective changes on environment;
– meteorological conditions;
– geologic research;
– impact of developmental activity on marine flora and fauna;
– if relevant, options of usage or dumping of dredged material.

Besides the given factors the quality of comparing different alternatives was followed, as the respective analysis can be decisive in the issuance of environmental permit.

**Table 1.** Definition and statistics of average grades.

| Numerical grade value | Average value | Per cents of ideal | Alphabetic grade | Graded EIARs | % of EIARs |
|---|---|---|---|---|---|
| 5 | 4...5 | 81-100% | A | 2 | 6,3 |
| 4 | 3...3,99 | 61-80% | B | 10 | 31,3 |
| 3 | 2...2,99 | 41-60% | C | 15 | 46,9 |
| 2 | 1...1,99 | 21-40% | D | 5 | 15,6 |
| 1 | 0...0,99 | 0-20% | E | 0 | 0 |

Each one of the listed factors of each analysed EIARs were graded in a scale from A (the best, 5 points) to E (the poorest, 1 point) according to Canelas et al. (2005). The meaning of the five grades is as follows:

A (very good): Full provision of information with no gaps or weaknesses.
B (good): Good provision of information with only very minor weaknesses, which are irrelevant in the decision process.
C (satisfactory): Adequate provision of information with gaps or weaknesses that is insubstantial in the decision process.
D (weak): Weak provision of information with gaps and weaknesses, which will hinder the decision process but require only minor efforts to complete it.
E: (poor) Very poor provision of information with major gaps or weaknesses, which would prevent the decision process from proceeding, requiring major efforts to complete it.

The average grade of covering the impact factors and grades of EIAs were found as arithmetic average of the grades of single factors. Obtained averages were reduced to integers according to Table 1. Two EIARs (6.3 %) obtained the average grade A. No EIAR obtained the lowest grade E. Most of the reports (about 47 %) got the grade C. There were relatively many EIARs (about 1/3) that obtained the grade B.

The described approach corresponds with the usage of the absolute assessment scale. The probable subjectivity of assessing is characterized to a certain extent by the distribution of grades. Figure 1 demonstrates that the distribution of grades approximates to normal distribution with a central value between B and C. The absence of the lowest grades (*resp.*

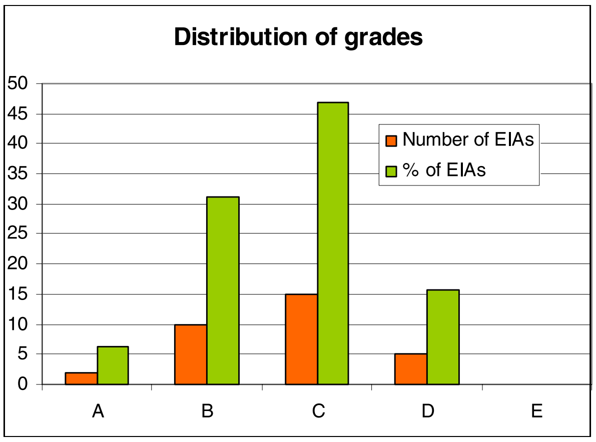


**Figure 1.** Distribution of grades. The vertical axis shows the percentage of assessment grades as well as the number of EIARs with the relevant grade.

very poor reports) reflects probably the efficiency of EIA process supervision. A small proportion of excellent grades (Table 1) refers to the fact that EIAs have been assessed from a relatively critical position, for top specialists and researchers have been participating in the composition of many EIAs and the best portions of several EIARs are probably also very good in comparison with the world practice.

### *2.2 Quality of analysis of impact factors*

The arithmetic averages of the results of our analysis have been presented according to impact factors and types of EIAs in Table 2. Average level of analysis of various factors in EIAs varies comparatively little regarding the total average. Geologic research has merited most of attention (average grade 3.63, 73% of the ideal, corresponds to grade B). Soil samples were taken and their laboratory analyses were made virtually in the process of each EIA. It is interesting to note that in relation with the change of § 12 in Chemical Act in 2003 (RTI, 03.12.2003, 75, 499), the decree of the Minister of Environment regarding the content of dangerous substances in surface and groundwater also lost its validity. Although the respective requirement was missing almost during the whole year (RTL, 16.04.2004, 40, 662), the results of surface samples analysis were still compared with the measures enacted in a decree that had lost its formal validity. Such a course of action meets best possible practise and yields an essentially correct answer.

The impact of the planned works on water flora and fauna has been examined most evenly and practically as accurately as geologic issues. The average of the respective analysis is 3.49 (69-70% of ideal, corresponds with grade B).

