Flooded Landscapes in the Lithuanian Waters of the Baltic Sea

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Abstract: In Lithuanian waters, six sites with preserved relict landscapes of the Yoldia–Early Littorina periods have been found. In finding and identifying submerged palaeo-landscapes, and possible traces of prehistoric human activity, traditional methods for such research were used: acoustic surveys and diving surveys. Samples from sites with preserved relict trees were required for palaeobotanical and geochemical research for phosphorus concentration testing. Samples of rooted pine tree stumps were used to perform this original research in order to extract DNA from Scots pine, circa 11,000 years old, that were found at the bottom of the Baltic Sea, and test the genetic links with the present-day gene pool of Scots pine in Lithuania. The samples of relict trees and peat were taken from depths of 10 to 30 metres and were dated to around 11,200 to about 7,800 cal BP. They have provided more possibilities to become acquainted with features of nature in the Holocene period, changes to the climate, and fluctuations of the sea level during the Yoldia, Ancylus Lake and Littorina stages.

The term 'underwater natural heritage' is not as familiar as it should be in Lithuania, and it is understandable that sites of relict landscapes, like natural maritime heritage, are not reliably protected at the national level. Areas with preserved relict underwater landscapes will be incorporated into the action plan for the implementation of the Maritime Spatial Planning procedure. Prehistoric settlements known in the coastal areas, and finds washed up by the sea, encourage the continuation of the search for Palaeolithic and Mesolithic settlements at the bottom of the sea.

Keywords: Baltic Sea, Lithuanian waters, Flooded landscapes, Sea level fluctuations, Tree sampling, Peat sampling, Remote sensing, Diving surveys

1.1. Introduction

In all cultures across the world, prehistoric coastal areas which included marine resources, coastal forest fauna, coastal migratory birds and animal migration paths, were a favourable place for human settlement. For these reasons, people moved from the coast of the former Baltic Ice Lake to the newly formed Yoldia Sea coastline, where the abundant fauna enabled humans to survive. The Yoldia coast of the Baltic Sea is now flooded and at the bottom of the sea. The location of the coastline during the Yoldia Sea and Ancylus Lake stages is not yet exactly clear. It is assumed that relicts of these coasts could have survived on the bed of the Baltic Sea at depths of 37 to 39 metres (Žulkus and Girininkas 2020, p. 6, Fig. 3).

One of the objectives of the ReCoasts&People project was to explore the seabed in order to find relict landscape elements under water, define the limits of their spread, and search for traces of prehistoric human activity in currently submerged coastal areas. In order to determine sea level fluctuations during the Yoldia, Ancylus Lake and Littorina stages, as well as the changes in natural conditions during the Holocene period, samples of relict trees and peat that were dated to around 11,200 to about 7,800 cal BP were taken from depths of 10 to 30 metres in different parts of Lithuanian territorial waters (Fig. 1.1). Besides the available samples, additional ones were taken that were necessary to corroborate the dates and to continue previous research. Samples from all the sites with preserved relict trees were required for geochemical research, which had not been done earlier, and for phosphorus concentration testing, as an indicator of possible prehistoric human activity. Samples of rooted pine tree stumps that were preserved on the seabed were used to perform this original research in order to extract DNA and amplify PCR fragments from nine Scots pine circa 11,000 years old that were found at the bottom of the Baltic Sea, and test the genetic links with the present-day gene pool of Scots pine in Lithuania.

Preserved relict forest trees and peat outcrops in areas near Juodkrantė and Klaipėda, and in the area of the Nemunas palaeo-estuary beside Nida, were explored by remote sensing technology and diving, and relicts of old coastlines and possible traces of human activity were searched for around Palanga and Šventoji. Based on the available research data, sites for new investigations were chosen based on the sounding of the seabed structure using sub-bottom profiling acoustic systems.

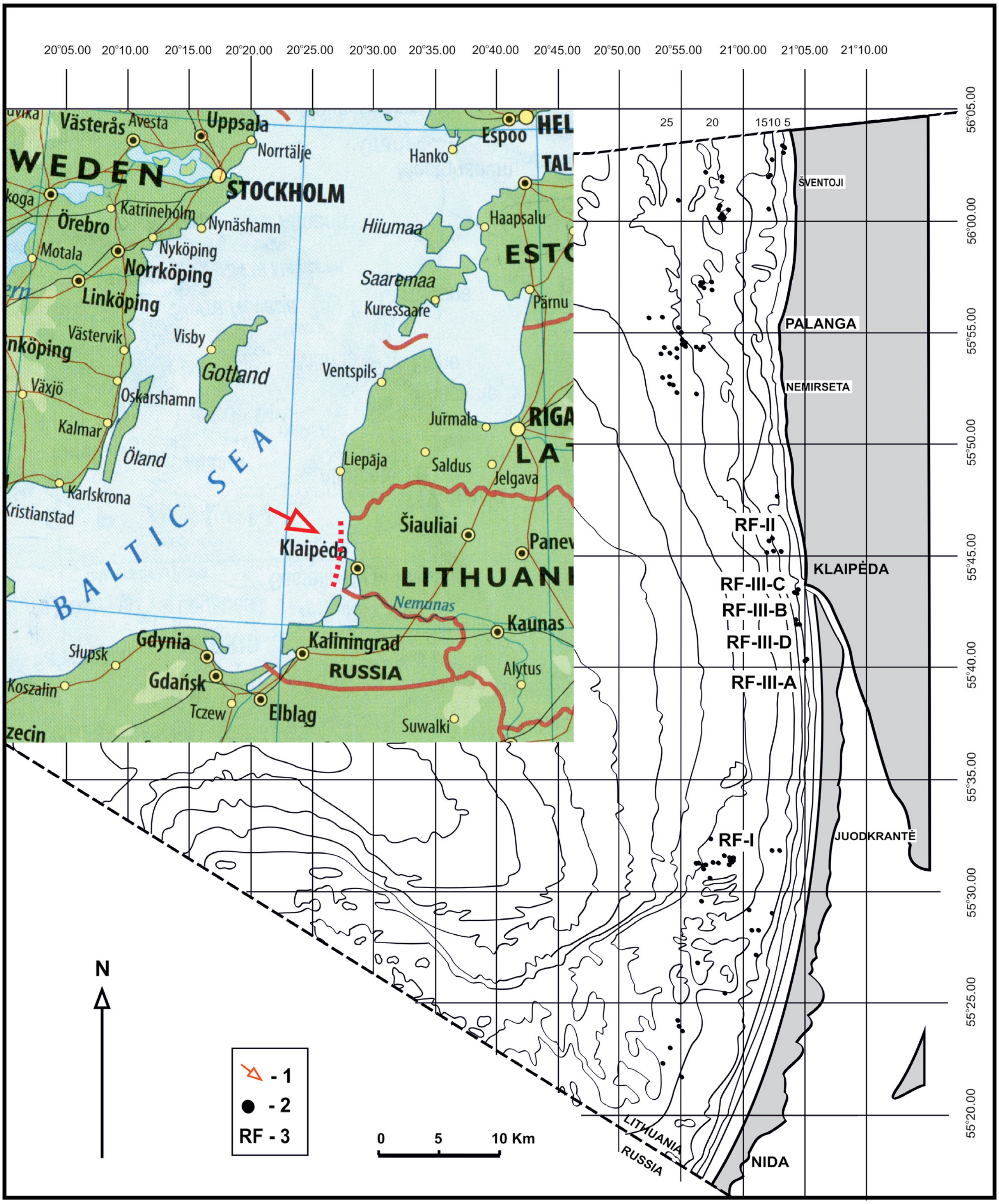

Figure 1.1. Map showing the locations of underwater relict forests in Lithuanian waters and the sites of the survey: 1. Lithuanian waters; 2. sites of submerged relict forests; 3. points of the diving investigation (drawing by Vladas Žulkus).

1.2. Research methods

In finding and identifying submerged palaeo-landscapes, palaeo-coastlines, and possible traces of prehistoric human activity, typical methods for research were used: acoustic survey, seismic remote sensing (sub-bottom profiling), diving surveys, underwater photography, and video filming.

Before planning any additional seabed observations by scuba divers and using side-scan sonar, data from previous research were used, and the research material and results of previous seabed explorations performed for scientific purposes and for the extraction of marine resources were collected and analysed. The results of multinational mine clearance operations (MCOPLIT) and Open Spirit (an international mine clearance exercise) in 1997, 1998 and

1999, underwater acoustic surveys, remote sensing and diving surveys were used. The bed of the Baltic Sea was explored during an international demining operation held in Lithuania's territorial waters and its exclusive economic zone. During these operations, some objects found at depths of 20 to 60 metres were identified as tree trunks and stumps, possibly the remains of ancient trees. According to signals recorded by side-scan sonar, the sites of surviving peat outcrops can be estimated. The possibility of making a mistake is always present when interpreting the results of explorations of the seabed using side-scan sonar if objects are not checked by a diving survey.

