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The present paper is a dedication from the authors to Professor Magdalena Ralska-Jasiewiczowa on the occasion of her birthday. We greatly appreciate her scientific and educational contribution to many international research projects, her willingness to contribute to the palaeoecological know-how in the PACT activities and in the Nordic-Baltic context, and her long-lasting warm friendship.

Half a century of interdisciplinary studies on the development of the natural and cultural landscape in the Stockholm region

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ABSTRACT. There are numerous studies in the form of graduate diploma works, licentiate and doctoral theses, which include investigations of material from sedimentary basins and archaeological sites in the Stockholm region. The reference list contains many of these titles, which are difficult to find in other contexts. Research courses, workshops, excursions and symposia were arranged in connection with the current projects by the Nordic Academy for Advanced Studies (NorFA), and the Council of Europe interdisciplinary network PACT. These activities represent an integrated approach of scientific and archaeological methods and techniques for the benefit of the European cultural and environmental heritage.

A synthesis of biostratigraphical-palaeoecological interdisciplinary studies in the Stockholm region and neighbouring areas is presented as an example of collaboration between geologists, archaeologists, biologists, historians and physicists during the recent decades. Within these studies, parallel to pollen and diatom analyses, new parameters (phytoliths, Cladocera, ostracodes, magnetic susceptibility, elemental analysis) and complex analyses, e.g. coprolites and waste strata, have been developed and tested. Examples are given of comprehensive projects concerning, e.g. the Stone Age in the Grödinge area on Södertörn peninsula, the Viking Age Birka on Björkö island in the Lake Mälaren, and landscape and vegetation history at the Arlanda airport area in Uppland.

The results of the studies have in many cases created new insights and a re-evaluation of the events and history of the landscape, environment and settlement. An important role has been to bring the local and national networks to a wider international level.

KEY WORDS: vegetation history, coastal settlement, shore displacement, human impact, landscape changes, Stockholm region, Sweden

THE DEVELOPMENT OF RESEARCH INTO THE ENVIRONMENTAL HISTORY OF THE STOCKHOLM REGION

The framework of palaeoecological and archaeological studies in the Stockholm region and the neighbouring counties of Södermanland and Uppland was established by Maj-Britt and Sten Florin in the middle of the last century (M-B. Florin 1945, 1957, S. Florin 1944, 1948). Pollen-analytical evidence of cereal cultivation was made at the Mogetorp settlement in central Södermanland and radiocarbon dated to the Early Neolithic, ca 6000–5300 cal yr BP (M-B. Florin 1957). Age intervals for archaeological periods in this paper are from NAA (2004), while calibrated ^{14}C ages are according to Stuiver et al. (1998). In the 1950–60s geological mapping was carried out on the four Stockholm map sheets (Stockholm NW, NE, SE and SW) by geologists at the (SGU) Geological Survey of Sweden (Möller & Stålhös 1969). At this time Urve Miller, being a young geologist mapping in the Stockholm region, got interested in the archipelago and its environment. This resulted in a diploma work entitled "Occurrence of *Alnus* in a coastal region", initiated by Professor Carl-Gösta Wenner at the Department of Quaternary Research, Stockholm University. The results of the diploma work were partly included in the regional study on "Comparison of clay varve chronology, pollen analysis and radiocarbon dating" (Miller & Wenner, in Wenner 1968).

The initial studies from the 1950s were later extended to include vegetation history, climate changes, shore displacement and coastal settlement history, namely the environmental changes of the past, present and future of the Stockholm region.