**Table 2.** Average grades of the analysis of factors according to the types of developmental works and the percentage from the theoretically ideal coverage of the factor. Higher grades have been highlighted in bold print. The grades of environmental expertise are located on a separate row.

| | Oil pollution | Suspended matter | Waves and currents | Meteorological conditions | Geologic research | Impact on water fauna | Comparison of alternatives | Options to use dredged material | Average of activity types |
|---|---|---|---|---|---|---|---|---|---|
| Construction works | 1,40<br>28% | 2,90<br>**58%** | 3,09<br>62% | 3,27<br>**65%** | 3,55<br>71% | 3,45<br>69% | 3,09<br>**62%** | 3,10<br>62% | 2,98<br>60% |
| Dredging operations | 0 | 1,50<br>30% | 1,63<br>33% | 1,70<br>34% | 3,30<br>66% | 3,50<br>70% | 2,50<br>50% | 2,40<br>48% | 2,36<br>47% |
| Establishments | 1,75<br>**35%** | 2,50<br>50% | 3,25<br>**65%** | 3,25<br>**65%** | 3,50<br>70% | 3,50<br>70% | 3,00<br>60% | 3,25<br>**65%** | 3,00<br>60% |
| Other activities | 0 | 2,50<br>50% | 2,83<br>57% | 3,17<br>63% | 4,17<br>**83%** | 3,50<br>70% | 2,83<br>57% | 3,17<br>63% | 3,17<br>**63%** |
| *Average of impact factors* | *1,58*<br>*32%* | *2,35*<br>*47%* | *2,70*<br>*54%* | *2,85*<br>*57%* | *3,63*<br>***73%*** | *3,49*<br>*70%* | *2,86*<br>*57%* | *2,98*<br>*60%* | |
| Expertise | 4,00 | 2,00 | 1,00 | 1,00 | 4,00 | 3,00 | 3,00 | 4,00 | |
| Average incl. expertise | 2,38 | 2,28 | 2,36 | 2,48 | 3,70 | 3,39 | 2,88 | 3,18 | |

The analysis of oil pollution is the least satisfactory (average grade 1.58, corresponds approximately to grade D). Quite often the probability of oil pollution is not analysed at all or has been only superficially mentioned. A high level analysis conducted in the EIA on Haapsalu border guard cordon port reconstruction works impinges on the eye as a pleasant exception (Vili and Meriste, 2002). Although in case of several operations there is a small oil pollution probability, also the EIAs where the needlessness of the respective analysis was not reasonably explained, got a low grade. A fact that in the process of establishing of new ports this subject has been left with no closer consideration gives rise to worry. The distribution of oil pollution was modelled out of four relevant EIAs only in the EIA on the establishment of Tamme (Saaremaa) port (Ratas, 2003). Unfortunately this assessment lacked in figures, which resulted in a low general grade to this factor. In the EIAR of Sillamäe port establishment (Juhat, 2003), oil pollution analysis was not deemed as necessary, despite the fact that oil products were going to transit the constructed port.

The remaining factors were analysed with more or less even acceptable quality. The coverage of the problems of generation, transport and potential impact of suspended matter seems to have a lot of room for development (average grade 2.35, corresponding to grade C). The options to use the dredged material, if relevant, have been dealt in a more rational manner (average grade 2.98 approaching to grade B).

As inactivity or the so-called zero alternative (0-alternative) is mostly a real alternative, it can be stated that alternative solutions have been briefly described in all the examined EIAs. Yet simple making mention of alternatives alone can not be considered as quality treatment, wherefore only the assessments where the alternatives were essentially expanded upon, deserved a high grade. Such severity is partially a reason why the average grade to alternative solution theme treatment is relatively low (2.86 or 57% of the ideal, corresponding approximately to grade C).

### *2.3 Factor analysis quality in EIAs on different kind of developmental work*

Quality of analysis of single factors in EIAs on different types of activities varies to some extent. The analysis of suspended matter issues has deserved more than half (58%) of ideal grade only in construction work EIAs. Dredging operation EIAs should cover the distribution of suspended matter in a much more detailed manner (grade only 30%), as during dredging and dumping it is virtually impossible to avoid the generation of suspended matter. The description and comparative analysis of alternative solutions is most profound (62%) in EIARs of construction works.

The biggest emphasis has been laid on geologic research in the process of conducting the EIAs of “other activities“. Evidently it has been caused by a fact that underwater mining makes up the majority of these works and the nature of operations requires a detailed discussion of geologic aspects. Impact on marine flora and fauna has been covered in a most homogeneous manner.

As to developmental activity types, the EIAs of “other activities” have the best quality (63% of the ideal grade). The EIAs of port establishment and construction works have virtually the same quality (both 60%). The environmental impact of dredging operations has been graded the lowest (average 47%). The main cause is the insufficient coverage of hydrometeorological conditions. In case of dredging the inner water basin of small ports, local wind, wave and current regime are insignificant indeed. Yet in many cases dredging is conducted in open sea area and absence of the analysis of these aspects is not justified. The shortage of discussion of hydrodynamic factors frequently is the reason for unsatisfactory analysis of the impact of suspended matter.

The presented analysis as a whole demonstrates that the quality of Estonian EIAs on developmental work in coastal sea conditions is basically good also in the light of international standards. Nevertheless, also there are potentially dangerous misunderstandings and fluctuations of the quality of the analysis.