In looking for possible preserved relict trees, a selection might have to be made from dozens, or even hundreds, of objects registered by side-scan sonar. The small size of the tree stumps (most have a diameter in a range of 15 to 30 cm) prevented their detection on side-scan sonar records. The acoustic backscatter is similar to that of stones or small ridges from a moraine. A difference is shown by the short distance (5 to 6 m) of sonar 'fish' over the seabed. This method was successfully applied in 2010 and 2011 when exploring the RF-I site (Žulkus and Girininkas 2012, pp. 14, 51). Of course, this possibility is available only to sites with quite an even seabed.

The correct recognition and interpretation of sediments and other seabed features on side-scan images in all cases needs further comparison with direct observations by divers and underwater video cameras (Tauber 2007, p. 75). In addition, the interpretation of the data obtained by side-scan sonar is hindered by shipwrecks and other technogenic objects present in the exploration area, the identification of which is possible only during scuba diving.

While carrying out the ReCoasts&People project, the seabed areas were also investigated using side-scan sonar. Objects that could be related to natural and cultural submerged relict landscapes according to data from sonar scanning were explored by divers. In achieving the objectives of the research, explorations were conducted at sea in seven zones in the area between Nida and Palanga between 2018 and 2021. In total, 200 diving sessions in pairs were performed. Mostly vessels from Klaipėda University were used for the diving work: the S/V *Brabander*, the yacht *Odisėja*, and motorboats for work in the offing. The total number of samples taken was 24. Summarising the results of the explored sites, the identified areas with preserved relict landscapes with rooted pine stumps below the water were mapped, and the limits of these areas were identified. The samples obtained from the bed of the Baltic Sea were studied using palaeobotanical (pollen, diatom, plant macrofossil) survey, isotopic (^{14}C) measurements, estimation of phosphate concentration, and an original DNA study of a pine found at the bottom of the sea (Fig. 1.2).

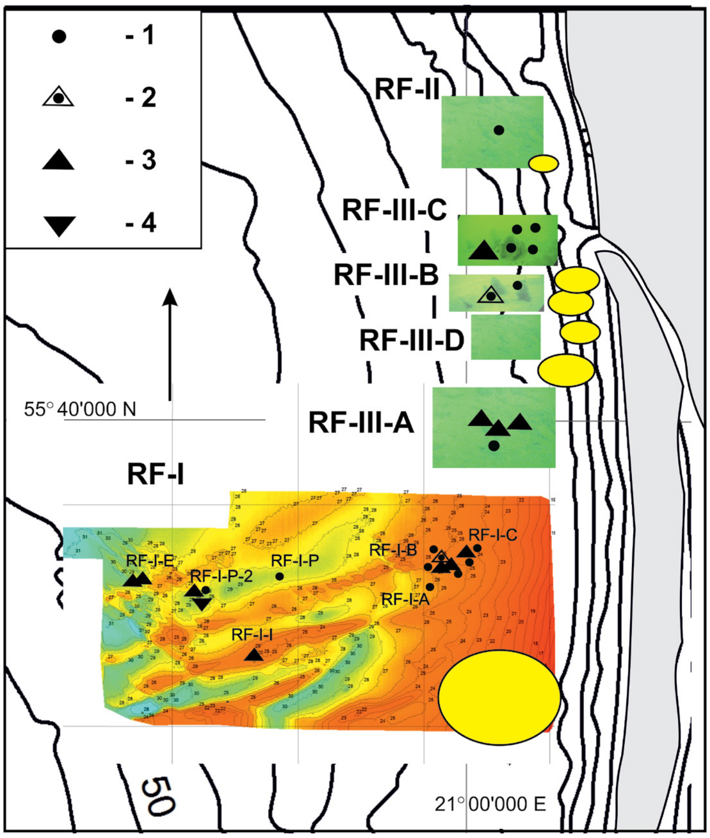

Figure 1.2. Map of relict trees and peat sampling points: 1. samples taken for ^{14}C dating; 2. samples taken for ^{14}C dating and geochemical study; 3. samples taken for ^{14}C dating, geochemical and tree DNA study; 4. samples taken for ^{14}C dating and tree DNA study (drawing by Vladas Žulkus).

Some unplanned problems arose during the research. Frequent poor underwater visibility hindered the investigations conducted by divers; this did not allow for high-quality underwater photography or video camera filming, and consequently the creation of 3D photos. Difficulties were encountered in trying to take large undisturbed samples from relict peat deposits lying at depths of 29 or 30 metres. The water pressure of the sea at a depth of 30 metres is four atmospheres. While rising to the surface, the pressure drops rapidly; therefore, even quite dense soil (in our case it was peat) is washed away. Simple equipment was constructed to take soil samples from great depths, by means of which samples of up to 30 centimetres in length were taken with their structure undestroyed. When performing exploratory archaeological research at the RF-III-B site, at a depth of 11 metres, airlift equipment was used. The compressed air for the airlift was supplied from the air tanks of the Klaipėda State Seaport Authority vessel *Naras*.

In order to identify a landscape feature such as a palaeo-river channel or traces of possible archaeological settlements, the seabed was explored using sub-bottom profiling acoustic systems, which allow for the identification and measurement of various marine sediment layers that exist below the sediment surface (Chapter 4 of this book). This research was carried out in three parts.

Three marine seismic reflection cross-sections were collected for mapping shallow sedimentary quaternary layers and to locate buried valleys of palaeo-rivers. High resolution seismic data allows us to distinguish relatively small geological structures, and provide valuable information for future underwater archaeological surveys.

A marine seismic survey gave promising results. During seismic data processing and interpretation, six palaeo-incisions were found. The discovered palaeo-incisions can be linked to the current rivers.

1.3. Research areas

RF-I

The area of the relict forest explored on the seabed near Juodkrantė (RF-I) represents a part of the landscape that developed on the Curonian Plateau (an underwater peninsula) during the Yoldia, Ancylus Lake and Early Littorina stages. Studies from 2010 to 2012 revealed the northern part of the Curonian Plateau seabed formations and coastlines. At depths of 15 to 25 metres (21° 04’ E to 21° 02’ E longitude), the bed of the Baltic Sea is relatively flat and sandy, with an inclination to the west. There are multiple two to three-metre-high mounds with deeper hollows between them (up to 30 metres below the surface) and further out to sea (up to 20° 57’ E longitude) throughout the whole explored area. The mounds and hollows run in a northeast–southwest direction. In RF-I, the investigation work consisted of two phases: exploration by side-scan sonar, and by multi-beam technology. Later, the verification of the sonar results was obtained by scuba examination.

After the initial side-scan sonar research, 477 targets were identified on the seabed. After a review of the RF-I site, out of the 477 selected targets, 109 objects were identified as likely to be trees. However, scuba examination showed that some horizontal trunks, especially smaller ones, were partially or almost completely covered over by sediment, and therefore invisible to the side-scan sonar. So, we can claim that in this 30 square kilometre area there may be twice as many relict forest rooted tree stumps and trunks preserved (Žulkus and Girininkas 2012, pp. 16, 51).

According to the exploration’s results, the largest submerged accumulations of objects were in the northeast and central parts of the area. In 2011 and 2012, six relict tree groups were identified and surveyed by diving. The central part of the area was investigated for four tree groups. Groups of rooted relict trees were found at depths of 24 to 29 metres. At 29 and 30 metres, peat from the RF-I-P group was found *in situ*. Currently, 22 trees and peat samples from the seabed have been dated in the RF-I area.

At the very western edge of the surveyed area, 15 to 15.5 kilometres from the coast, an ancient coastal structure was discovered. At a depth of 37 to 39 metres, the sonar showed very unusual underwater terrain. This was probably the remains of the ancient, washed-away coast. At a depth of 39 metres, the degraded traces of terraces were detected; and further west, further into the sea, at a depth of 43 metres, a low continuous underwater terrace extending in a north–south direction was detected as well. At depths of 44 and 47 metres, underwater ridges parallel to the coast, small terraces and presumed disrupted coastal structures were observed (Žulkus and Girininkas 2020, p. 7, Fig. 3).

In 2011 and 2012, seven test samples of pine (*Pinus sylvestris*) trunks lying underwater were extracted for dendrochronological testing. Five test pieces were suitable for tree-ring measurement. When synchronised with each other, the wood samples showed that they did not stop growing at the same time: the distribution of the withering trees covers a 32-year interval. It was not possible to date the trees using the dendrochronological method, because a dendrochronological scale of the Holocene period with absolute dates for the Baltic region does not exist (Žulkus and Girininkas 2012, pp. 35, 53).