The Stockholm region is an area of continuous change because of several reasons. From being covered by the extensive Baltic Ice Lake 11 500 cal yr BP, the first islets (skerries) started to emerge at the transition to the Ancylus Lake stage ca 11 000 cal yr BP. These areas south of Stockholm (> 60 m a.s.l.) are now the highest hilly districts. During the Litorina Sea stage, which began at ca. 9200 cal yrs BP, there was a transformation into an archipelago and marine conditions prevailed until the end of the Neolithic, ca 3800 cal yr BP. Lake Ådran and the Grödinge area on the Södertörn peninsula, south of Stockholm, became the chronostratigraphical basis for reconstructing the changing environment of the Mesolithic/Neolithic landscape (Miller & Robertsson 1977, Miller 1982a, b, Annerberg & Risberg 1983, Brunnberg et al. 1985, Risberg & Karlsson 1989, Risberg 1991, Risberg et al. 1991, Åkerlund et al. 1995a, b, 2004, Alpsten 1995, Olsson & Risberg 1995, Åkerlund 1996, Gardemeister 1999, Hedenström & Risberg 1999). During the brackish Post-Litorina stage, beginning at ca. 3800 cal yr BP, fine-grained sediments accumulated in the lowlands, which later became arable land during the Bronze Age (3800–2500 cal yrs BP) and Iron Age (2500–900 cal yr BP) (Ambrosiani 1981, Miller & Hedin 1988, Karlsson & Robertsson 1997).

During the 1970–80s intense collaboration with archaeologists resulted in joint projects in the Stockholm region (Miller 1973, 1982a, b, Miller & Robertsson 1981, Robertsson 1988, Miller & Hedin 1988, Robertsson & Miller 1989). These projects were associated with the construction of highways (Enköping), railways (Grödinge, Arlanda) and new buildings in the centre of Stockholm (Fig 1). The studies also aimed to improve the sampling and analysis techniques in palaeoecological investigations (Korsnäs, Helgö). Urve Miller together with Ann-Marie Robertsson, and later also Jan Risberg and Sven Karlsson, took part in the Helgeandsholmen, Klara Kloster and Fatburssjön excavations in the city centre. The results were displayed at the permanent and temporary exhibitions in the Stockholm museums (Miller & Robertsson 1982, Miller 1989, Robertsson et al. 1995, Gaillard et al. 1995, Karlsson et al. 1998).

At the beginning of the 1980s the PACT palaeoecological group was founded at the Council of Europe for collaboration between archaeologists, natural scientists and technologists in the field of European cultural and environmental heritage. There were many symposia, postgraduate courses and excursions arranged in Italy (Ravello) and in the Nordic countries 1984–1991. Palaeoecology, including environmental history, was a popular theme of great interdisciplinary interest (Miller 1993). Together with our Nordic colleagues we tried to introduce a current European "cultural" know-how of this research. The Stockholm region became one of the key areas for these interdisciplinary research courses and methodological pilot studies. The results are published in PACT volumes No. 24 (Hackens & Miller 1989), No. 31 (Moe & Hicks 1990), No. 33 (Hicks et al. 1991), No. 41 (Hicks et al. 1994), No, 47 (Vuorela 1994), No. 50 (Robertsson et al. 1995). During the 1990s and the first years of the new millennium 2000–2002, international collaboration was focused on the Baltic States, the St. Petersburg region and the Nordic countries. The studies are documented in PACT volumes No. 37 (Hackens et al. 1992), No. 51 (Hackens et al. 1996), No. 52 (Miller et al. 1997), No. 54 (Kabailiene et al. 1998) and No. 57 (Miller et al. 1999).