## 3. Problems in impact factor analysis

### *3.1 Frequently occurring problems*

A certain amount of suspended matter is released to water column virtually in case of all the developmental works in the coastal sea. The resulting deterioration of optical water quality is more of an aesthetic problem, but e.g. the drift of fine grained suspended matter to spawning areas can negatively affect the reproduction of fish stocks. Old EIA act (RTI, 06.07.2000, 54, 348) does not discuss water quality issues separately. In a new EIA act this gap has been filled in. The author of EIA is obligated to determine "the impact [....] of the planned activity [...] to the water [...] quality [...]" (RTI, 24.03.2005, 15, 87).

Although the issues of suspended matter are scrutinised in EIAs, still too little attention is paid to that. The situation is especially worrying in the case of dredging operation EIAs (Table 2) where the impact of suspended matter is one of the central concerns. The analysis of suspended matter issues has been frequently based on assumptions, but not on measuring or modelling results, even in the case of major projects of establishment of ports (Veere port in Saaremaa, Kartau, 2002; Sillamäe port in Ida-Virumaa, Juhat, 2003).

Possible oil pollution is another common risk in nearly all activities in the coastal sea. This risk is moderate only in the case of certain types of operations (underwater mining, cf. Kask et al. 2006, or dredging in open sea fairways), when it is only manifested during a short time interval in the form of possible (vessel) accident. Its analysis is still required both according to sustainable development and precautionary principle. In case of ports, it drastically increases danger to nature both in the vicinity of port as well as fairways leading to port, yet EIAs frequently pay often groundlessly little attention to that. The most marked example in this field is related to construction of the Sillamäe port (Juhat, 2003). The fact that oil products were going to transit through the port was mentioned only in the chapter on alternatives (containing a comparison which one would enable to serve bigger tankers).

Both the old and new EIA act (RTI, 06.07.2000, 54, 348; RTI, 24.03.2005, 15, 87; see also the act of Environmental Minister, RTL, 13.02.2001, 20, 274) tell that along the analysis of the planned activities also realistic alternative solutions have to be described. As mentioned above (Table 2, §2.2), alternatives are not considered prevalently too vital of a theme. Most of all only the version preferred by developer is discussed in detail. It can be understood that the developer is interested in one specific version alone and has no desire to finance the analysis of economically unrealistic solutions. However, such a position is in contradiction with the requirement to cover alternative solutions.

Alternative solutions and the accompanying potential impacts are meticulously and correctly described only in very few EIARs. In case of some EIAs it seems (it is possible that subjectively) as if other solutions were demonstrated consciously in a worse light than the activities planned by the developer. There are cases when EIA suggests a solution that poses a bigger threat to environment than several other alternatives (for example, Juhat, 2003). The expert explains such a view mainly by economic conditions. Although the realistic alternatives should be both technically realizable and also economically acceptable, and the expert is obligated to assess also the potential damage to the existent cultural-historic and socio-economic conditions, it is problematic to lean in the frames of EIA on the profit oriented economic aspects of the developer.

The essential discussion of 0-alternative is often refrained from with the explanation as if it were economically unreasonable. Although such a position is dominating, 0-alternative was adopted, for example, at the initial attempt to set up Sillamäe port in 1994, in other words the construction works of the port were not launched (A. Järvik, personal communication).

In addition to the three parties (developer, expert and decision-maker) EIA report also has to contain information about all other interested parties in order to make sure that the public opinion is actually involved in deciding (Hartley and Wood, 2005). According to Århus convention (UNECE, 1998) everyone has a right to access environmental information. Realization of that right (still being the problematic issue in former socialist countries, Almer and Koontz, 2004) presumes that the version of the report that is going to be presented to the general public will already include information about all possibly interested parties. Most of the analysed reports lacked in the respective information. It may be noted as an interesting observation that the protocols of open discussions on EIA reports have never referred to this shortcoming.

### *3.2 Possible causes of problems*

One of the reasons of EIAR quality fluctuations can be the lack of common standards and norms. Although it has been regulated in the EU (EC, 1997) what needs to be assessed in the process of EIA, it is not enacted what exactly and to which extent needs to be assessed. This enables different parties to interpret the EIA act and statutes regulating the EIA execution in different ways. Many analysed EIA reports express a tendency that if the provisions presented in an act have been met even at a minimal level, then there has been no direct violation of law.

The absence of unambiguous requirements regarding the coverage of indirect, combined, cumulative or remote impact of several factors has caused severe complications. Perhaps the most acute criticism based on different interpretations of these aspects was directed to EIA of the Tamme (Saaremaa) harbour (Ratas, 2003). The Estonian Green Movement placed doubt on the whole EIA because of Natura 2000 area, located in the vicinity of the planned port. It was asked whether an impact accompanying the construction of any object should be assessed as a whole (incl. the secondary impacts) or would the assessment of the impacts of any individual environmental element be sufficient enough (Keerberg, 2005).