In recent years, considerable seabed research has been carried out for different purposes at the RF-I site and its area (Fig. 1.3). In 2017, measurements were conducted using a multi-beam echo sounder in neighbouring sites, partly covering the areas previously investigated. Last year, using a multi-beam echo sounder and side-scan sonar, around 150 square kilometres of the seabed southwest of the RF-I exploration site on the northern edge of the underwater Curonian Plateau was investigated. The scanning was conducted for research purposes and in order to evaluate the possibility of dredging sand to replenish beaches. The seabed

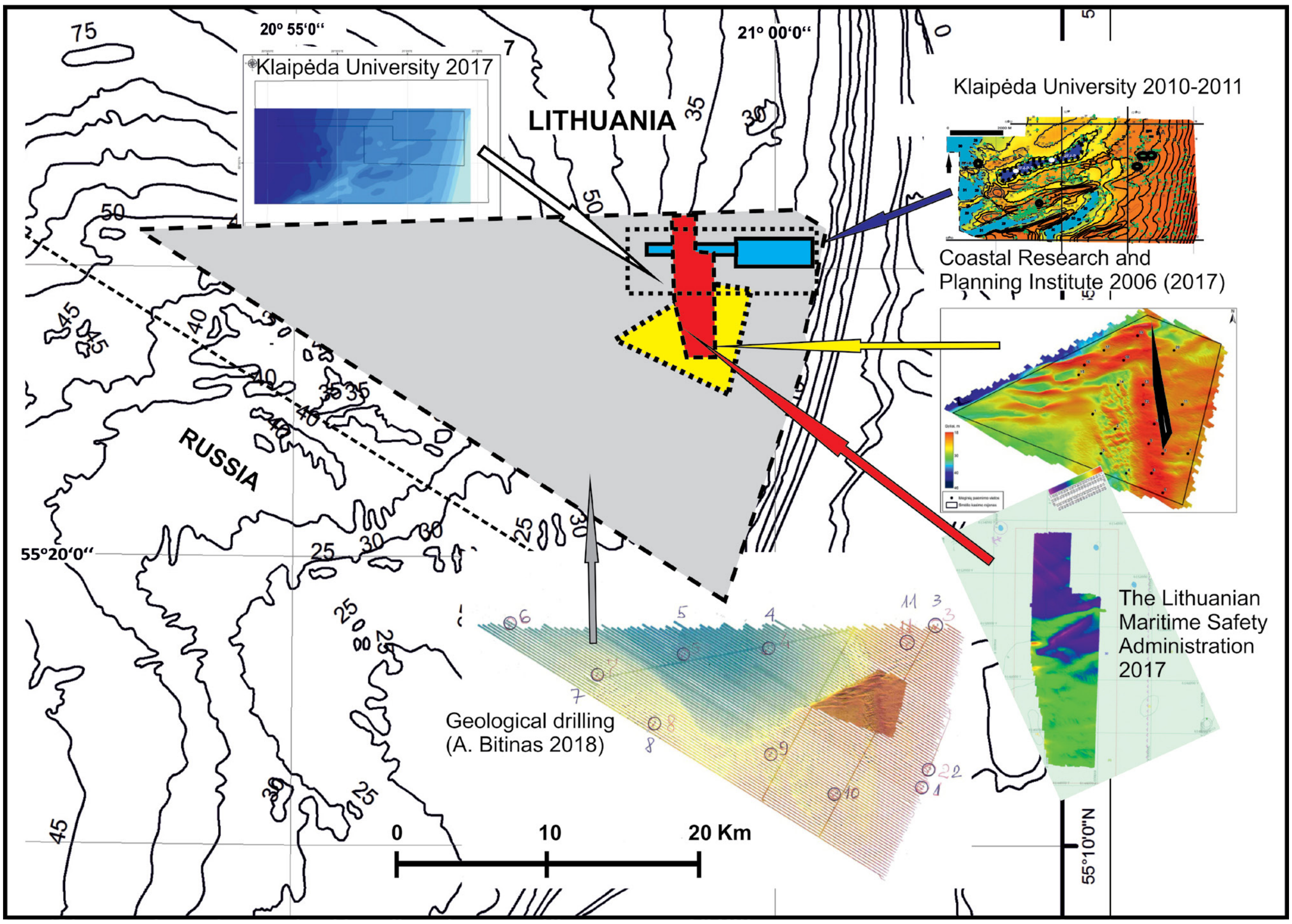

Figure 1.3. Seabed research was carried out for different purposes at the RF-I site and its surroundings using multi-beam and side-scan sonar (drawing by Vladas Žulkus).

in this area contains relict coast formations similar to the ones discovered at the RF-I site. The underwater northern slope of the plateau is steep, plunging from 20 metres to almost 50 metres in depth (Zakarauskas 2017). This area may be suitable for searching for ancient relicts of the Baltic Sea.

During explorations performed by different institutions, the identification of objects registered on the seabed was not obtained by scuba diving examination. Objects recorded by side-scan sonar were inspected during diving sessions from 2018 to 2021, while the ReCoasts&People and BalticRIM projects were being conducted (Figs. 1.1, 1.2).

Between 2018 and 2021, diving was performed at the RF-I site in order to identify objects on the seabed and parts of relict landscapes (Fig. 1.4**;** Fig. 1.5), and to take

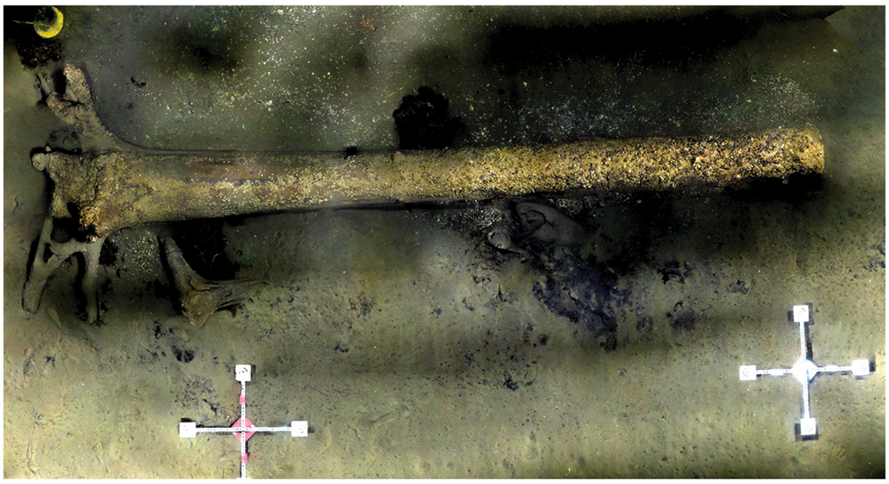

Figure 1.4. A 3D model of the RF-I-B-1 tree trunk dated to about 10,400 cal BP on the seabed at a depth of 25 metres (by Janusz Różycki, National Maritime Museum in Gdansk, Poland).

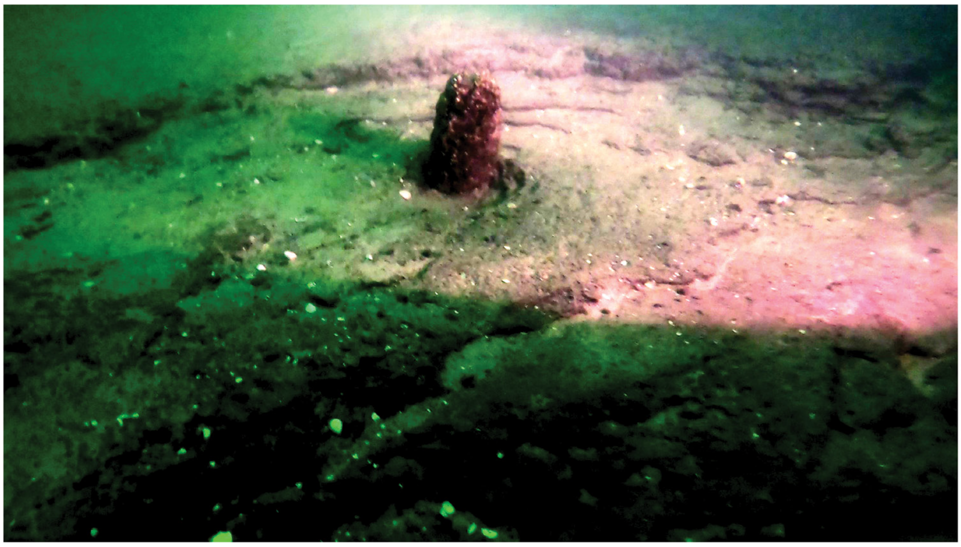

Figure 1.5. The remains of the RF-I-P-2(2) tree and peat layer, dated to about 11,850 cal BP on the seabed at a depth of 30 metres (photograph by Vladas Žulkus).

samples of relict trees and peat. A total of 18 sites were explored underwater, and 17 samples of relict trees and peat were taken for ^{14}C dating, geochemical and tree DNA analysis (Chapter 2, Table 2.1 of this book). Summarising the available research data at the RF-I site, the total area of relict trees and peat spread was identified.