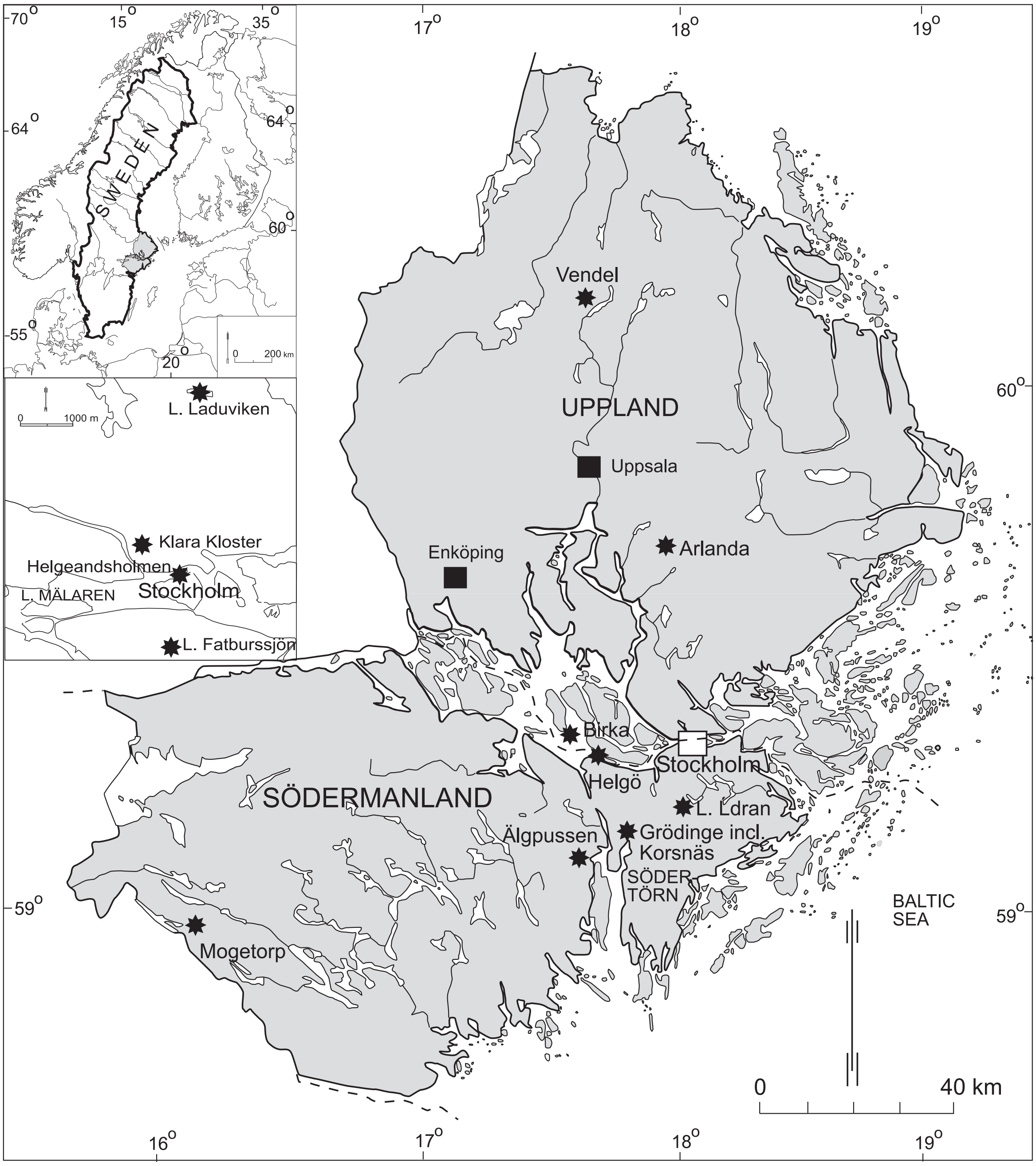

Fig. 1. Eastern Svealand with the Stockholm region, and detailed maps showing the location of sites mentioned in the text. A characteristic feature of this landscape is the gradual extension of the archipelago eastwards caused by the regressive shore displacement (cf. Åkerlund 1996)

In the Mälaren region a comprehensive excavation project of the early Viking Age town Birka (Björkö), AD 750–975 (1200–975 cal yr BP), was carried out 1990–95 (Ambrosiani & Clarke 1995, Miller et al. 1995). Environmental history was included in the archaeological research, with vegetation, land-use history and shore displacement as important parameters to study by means of litho-, bio- and chronostratigraphical methods. New methods were tested and developed and several graduate diploma works and post-graduate theses included studies dealing with this island (Miller et al. 1997, Björck 1997, Karlsson & Robertsson 1997, Karlsson 1997, 2000, Engblom & Lennevi 1999, Heimdahl 1999, Risberg et al. 2002a, Westermark et al. 2004).