As everything cannot be (and should not be) prescribed exactly, the qualification and factual independence of experts and decision-makers are critical parameters within the EIA system. It can be understood that, for example, the specialists in mainland geology or hydrology cannot always assess adequately the importance of processes occurring at sea or in the coastal area. Specification of expert competence at issuing the licences has been enacted only since 2000. The competence of decision-makers has been specified by the requirements presented to the officials of the respective ministry. If the decision-maker is not familiar with the specific issues of processes occurring in marine and coastal environment, it is difficult for him/her to assess the correctness of the presented analysis. The probable cause of the fluctuations in the quality of the observed EIARs can therefore lie in insufficient competence of experts and decision-makers in the issues related to marine and coastal environment.

As the new EIA act emphasises that the fields of action of an expert are determined according to his qualification (RTI, 24.03.2005, 15, 87, §15/4), a continual increase in the qualification of EIA experts can be expected in future. In order to help the decision-makers, Helsinki Commission (Helcom, 1998) suggests that the principal results of EIAs, which have formed the basis for the decision regarding the extraction permit, should be made available for scientific evaluation. EIA materials demonstrate that comments on substantial shortcomings have been made mostly by scientists and experts specialising in marine or coastal research indeed.

A significant issue, which partially lies out of the scope of the current study, is that there has been a weak link between the restrictions suggested in the EIAs and respective supervision of developmental activity. According to old EIA act, developer was frequently obligated to conduct extensive monitoring before, during and after the works. Yet the developer was totally free in his choice of executor and volume of monitoring. It could be stated with some exaggeration that basically no one was responsible for adhering to suggestions made in EIAs and for their actual supervision.

The described gap has been largely eliminated in the new EIA act with the requirement that a supervisor has to conduct follow-up assessment of EIA according to monitoring data. Yet it is not clear how to exclude unnecessary damage to environment during the construction work. For example, during the year following the sand mining near the island of Prangli, a portion of Liivsääre headland was carried away (Rooväli, 2004). According to some opinions, the relevant EIA was inadequate (Orviku, 2005, p. 54). A more probable reason is that requirements formulated in the EIA were apparently ignored during the mining. At places several meters of a thicker layer was probably mined (Rooväli, 2004) and a part of mining was evidently performed in a restricted area (Tooming, 2005). In order to prevent such situations both the responsibility of the developer (for example, by fiscal means that would be more effective than the 5000 EEK, or about 320 €, fine appointed for violation of law, Rooväli, 2004) and supervision of underwater work should be made more efficient.

### *3.3 Other observations*

EIARs made for coastal sea operations are at present stored in various departments of the Ministry of Environment. The report seems to remain with the person whose task has been to handle it. The location of some reports is unknown. Therefore access to reports is relatively complicated and the system of archiving the reports is in need of perfecting. EIARs often include unique data and analysis of local conditions composed by high-class experts that may provide significant additional information to developers, other experts, decision-makers, and also scientists.

In case of some reports it is hard to get rid of a feeling as if environmental impacts were not assessed objectively enough. Objectivity (or subjectivity) in EIAs is a discrete subject, as all the involved parties are interested in the matter to a certain extent. The criterion of objectivity could be chosen on the basis how many adverse impacts have been highlighted, to which extent they have been covered and whether they have been considered as (in)essential. Possible subjectivity could be manifested in the tendency of EIA towards getting a special water usage permit alone. Although, such an analysis would also be subjective by itself.

Although a small portion of EIAs is really good, the "average" EIA leaves us (probably subjectively) an impression as if many of the impact factors were covered insufficiently from the environmental protection perspective. It gives an impression as if there would be an implicit presumption that the sea would always behave according to a favourable scenario. The confidence underlying this assumption can turn out to be a so-called false sense of security, for in case anything serious might happen, coastal environment could be damaged irreversibly (Carter, 2002).

Several aspects of environmental impact can be noticeably reduced by optimal planning of operations. The impact of the release of suspended matter to the water body can be reduced, for example, by conducting dredging operations within a certain time slot when transport of suspended matter to vulnerable areas is improbable. Such practice is common in Estonia and operations that generate a lot of suspended matter are no longer scheduled to spawning time of fishes. Anthropogenic load can probably also be reduced by splitting extensive construction or developmental works into several stages, with the impact of each individual stage remaining within acceptable limits.

### *3.4 Possibilities of improvement of EIA reports*

The improvement of EIA regulation is complicated by a fact that each work differs generally from the previous ones. Environmental conditions, scope of works and their purpose differ, environment develops and changes continually. Thus every planned activity needs to be approached on an individual basis and the peculiarities of the location (Natura 2000 area, wetland area, protected flora and fauna, land protection areas, water exchange etc.) should be considered. The elaboration of respective standards should therefore also include besides the legislative authorities and representatives of developers also individuals with technical, nature protection and juridical education.

Parts of EIA reports are very technical. Information included in EIAR (first of all in the conclusive section) should be presented in such a form that is easily understood by non-experts without placing its honesty and integrity under doubt (Morris and Therivel, 2001). Otherwise the public participation may prove to be a simple buzzword. Information regarding the possible restrictions should be especially accurate and transparent.