During the course of the project, a search was conducted in other locations south of the RF-I site, and also near Nida, around the former Nemunas palaeo-estuary (Gelumbauskaitė 2010). According to data from earlier sonar research, parts of palaeo-landscapes and rooted relict trees were likely there. During diving sessions, the seabed was explored at seven sites at depths of 14 to 33 metres (Fig. 1.6). In some places, formations of regular shapes similar to traces possibly left by human activity were detected (Fig. 1.7). Undamaged formations of relict coasts, rooted relict trees, and sediment deposits were not found.

RF-II and RF-III

There were two more explored sites to the north of the RF-I site, near Klaipėda port. A relict rooted stump RF-II was found earlier at a depth of 14.5 metres at the site at Melnragė II beach (to the north of Klaipėda port). In addition, a T-shaped red deer antler axe was found on the shore in that location (Rimkus 2019, pp. 8–9). The date of the axe (7163–6958 cal BP; 5214–5009 cal BC) is close to the date of the rooted stump RF-II (8008–7571 cal BP; 6059–5622 cal BC) (Chapter 2, Table 2.1 of this book).

The seabed in the area of these finds was also explored using side-scan sonar. Later, the search was continued by diving at six sites where relic landscapes or traces of human activity were expected (Fig. 1.8). At one of the sites, a boulder that was unusually big for Lithuanian coastal waters was detected during earlier explorations on the stony bed of the washed moraine, at a depth of 25 metres (Žulkus 2016). This boulder, of quite a regular form, was cleaned, measured and filmed. The boulder stands out not only by its size (4.4 by 3.65 m, it rises up to 2.6 m above the seabed), but also by the quite regular cut-off sides, and the even upper surface with strange hollows and splits (Fig. 1.9). Investigations were conducted in order to find possible traces of human activity; however, they were not found.

No other objects that could be related to relict natural or cultural landscapes, except the rooted stump RF-II, were found at this site. The seabed there consists of a washed moraine. An additional search was carried out around this relict tree, but no other similar finds or artefacts related to the activities of prehistoric people were found.

Another exploration site was the RF-III-1 (RF-III-A) area south of Klaipėda. A rooted stump of a relict pine was found there at a depth of 11 metres, and it was dated (Fig. 2.2). Pursuing further research in the vicinity of this find, seven still unseen rooted relict trees were found on the sandy seabed. Three samples were taken for laboratory tests (RF-III-A-2, RF-III-A-3, RF-III-A-4). This site is one of the most promising for further exploration.

The relict landscape sites RF-III-B and RF-III-C, submerged by the sea, were found in 2016 (Žulkus 2017). During non-invasive investigations using side-scan sonar, an indistinct object was detected at a depth of 11 metres to the southwest of the southern leg of the breakwater of Klaipėda port. During the diving session, the remains of six rooted relict trees, and, as was thought, poles left by people, 13 or 14 centimetres high, and five

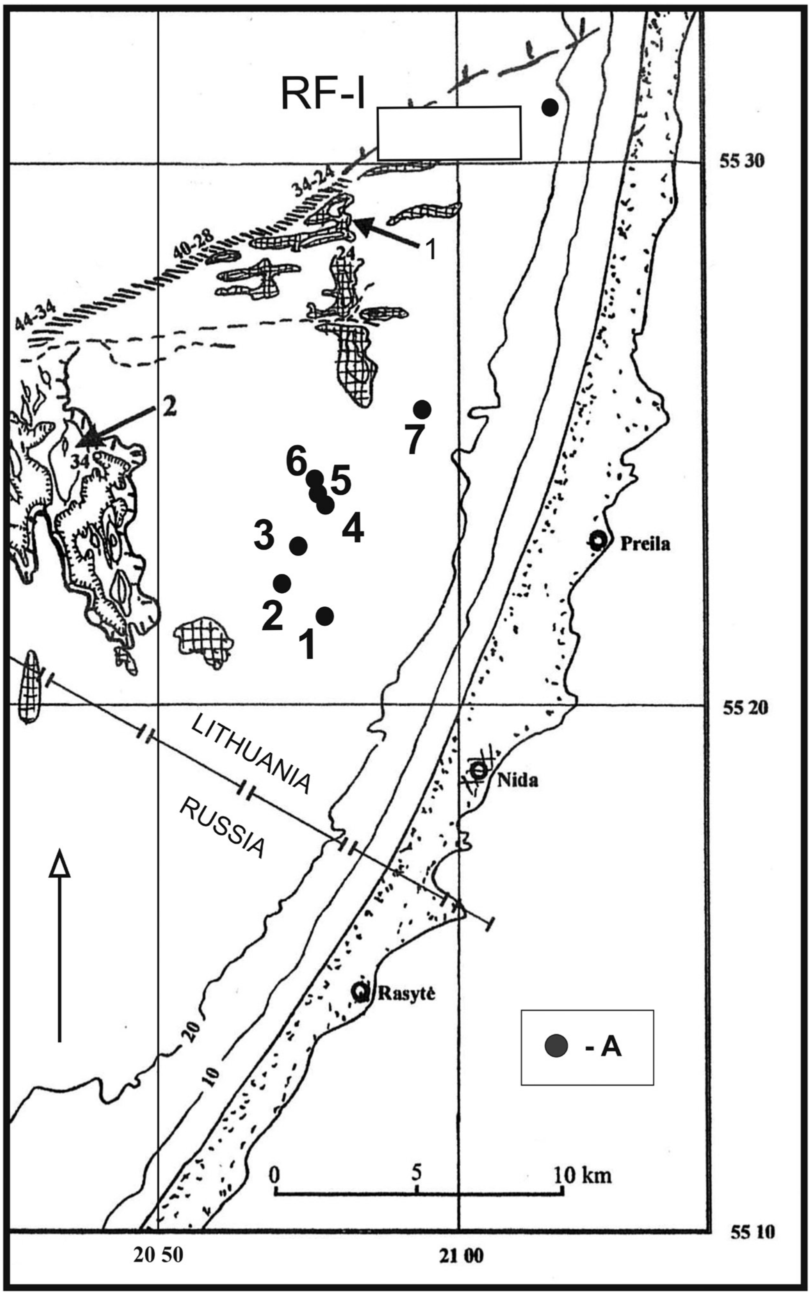

Figure 1.6. The locations of the acoustic survey (RF-I) and diver inspection sites (A) around the former Nemunas palaeo-estuary: 1. old shore dunes ridge; 2. the old Nemunas delta (bathymetry and morphogenetic forms after Gelumbauskaitė 2010, p. 110, Fig. 1, drawing by Vladas Žulkus).

or six centimetres in diameter, were found at the site, in an area of about 16 by 11 metres (Fig. 1.10). Ten metres to the north of the supposed group of poles, one more separate pole with supposedly a regular cut was found. Two samples were dated using ^{14}C, and their dates were determined to be around an average of 7,530 cal BC. It is presumed that the poles were possibly left by people beside the Danė palaeo-estuary, or they are possibly the remains of fish weirs (Žulkus and Girininkas 2020).

In 2020, the seabed was further investigated by divers in order to detect unknown objects. Underwater archaeological research was carried out at the site of the possible fish weir (Rimkus 2021). A test pit was made at the site using a prefabricated metal caisson. It was necessary to prevent the collapse of the test pit walls and the fall of sediment. The caisson was constructed so that it allowed the deepening from the present surface of the seabed by to up to one metre. The research was carried out by pumping seabed silt by means of an airlift, which is normally used in underwater research at depths greater than 10 metres.