North of Stockholm the Arlanda Airport was extended in the mid-1990s, which motivated detailed documentation before the construction work could start. Reconstruction of past environments including human impact on vegetation and shore displacement was an essential part of the archaeological documentation (Karlsson & Risberg 1998). During this comprehensive project students made their diploma work on shore displacement (Alsø 1998), vegetation history and human impact (Hättestrand 1998, Borgmark 1998).

The history of the northern part of the Stockholm region was studied in connection with archaeological excavations of Neolithic (6000–3800 cal yr BP), Bronze Age (3800–2500 cal yr BP) and Iron Age (2500–900 cal yr BP) settlements (Arrhenius et al. 1990, Atkinson 1990, Karlsson & Risberg 1998, Karlsson 1999a, Hemström 1999, Risberg 1999). The emergence and history of the oldest archipelago north of Stockholm ca 8500–5500 cal yr BP, which is of great importance for archaeologists investigating Stone Age settlement, was the subject of a doctoral thesis (Hedenström 2001). The shore displacement in northern Uppland since ca 6500 cal yr BP were compiled by Hedenström and Risberg (2003).

Studies of the recent vegetation and depositional environments in comparison with past environments have been an important part of the research. These studies are necessary for understanding and evaluation of past and future natural changes and the intensity of human impact (Hicks 1992, 1997, Karlsson et al. 1997, Robertsson & Miller 1997, Karlsson 1998, 1999a, 1999b, Bergström 2001, Bergkvist et al. 2003, Lenngren 2003, Sohlenius et al. 2003).

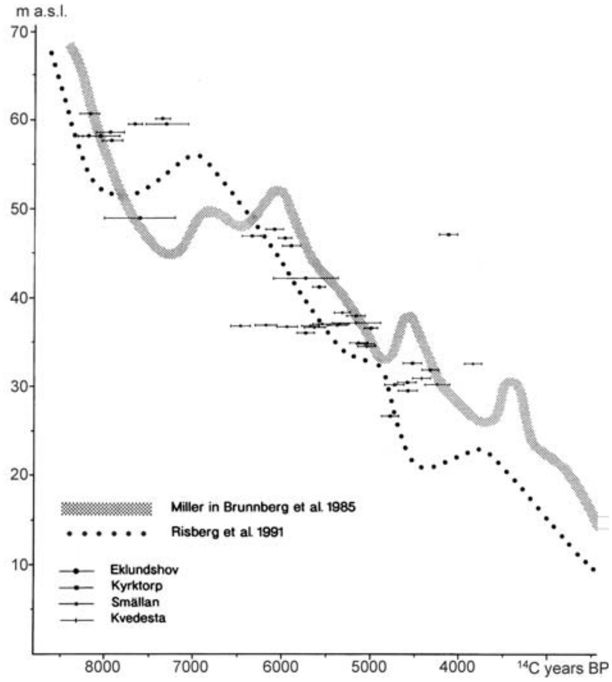

Fig. 2. An illustration of interdisciplinary studies of shore displacement curves and how the interpretation has become more complicated with several parameters included. The tentative shore displacement curve of Miller (in Brunnberg et al. 1985) is based on radiocarbon dating of Litorina transgression phases, isolation levels and pollen analytical levels (e.g. *Picea* expansion) in deposits from overgrown basins. The shore displacement model of Risberg et al. (1991) is constructed by means of dating diatom analytical isolation levels in lake sediments. The radiocarbon dated macrofossils from archaeological sites include 42 samples of charcoal, seeds/nuts and food crusts from Stone Age layers at Kyrktorp and neighbouring sites (compiled by Åkerlund. See Åkerlund et al. 1995, Fig. 5)

FIELD METHODS APPLIED

In a region with isostatic land-uplift stratigraphic investigations are important and careful levelling of isolation thresholds of sedimentary basins is necessary (Risberg 1991). Studies of a series of sites situated at different altitudes, and their isolation from the Baltic Sea basin, form the basis for construction of local shore-displacement curves (Fig. 2).