Third persons (who formally do not belong unto the interested party and also do not represent the general public in the classical sense of the term) have mostly pointed out the superficial coverage of hydrodynamic conditions. For example, in EIA on constructing a pier to Ringsu port (Ruhnu) it was stated that there were active currents and sediment transfer (Kartau, 2003). Their potential danger to the constructed pier was not accounted for. The researcher of TUT Marine Systems Institute highlighted the potential results of intense hydrodynamic activity. The decision-maker required additional analysis of hydrodynamic conditions. A sort of modelling was conducted (although the EIAR did not disclose its results). The decision-maker found it to be sufficient. Yet it happened that by the opening of pier it had already sunk underwater. Environment was not directly damaged by that, yet better co-operation between the parties involved and acting according to the principles of sustainable development could have prevented remaking the work.

Systematic involvement of scientists in EIA process could diminish the probability of such excesses. Their role could be in consulting the EIA expert concerning the analysis of peculiarities in a certain location and identifying the aspects of significant impact. In many cases the involvement of high-level researchers is not justified. For example in case of major ports, having been in operation already for years, renovation of interior piers exerts mostly an insignificant impact. Construction of new piers, major dredging and mining operations are most of all significant from several aspects. These operations can drastically impact the circulation patterns and coastal processes. An inaccurate assessment concerning the (in)significance of impacts can culminate in such cases also in addition to torpedoing the developer activity in a total alteration of the local ecosystem (Carter, 2002).

As EIA is mostly made based on existent data, it will often give rise to a question what to do when there is no data about a specific location? When there is an intention to build a small pier to the location that has been used as a boat landing place for years, there is no need for detailed data about the hydrometeorological conditions. But in case of massive operations, the cost of collection of the required data and their analysis should be reckoned with already in the planning stage of the project. Passing the respective decision is in the competence of an expert who has an obligation to assess the sufficiency of data. If there is not enough data for decision making, expert should formulate the need for respective research and EIA should be postponed. To decrease subjectivity at this stage the creation of a more detailed regulation mechanism and active involvement of scientists might be considered.

### *3.5 Possibilities of improvement of the EIA procedure*

The material presented in previous sections displays vividly that in the process of planning major assignments, EIA should be launched already at the earliest possible stage. Alternative solutions should be discussed with various interest groups as early as possible to identify potentially significant impacts. An essential public participation and reckoning with its opinion should not be an unpleasant task for the developer, but an opportunity to find out already at the planning stage which solutions are plausible and which ones will lead to endless discussions. Court cases related to EIA on Tamme (Saaremaa) harbour (Keerberg, 2005) demonstrate the loss of time occurring when certain interest groups are ignored.

The relationship between 0-alternative of developmental work and environmental protection has often remained without adequate interpretation. Zero-alternative in Estonian practice means retaining the existent natural balance by inactivity. In exceptional cases when 0-alternative cannot be accepted due to any reason, but developmental activity can cause extensive environmental damage, additional projects are often foreseen in international practice, directed to maintaining or improving any condition likely to be damaged by developmental activity. Such „shadow projects", (Morris and Therivel, 2001) deal with assignments made for the protection of certain environmental aspects and 0-alternative is unacceptable.

In certain cases 0-alternative or inactivity can turn out to be a threat to environment. There will be an environmentally hazardous situation, for example, when a breakwater or an amortised pier will break, resulting in severe damage to vessels located in the port. A similar problem is related with heavily polluted bottom sediments of former military ports. These examples demonstrate that very often more attention should be paid to the results of inactivity in the process of EIA.

EIAs made for coastal sea objects concentrate frequently on such aspects that are insignificant for the developmental activity in mainland. The present valid acts and guidelines do not enact which aspects and to which extent should be assessed in the process of coastal sea object EIAs. In such cases all the involved parties will proceed from general legislative acts. Although in such a way the legally enacted requirements will be met, it does not always suffice from the perspective of marine environment protection. For example, there are no specific requirements in Estonia regarding the content of dangerous substances in marine sediments. In practice normatives valid for ground surface (RTL 02.07.1999, 105, 1319) are applied, but their adequacy in case of marine sediments is doubtful (A. Järvik, personal communication).

Propagation of potential pollution in marine environment differs drastically from its behaviour in mainland conditions. Parameters of pollution transport can be forecast by mathematical models (for example, Elken et al., 2001, 2004). The use of models is extremely advisable also in the analysis of suspended matter and wave issues (cf. Kask et al., 2006). There is a reasonable practice spreading in Estonia that deserves to be followed and regards model calculations as an essential assessment method. Modelling the suspended matter and the opportunities for respective satellite and contact monitoring in Estonian coastal sea (cf. Sipelgas et al., 2004) should be a standard part of daily EIA routine.