Underwater explorations on the seabed to the southwest of the southern leg of the Klaipėda port breakwater showed that at the RF-III-B site, around the presumed relict River

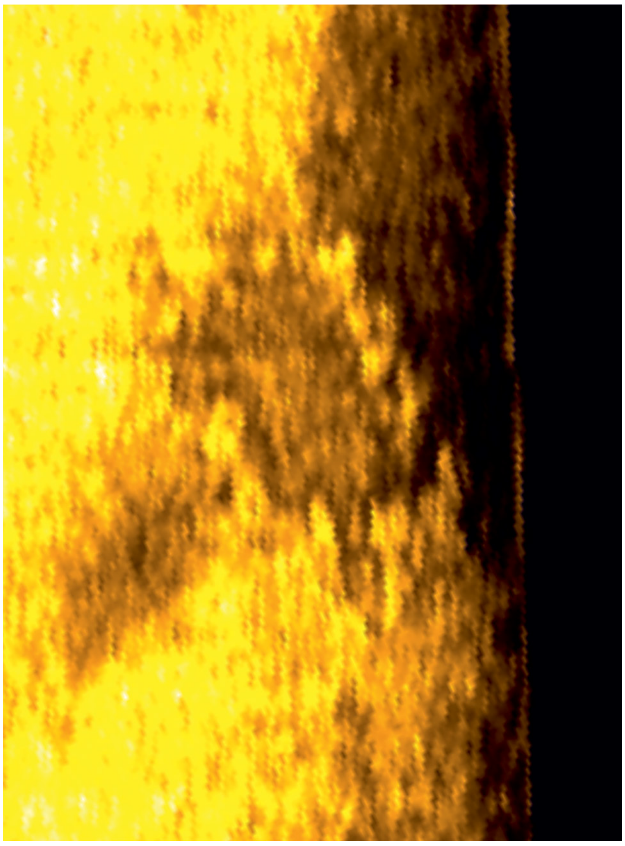

Figure 1.7. The structure of the area of the former Nemunas palaeo-estuary at a depth of 36 metres, discovered using side-scan sonar.

Danė estuary, at a depth of 11 metres, a group of four poles, RF-III-B-1, presumably left by people, and a supposed pole, RF-III-B-8, are of natural origin. The roots of these trees were discovered under layers of sand and gravel when a depth of 60 centimetres from the present seabed was reached during the excavation. Unlike the trees that were found 6.5 to 12 metres from the exploration site with washed-up roots, this group of trees seems to have grown in a small lower area, and their roots were covered by sand. Only small trunks of trees were seen on the surface of the present seabed, which created an impression of hammered poles. No signs of a cultural layer were noticed at the site, no finds with traces of human activity, and no human or animal bones were found. Samples of preserved rooted tree stumps were taken from around the test pit for further research (^{14}C dating, tree DNA determination, geochemical analysis, and phosphate concentration testing).

About 15 metres to the south of the RF-III-B-1 group of trees, one up-rooted tree stump was found of about 30 centimetres in diameter and one metre high, which was not detected earlier. This find shows that at the RF-III-B exploration site, the relict preserved landscape has survived in a larger area than was thought before.

At about 70 metres to the east of the RF-III-B exploration site, at a depth of 12 metres, yet another fragment of relict forest, marked RF-III-C (Fig. 2.10, C), was found. It consists of groups of small trees and large up-rooted tree stumps, and a peat outcrop. Three tree samples (RF-III-C-1, RF-III-C-2 and RF-III-C-3) and a peat sample (RF-III-C-P1) were dated using the ^{14}C method. These relicts belong to a similar period as the ones found at the RF-III-B site (Chapter 2, Table 2.1 of this book).

RF-III-D

The relict submerged landscape at site RF-III-D (Fig. 1.1) with tree stumps with roots embedded in the sandy seabed

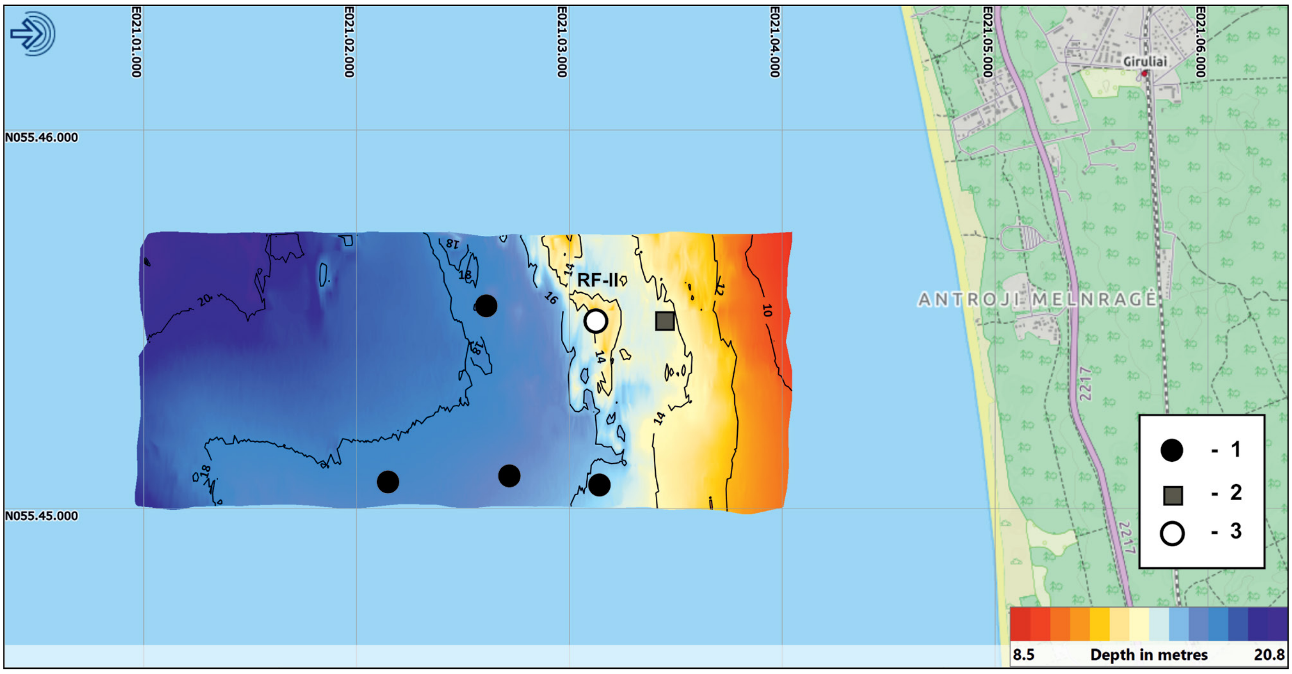

Figure 1.8. Map of the seabed north of Klaipėda, scanned using side-scan sonar: 1. the points of the diving investigation; 2. a rooted pine stump dated to about 7,800 cal BP; 3. a boulder of regular shape (drawing by Vladas Žulkus).

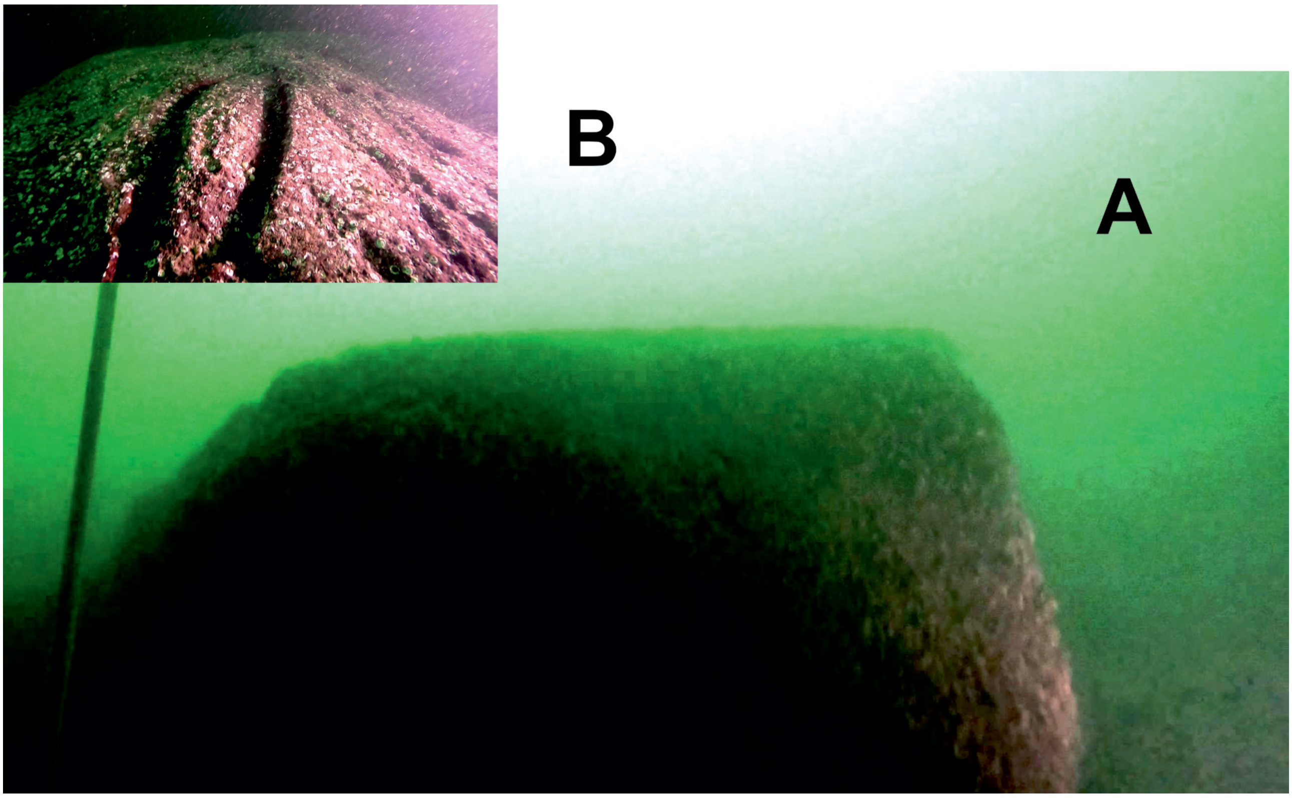

Figure 1.9. The boulder with supposedly regular, cut-off sides and a hollow on its upper surface (photographs by Vladas Žulkus).