Specific methods for assessing impacts on marine and coastal environment have been discussed, for example, in the reports and guidelines of the respective ICES workgroup and in the materials of US Environmental Protection Agency and Marine Engineering Corps. Defining the specific set of methods and requirements for EIAs conducted in Estonian marine environment could even up their quality. Until there are no specific guidelines for EIAs on marine environment, one should proceed from a basic principle of international environmental law – the precautionary principle (Anonymous, 2002). It applies always where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the high level of protection chosen by the EU (Tvedten, 2000). Precautionary principle has been recognised in Estonian legislation, but the need to consider it has not been directly enacted in the new EIA act (RTI, 24.03.2005, 15, 87).

## 4. Discussion

The goal of the present research was to map the quality of analysis of main factors, exerting an impact on the environment and the analysis of potential impacts of developmental activity of the past four years (2001-2004/2005) in environmental impact assessments for various activities in Estonian coastal sea. Although there is a comparatively short-term tradition of conducting EIAs in Estonia, the quality of relevant EIAs is fully acceptable also in the light of criteria used in international practice. A prevailing amount of EIAs contains at least a satisfactory overview of all aspects of the required information. No EIAs of fully insufficient quality were identified. The average level of EIAs specified on the basis of analysis quality of single factors makes up about 60% of the ideal.

Although there is still enough room for development, the basic message from the performed analysis is that decisive steps in creating the EIA system and efforts towards making it effective for activities in Estonian coastal sea have been successful. It is regrettable that the use of valuable data included in EIAs is not easy because of difficulties of accessing the reports and absence of unified archive.

The quality of analysis of various impact factors in individual EIAs is comparatively uneven. Reasons for such heterogeneity are not unequivocally determined. Evidently both the gaps in legislation and the competence of involved parties regarding the specific conditions of marine environment play a certain role. As the coastal sea ecosystem is very complex intrinsically, it is often complicated and sometimes virtually impossible to separate anthropogenic influence from the natural variability (Carter, 2002; Morris and Therivel, 2001). The work of experts could be simplified and the level of EIAs can be unified by the elaboration of specific guidelines for conducting EIAs in Estonian coastal sea.

Relatively little attention has been paid to the analysis of most vital aspects of coastal sea dynamics – hydrometeorological conditions. As a direct result, the analysis of oil pollution and impact of suspended matter has often gaps in it. It can be hypothesised as one of the reasons that there is a more stable tradition and more extensive culture of geologic and hydrobiological research in comparison with the analysis of marine meteorological and hydrodynamic aspects. The other probable reason is that the research of hydrodynamic conditions is relatively expensive. The assessment of impact of currents and waves according to bare assumptions and/or outdated data has led quite a few times to wrong conclusions and the developer has had to pay manifold costs. Reasonable solution could include consistent introduction of modelling the hydrodynamic conditions as one of the main assessment methods in an EIA process and also planning the respective means to EIA budget.

Conducting the actual supervision of underwater operations has become a serious problem. It is hard to avoid situations similar to excessive mining of sand at the shore of Prangli Island (Rooväli, 2004; Tooming, 2005). It can be stated with some exaggeration that the full set of environmental laws favours circumventing the laws or partial abiding by them in coastal sea conditions. Probably the size of environmental fines is insufficient and both the legal process following the violation of law and the procedure of withdrawing the mining or building permit are too complicated. The practice of environmental policy in developed countries generally relies on the principle that economic cost benefit should not exceed the buffering capacity of environment. The value of environment has been drastically underestimated in Estonia; hence the respective proportions have been severely distorted.

## Acknowledgements

The authors want to express their gratitude to Dr. Ahto Järvik, whose benevolent remarks and professional advice enabled us to correct several inaccuracies in the initial version of the given article. The article has been completed with the help of the Estonian Science Foundation grant no 5762 and EU-supported INNOVE project 1.0101-0208.

## References


Act on Environmental Impact Assessment and Environmental Auditing. *State Gazette (Riigi Teataja)* RTI, 06.07.2000, 54, 348.

**Almer H. L., Koontz T. M.** 2004. Public hearings for EIAs in post-communist Bulgaria: do they work? *Environmental Impact Assessment Review* 24, 5, 473–493.

Anonymous 2002. *International Environmental Law: Concepts and Issues*. Available at http://www4.worldbank.org/legal/legen/legen_iel.html (accessed 23.07.2005).

Anonymous 2003, Improving Development Effectiveness Through Impact Assessment. Available athttp://lnweb18.worldbank.org/mna/mena.nsf/attachments/Events20Juin2003IAIAWBpressrelease/$File/20Juin2003IAIAWBpressrelease.pdf (accessed 23.07.2005).

Boissonnas J., Connolly N., Mantoura F., d'Ozouville L. (Eds.) 2002, *Integrating Marine Science in Europe*. Marine Board, European Science Foundation, Strasbourg.

**Canelas, L., Almansa, P., Merchan, M., Cifuentes, P.** 2005. Quality of environmental statements in Portugal and Spain. *Environmental Impact Assessment Review* 25, 217–225.

**Carter, R. W. G.** 2002. *Coastal environments: an introduction to the physical, ecological, and cultural systems of coastlines*. 8th Printing. Academic Press: London, UK.