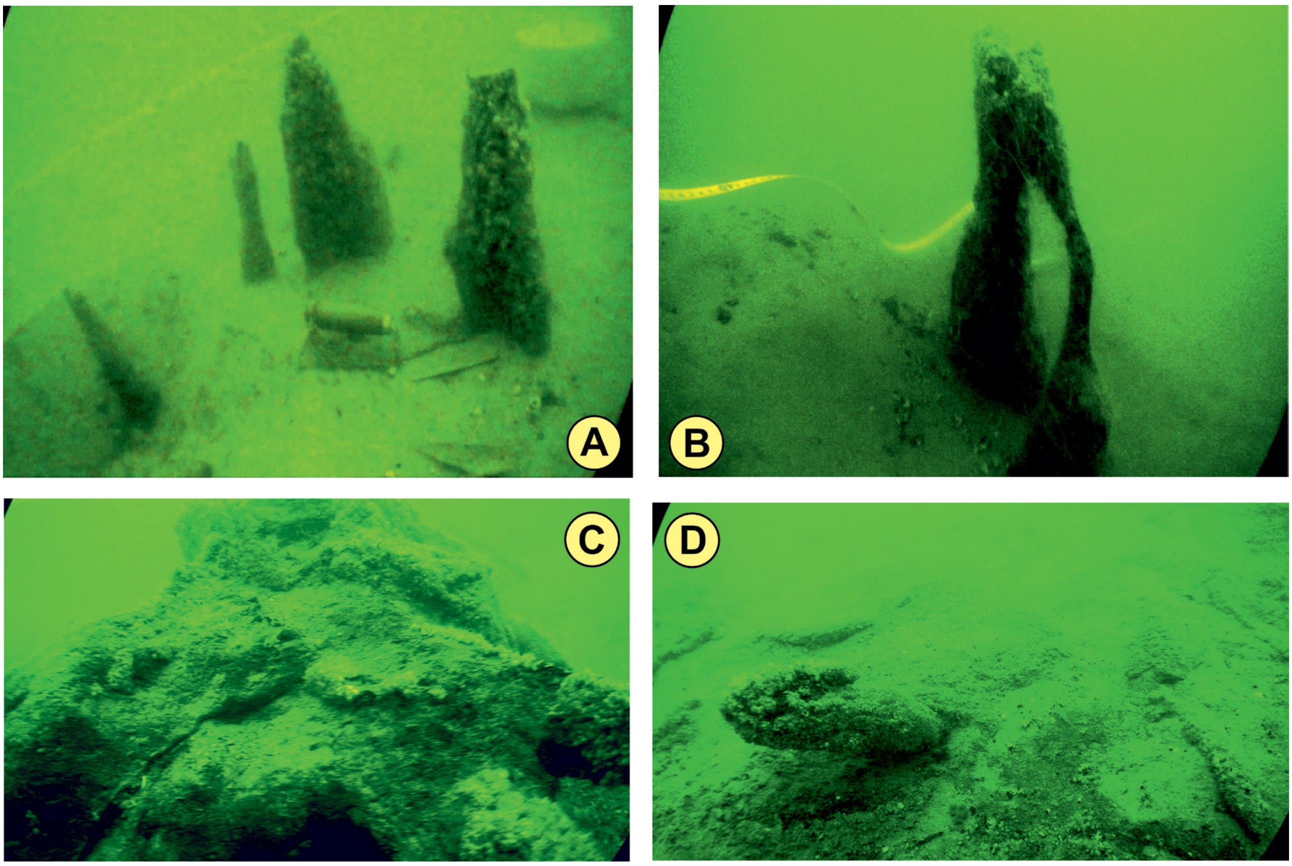

Figure 1.10. Trees (A, B) dated to about 9,400 cal BP and peat formation (C, D) dated to about 9,200 cal BP found at a depth of 11 or 12 metres at the RF-III-B and RF-III-C sites around the relict estuary of the River Dangė (photographs by Vladas Žulkus).

was found in 2020 at a depth of 10 metres (information from the Lithuanian Navy Divers Team). Underwater explorations on the seabed at this site have not been conducted.

The Palanga area

The reason for the explorations of the seabed around Palanga was the fact that prehistoric settlements were found on the present coastal area. A Late Mesolithic period settlement was situated on the edge of a moraine next to the River Rąžė. Finds from the Late Neolithic and the Early Bronze Age were also discovered in the vicinity (Girininkas 2011, pp. 50–56).

Research conducted by the Lithuanian Transport Safety Administration was used in the research project. In 2014, at a distance of six to 12 kilometres from the coast, an area of seabed was sounded by means of side-scan sonar. The formations on the seabed enabled an assumption to be made about possible traces of the River Rąžė palaeo-valley on the present seabed. In order to extend the research to already-explored ground, one more area was scanned in 2018, in which 27 objects on the seabed were distinguished as potential relicts of prehistoric landscapes. The total area sounded by side-scan sonar around Palanga comprised more than 40 square kilometres (Fig. 1.11). The depths in the area are from 12 to 30 metres.

The sites selected in this area were explored by divers (Fig. 1.12). Traces of possible surviving natural and cultural landscapes, and signs of human activity, were searched for. In the explored area, the sandy seabed with small mounds, rock formations with sandy patches, and moraine ridges alternated with rock formations, fine silty sand, and gritty sand. There are occasional boulders two to three metres in size. In none of the 26 explored sites were traces of surviving prehistoric landscapes detected. The oldest coasts are transformed by processes of erosion during later transgressions and regressions.

1.4. Discussion. The survival of relict landscapes

Six sites are currently known in Lithuanian territorial waters in the Baltic Sea where fragments of relict landscapes submerged by the sea have been detected. The oldest peat outcrop and rooted trees are from the Yoldia Sea stage. We cannot yet explain how they have survived, or what the possibilities are to find other sites with undamaged or barely damaged formations of relict coasts. We can only make assumptions.

The fact that at the RF-I site near Juodkrantė so many relict forest trees have survived *in situ*, and so few residues of washed shores are present at depths of 24 to 30 metres, would indicate that the rise in sea level was very fast.

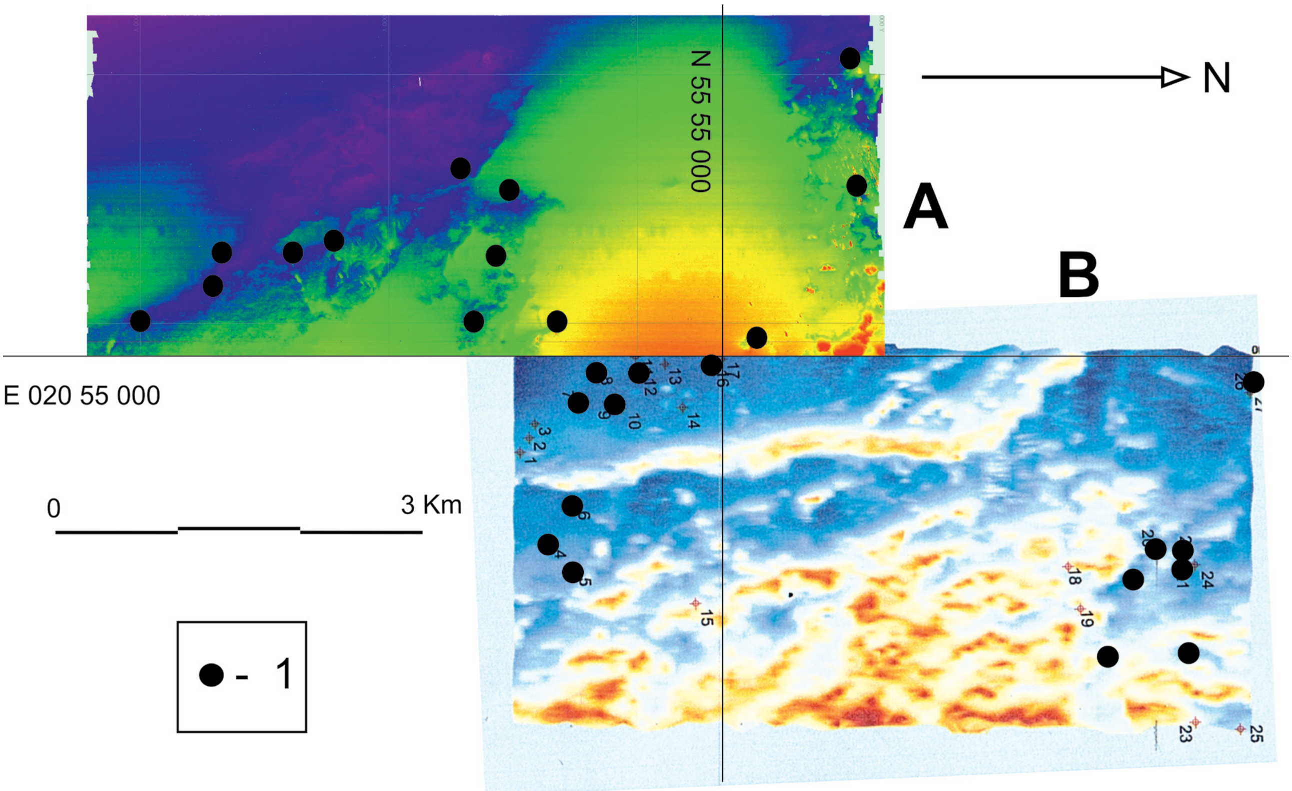

Figure 1.11. The seabed areas near Palanga scanned using side-scan sonar: 1. the points of the diving investigation (drawing by Vladas Žulkus).

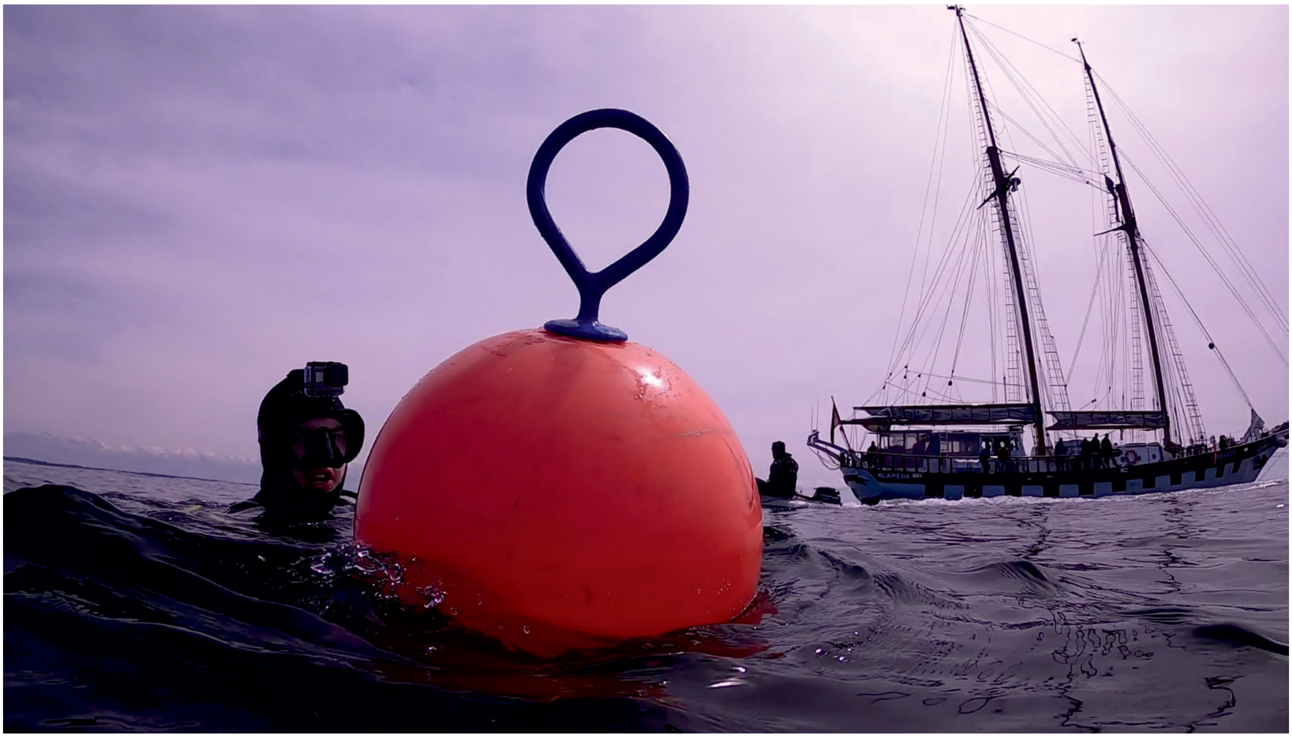

Figure 1.12. Diving from the SV *Brabander* (photograph by Ieva Želvytė).

A well-preserved relict ‘forest’ RF-I near Juodkrantė suggests that after its remains were flooded, a layer of sediment must have settled there which preserved the remains of trees and peat deposits, and protected them during the Ancylus transgression and regression, and the Early Littorina transgression, until the area was flooded again in around 7500 cal BP. The formation of sediments could have been infuenced by the previously adjacent river silt. During the Littorina transgression, the rising water and waves eroded the coasts of that time unevenly in different places, and the remaining relicts of the Yoldia Sea were preserved until today.

Similar phenomena can be observed in other regions of the Baltic Sea. The reason for the survival of so many submerged sites and the preservation of rich assemblages of organic material are similar in different locations. Burial and preservation are dependent on interaction between environmental factors, the coastal configuration and geodynamics, biological interactions, and geochemical processes (Hansson 2018, p. 33).

Burial in sediments, followed by permanent submergence under water, provides anaerobic conditions that protect organic material from destruction by bacteria. As always, when considering issues of underwater preservation, there is a delicate balance between sediment accumulation which is sufficiently rapid to provide protection for land surfaces and archaeological material, but not so rapid as to bury them deeply beyond reach of easy observation (Bailey and Jöns 2020, p. 35).

In Haväng and western Blekinge (Sweden), stumps and tree trunks from the Ancylus Lake stage have been preserved, but no stumps or tree trunks from the Initial Littorina Sea stage have been found. The rate of transgression will determine how long the trees are exposed to terrestrial decay processes, which in turn will determine if the trees can withstand erosive forces under water. Consequently, the comparably slow transgression rate during the Initial Littorina Sea stage most likely meant that the trees were more or less totally decomposed before the water level reached their positions (Hansson 2018, pp. 33–35).

Otherwise, the pine forest of stumps, trunks and branches (Fig. 1.13) would have been destroyed or covered by subsequent layers. It is not known how many pieces of this landscape have been preserved at the RF-I site. It is also unclear whether elements of the relict landscape have been preserved at depths shallower than 16 or 15 metres. Of course, relicts of old landscapes could be found in other places under a thicker layer of silt, but they are not seen in investigations with side-scan sonar or scuba divers.

Traces of prehistoric settlements were not found at the exploration sites. We can offer two reasons for this. Firstly, during the Baltic Ice Lake, Yoldia and Ancylus Lake stages (the Late Palaeolithic and Mesolithic periods), the number of settlements was not high, despite the favourable conditions for survival (Girininkas and Daugnora 2015, p. 38). The second reason is that during the erosion of the coast, the cultural layers of such settlements were destroyed quite rapidly.