**Cherp, A.** 2004. Editorial from the Guest Editor. *Impact Assessment and Project Appraisal*, 22 (2), 86–88.

EC (1997), Directive 97/11/EC, *EC Official Journal* No. L073, p. 0005.

**Elken, J., Kask, J., Kõuts, T., Liiv, U., Perens, R., Soomere T.** 2001. Hydrodynamic and geological investigations of possible deep harbour sites in north-western Saaremaa Island: Overview and conclusions. *Proc. Estonian Acad. Sci. Eng.* 7, 2, 85–98.

**Elken, J., Kõuts, T., Raudsepp, U., Sipelgas, L.** 2004. Portable coastal operational oceanographic system to monitor the harbor-related environmental impacts in Estonia, in *Proceedings of the USA-Baltic International Symposium ''Advances in marine environmental research, monitoring and technologies", Klaipeda, 15-17 June* (CD)

Environmental Impact Assessment and Environmental Management System Act. *State Gazette (Riigi Teataja)*, RTI, 24.03.2005, 15, 87.

**Hartley N., Wood C.** 2005. Public participation in environmental impact assessment - implementing the Aarhus Convention. *Environmental Impact Assessment Review* 25, 4, 319–340.

HELCOM 1998. *Recommendation 19/1, Marine sediment extraction in the Baltic Sea area,* Adopted 23 March 1998. Available at http://www.helcom.fi/Recommendations/en_GB/rec19_1/ (accessed 23.07.2005).

**Juhat, K.** 2003. *EIA on constructing the hydrotechnical buildings of Sillamäe port jetty and quay.* Manuscript. E-Consult LCC.

**Kartau, K.** 2002. *Saare county Kihelkonna commune Veere village Veere port. Detailed planning of the adjoining areas and dredging operations.* EIAR. Manuscript. Hendrikson & Ko, Kuressaare.

**Kartau, K.** 2003. *EIAR of Ringsu port development special water usage permit request*. Manuscript. Hendrikson & Ko, Kuressaare.

**Kask, A., Kask, J., Soomere, T.** 2006. EIA of marine sand mining. *Proceedings of Estonian Maritime Academy*, 3, pp 19-30.

**Keerberg, L.** 2005. News on green court cases. *Rääk* no 3 (16), p. 2.

**Kristoffersen, H., Tesli, A.** 1997. Environmental impact assessment in the Baltic countries and Poland - screening and quality control. *Electronic Green Journal*, Issue 7. Available: http://egj.lib.uidaho.edu/egj07/doughty.htm (accessed 22.07.2005)

**Lapimaa, T.** 2005a. *EIAs conducted in Estonian coastal sea and the present condition.* Course paper. Tartu University.

**Lapimaa, T.** 2005b. *Coastal waters usage related EIA methods and their application in Estonian conditions.* Bachelor paper. Tartu University.

Law of altering §12 of Chemical Act. *State Gazette (Riigi Teataja)* RTI, 03.12.2003, 75, 499.

Limit normatives of dangerous substances in surface and groundwater. Act no 58 of June, 16, 1999 by the Minister of Environmental Affairs. *State Gazette (Riigi Teataja)* RTL, 02.07.1999, 105, 1319.

Limit normatives of dangerous substances in surface and groundwater. Decree no 12 of April, 2, 2004 by the Minister of Environmental Affairs. *State Gazette (Riigi Teataja)* RTL, 16.04.2004, 40, 662.

Morris, P., Therivel, R. (Eds.) 2001. *Methods of Environmental Impact Assessment.* 2nd edn. UK: Spon Press.

**Ojaveer, E.** 2004. National ICZM [Integrated Coastal Zone Management] strategies in Estonia. Schernewski, G., Löser, N. (eds.): Managing the Baltic Sea. *Coastline Reports* 2, 17–21.

Order for performing environmental expertise, 1992. Statute no 314 of 13 November 1992 by the Government of the State. *State Gazette (Riigi Teataja)* RT 1992, 50, 619.

**Orviku, K.** 2005. Rational usage of coastal areas, *Proceedings of Estonian Maritime Academy*, 2, 42–61.

**Paist, V.** 2003. *Dredging related environmental impacts and their assessment in Estonia (based on 2001-2003 examples)*. Diploma paper. Estonian Maritime Academy, Tallinn.

**Peterson, K.** 2001. SEA- what it is? *Environmental technics*, No. 3, 16–17.

**Peterson, K.** 2004. The role and value of strategic environmental assessment in Estonia: stakeholders' perspectives, *Impact Assessment and Project Appraisal*, 22 (2), 159–165.

**Peterson, K., Uustal M.** 2005. Overview of the EIA practice in Estonia in years 2001-2004/2005, Sustainable Estonian Institute (SA Säästva Eesti Instituut, SEI-Tallinn).