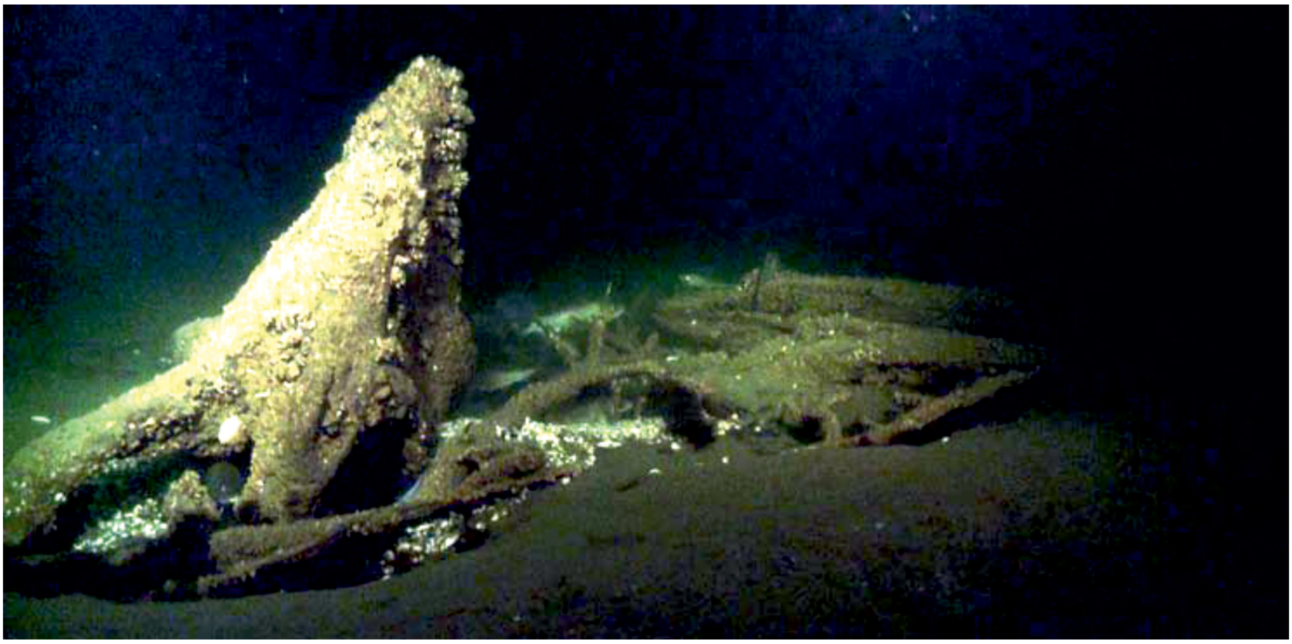

Figure 1.13. Branches preserved at a depth of 25 metres at the RF-I-C site, near a rooted pine stump dated to about 10,500 cal BP (photograph by Vladas Žulkus).

The survival of a relict landscape is influenced by constantly recurring factors: hurricanes, activation or changes in sediment flows, and, recently, the impact of human activity in exploiting marine resources. This was encountered during our research. At the RF-III-A site, it was discovered that the seabed here was different in 2020 compared to previous years. Part of the site with about 0.5 metre high stumps was covered in sand. In another part, seven stumps were uprooted and had not been found previously by divers as they had been under the silt.

In order to inspect the earlier detected peat deposit *in situ* and take samples, in 2020 diving was performed at the RF-III-C site. It is adjacent to the relict forest RF-III-B site, and about 250 metres south of the southern leg of the Klaipėda port breakwater. In 2016, fragments of a relict landscape, groups of small trees with uprooted roots, and a peat deposit, were found there at depths of 11.5 or 12 metres. Three samples of trees (RF-III-C-1, RF-III-C-2 and RF-III-C-3) and a peat sample (RF-III-C-P1) were dated using ^{14}C (Chapter 2, Table 2.1 of this book). In 2020, the objective was to take samples for ^{14}C dating, tree DNA determination, and analysis of phosphates. It was found that the seabed at the site had changed a lot. The rooted tree stumps and peat deposit were totally covered with sand. The depth there was only about ten metres. At about 20 metres south of the earlier explored site, one small, rooted tree stump was eventually detected, samples of which (RF-III-C-3) were taken for further study. It is obvious that the seabed at this site was covered with a layer of sand 1.5 metres or even two metres thick.

In the eastern part of RF-I, at a depth of 25 metres, five rooted stumps of trees were found in 2011 (Žulkus and Girininkas 2012, p. 27). During diving in the summer of 2019, stumps were not found in that site. In the summer of 2020, one stump rising about 70 centimetres above the seabed was detected at a depth of 24.5 metres.

It is obvious that, under the influence of currents and silt, relict trees are covered with sand and uncovered again, depending on the directions of the currents that form on the seabed, their strength, and the amount of silt carried. In Lithuanian waters, the sources of sediments in shallow waters are moraine plateau relicts affected by abrasion, flows of terigenic sediment material from the Curonian Lagoon, and silt carried by currents on the seabed. A longitudinal front of silt moves from the Sambian Peninsula in a south–north direction (Gelumbauskaitė 2014; Žaromskis 2020, p. 29, Fig. 2.7). Around Klaipėda port, the geodynamic balance can be damaged by port dredging operations (Gelumbauskaitė 2014).

The significant increase in the sand sediment layer on the seabed in the RF-I and RF-III sites of relict forests could be related to two factors. An area of excavated sand is located very close to the RF-I site, where submerged landscapes have been preserved across quite a large area (Fig. 2.3). In 2020, dredging was carried out there to enlarge Palanga beach. The sand was taken from the sea bed with special equipment, and deposited on the beach. The volume of imported sand was >180,000 cubic metres.[1] The sand moved during the excavations is transported during storms by waves and currents in a northerly direction. This was the reason for the layer of sand sediment at the RF-I, and probable RF-III-A sites.

[1] https://welovelithuania.com/palangos-papludimiai-bus-papildyti-smeliu/

A 1.5 to two-metre-thick layer of sand that covered the areas of relict forest and peat bog at the RF-III-C site could have formed after currents brought dredged material which formed small hills on the bed around the fairwater of Klaipėda port. The dredged material was dumped at sea. The main offshore dumping site that is used for dumping all lithological types of sediments is located 20 kilometres southwest of the entrance to Klaipėda port, at a depth of about 43 to 48 metres (Dembska et al. 2014, p. 4). Operations to increase the depth of ports are carried out constantly, and they were especially intensive in the spring of 2021.

In both cases, the changes to the seabed in the investigated areas are related to human activity. It changed the surroundings of the relict landscapes considerably, but it was not invasive in nature. Relict coasts flooded by the sea were not destroyed, only covered with soil. Direct human activity, intensifying the commercial and industrial exploitation of the seabed areas, where natural and cultural landscapes have survived, would destroy them.

1.5. Conclusion

In a small basin in Lithuanian territorial waters, six sites were detected where relicts of the Yoldia, Ancylus Lake and Early Littorina stages with comparatively large numbers of well-preserved rooted trees, and in some places peat outcrops, were investigated. The mapping of the identified areas with surviving relict landscapes under water showed that these sites are in an area smaller than 30 kilometres, in the southern part of the territorial waters, from around Klaipėda to Juodkrantė. This is the northern edge of the underwater Curonian Plateau (an underwater peninsula) and the basin to the north of it. At these sites, the bed of the Baltic Sea is relatively flat and sandy (Gelumbauskaitė 2010). To the north of Klaipėda, where the seabed is formed of moraine ridges and rock formations, no surviving sites of relict landscapes were found, except one, the RF-II site. The old coasts are more eroded in this part of the sea, and the possibility of survival for relict trees or sediment formations is lower. Sites where sub-bottom profiling acoustic systems suggest there is a palaeo-river channel are more promising for further research.

Palaeobotanical and chemical surveys of sediments from the seabed, and DNA studies of the trees, have provided more possibilities to get acquainted with the features of nature in the Holocene period, changes to the climate, and the circumstances of the emergence of pines in the southeast Baltic coastal areas during the Yoldia stage.

The coast was a favourable place for human settlement, despite the fact that there are no data about any economic activity or any other traces of human behaviour in the research locations investigated so far. Prehistoric settlements known in the coastal areas, and finds washed up by the sea, encourage the continuation of the search for Palaeolithic and Mesolithic settlements on the bottom of the sea.

Parts of relict coasts and landscapes found as a result of our research have raised a new issue: the management of underwater natural heritage. Offshore waters are an area of economic activity. The term ‘underwater natural heritage’ is not as familiar as it should be in Lithuania, and it is understandable that sites of relict landscapes, like natural maritime heritage, are not reliably protected at the national level. Discussions that take place at an international level promote efforts at the national level. Maritime cultural heritage authorities in the Baltic Sea region have begun to pay attention to the underwater landscape. The concept of ‘underwater landscape’ should be implemented in Maritime Spatial Planning (MSP) documents. Areas with preserved relict underwater landscapes will be introduced into the action plan for the implementation of the MSP. An MSP with potential maritime cultural heritage sites was approved in Lithuania in 2014. The latest edition of the plan is currently in the final stages of its development, and should envisage the preservation of underwater landscapes when exploiting marine resources (Lehtimäki et al. 2020, pp. 40, 55, 59).

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