**Randmer, A., Ruut, J., Põder, T.** 2002. *EIA.* Handbook. Ministry of Environment, KIK. Tallinn.

**Ratas, R.** 2003. *EIA of Saaremaa port construction*, Manuscript. Tallmac Corp., 2003.

**Rooväli, K.** 2004. Dredged sea erodes the sandy shore of Prangli island. *(The Postman) Postimees* 23.11.2004.

**Sipelgas L., Arst H., Raudsepp U., Kõuts T., Lindfors A.** 2004. Optical properties of coastal waters of northwestern Estonia: in situ measurements *Boreal Environment Research* 9, 5, 447–456.

Specified requirements for EIARs, 2001. Statute no 4 of January, 31, 2001 by the Minister of Environmental Affairs. *State Gazette (Riigi Teataja)* RTL, 13.02.2001, 20, 274.

**Tooming, U.** 2005. Environmentalists continue activities towards making sure the reason of erosion of a sandy coast of Prangli. *Postman* (*Postimees*) 30.12.2005.

**Tvedten, S.** 2000. *Debating the Precautionary Principle*. Available at http://www.safe2use.com/ca-ipm/00-03-08.htm (accessed 23.07.2005).

UNECE (United Nations Economic Commission for Europe) 1998. *Convention on access to information, public participation in decision-making and access to justice in environmental matters (Århus Convention)*, Århus, Denmark, 25 June 1998, available at http://www.unece.org/env/pp/welcome.html (accessed 23.07.2005).

**Vili, S., Meriste, T.** 2002. *Elimination of port quays and reconstruction of jetty in Haapsalu Border Guard Station territory*. EIA. Manuscript. EcoPro Ltd., Tallinn.

## Keskkonnamõju hindamistest Eesti rannikumeres

## Resümee

Töö eesmärgiks oli välja selgitada Eestis aastatel 2001-2004 kehtinud seadusandluse raames rannikumere arendustööde jaoks läbi viidud keskkonnamõju hindamiste (KMH) tugevad küljed, identifitseerida levinumad puudused ning määratleda KMH-de kvaliteedi kõikumise võimalikud põhjused. Detailselt vaadeldi mitmesuguste keskkonda potentsiaalselt mõjutavate faktorite analüüsi kvaliteeti 32 KMH-s. Valdava osa KMH-de tase on vähemalt rahuldav ka rahvusvahelises praktikas kasutatavate kriteeriumide valguses. Üksikute faktorite analüüsi kvaliteedi alusel määratletud KMH-de keskmine tase moodustab ligikaudu 60% ideaalsest.

Kõige kvaliteetsemalt on teostatud geoloogilisi uuringuid ja hinnatud planeeritud tööde mõju vee-elustikule. Argumenteeritult käsitletakse tööde käigus ammutatava materjali kasutamise võimalusi. Vähem tähelepanu pööratakse hüdrometeoroloogiliste tingimuste analüüsile, mistõttu on sageli lünklik ka heljumi leviku ning vee optiliste omaduste halvenemise analüüs. Soovida jätab alternatiivsete lahenduste käsitlus. Kõige kaugemal ideaalist on õlireostuse leviku analüüs.

KMH aruannete kvaliteedi kohatise ebaühtluse üheks põhjuseks võivad olla lüngad seadusandluses. Puuduvad selged nõudmised, milliseid aspekte ja millisel määral rannikumere objektide KMH käigus tuleb hinnata, aga ka tegurite kaudse, kombineeritud, kumulatiivse või mittelokaalse mõju käsitlemise kohta. See võimaldab osapooltel, kes vahel pole piisavalt pädevad mere- ning rannikukeskkonna spetsiifikas, seaduste nõudeid erinevalt ning kohati subjektiivselt interpreteerida. Lahenduseks oleks ühtsete normide väljatöötamine merekeskkonna tingimuste analüüsiks ning juhendmaterjalide koostamine KMH-de läbiviimiseks Eesti rannikumeres.

Teostatud analüüsi võrdlus ajakirjanduses ja muudes allikates ilmunud vastukajadega näitab, et seos KMH aruannetes tehtud järelduste ja soovituste ning arendustegevusele seatud piirangute vahel on olnud nõrk. Tõsiseks probleemiks on kujunemas järelvalve teostamine veealuste tööde üle. Tõenäoliselt on ebapiisav keskkonnatrahvide suurus ja liigselt keerukas seaduserikkumiste fikseerimise protsess.

KMH aruannete avalikustamise käigus on tehtud mitmeid väärtuslikke ettepanekuid. Suuremate tööde planeerimisel tuleks KMH-d teostama hakata juba võimalikult varases etapis. Täpsem peaks olema võimalikesse piirangutesse puutuv informatsioon. Tulemuste esitlus peaks baseeruma mittespetsialistidele mõistetavatel kaartidel, graafikutel, tabelitel jne. Situatsioonides, kus otsustamiseks pole andmeid piisavalt, võiks kaaluda eriteadlaste süstemaatilist kaasamist ning lainetuse ja hoovuste matemaatilise modelleerimise juurutamist ühe põhilise hindamismeetodina, eriti heljumi ja õlireostuse analüüsi vajadusteks. Teostatud KMH-des sisalduvate andmete kasutamist raskendab aruannetele ligipääsu keerukus.