Coring was carried out in sedimentary environments, representing different phases of the changing landscape, e.g. shallow bays of the Baltic Sea, lagoons, lake basins and mires. Moreover, sediments were sampled vertically from trench walls and also horizontally from strata and features in archaeological excavation areas, and the stratigraphy recorded in detail.

Field studies of recent and sub-recent vegetation and pollen deposition in the archipelago (Miller & Wenner 1968, Hicks 1997, Robertsson & Miller 1997, Karlsson 1998) and on the island of Björkö in Lake Mälaren (Engblom & Lennevi 1999) provided valuable modern analogue reference material for interpreting pollen diagrams from sedimentary basins.

A field study of the recent mollusc fauna on the Björkö Island was carried out to provide a reference study to put the sub-recent and fossil mollusc assemblages in an archaeological context, as well as in the surrounding environment (Johansson 1997, 2004).

RANGE OF ANALYSES USED FOR THE ENVIRONMENTAL RECONSTRUCTION

Biostratigraphical analyses focused on pollen and spores, algae (diatoms, chrysophyte cysts, green-algae and dinoflagellate cysts) and phytoliths (Risberg & Miller 1998). In some studies plant macrofossils, molluscs (Birka), insects and Cladocera (Fatburssjön) were included (Robertsson et al. 1995, Hansson 1996, Hansson & Dickson 1997, Johansson 1997). Analyses of ostracodes and foraminifera were also applied (Schoning 2001).

Organic material found in a ship wreck was studied by pollen analysis (S. Karlsson), plant remains (M. Aronsson), mossses (L. Hedenäs), and insects (G. Lemdahl). The results are published as a pilot investigation of sediment samples from the wreck (L. Miller 1994).

Charcoal particles and total organic carbon content (TOC), loss on ignition (LOI), grain size, mineral magnetics and shallow seismic refraction were measured and analysed. The radiocarbon technique was applied, often in close collaboration with the Ångström AMS Laboratory in Uppsala. Soil micro-morphological studies were tested on the complex accumulations constituting the Black Earth in Birka (Håkansson 1997).

Siliceous microfossil analyses were applied mainly in shore-displacement studies (Miller 1982a, 1986, Risberg 1991, Hedenström 2001), but soil-living diatoms are also good indicators of soil erosion, as well as morpho-types of chrysophyte cysts (Miller 1991, 1994, Risberg & Miller 1997). Phytolith analysis was applied as a parameter indicating land use and soil erosion. Classification of phytolith morphotypes is, however, complicated and determination of the parent-plants is ongoing (Miller 1996, Tingvall 1997, Borgmark 1998, Kurberg 2000, Risberg et al. 2002a, b).

Analyses of coprolites include several methods and interpretation of the results is a very complex. Synthesis is still in progress, which needs testing before application in wider contexts (Moe 1995, Karlsson 2000).

Studies of environmental history by means of elemental analysis of mollusc shells included also a *Mytilus* shell from the Birka excavation (Westermark et al. 2004).

PRESENT STATE OF KNOWLEDGE OF THE PAST ENVIRONMENT OF THE STOCKHOLM REGION

Many of the research projects carried out during the last decades have given new insights and have partly rewritten shore-displacement and vegetation history, including human impact, in the Stockholm region (Tab. 1). The AMS method for radiocarbon dating has resulted in more accurate dating of different kinds of human impact, coastal settlements and shorelines. Some important results can be summarised chronologically as follows:

The oldest early Holocene islands emerged south of Stockholm during the Preboreal chronozone between 11 500–10 200 cal yr BP (Hedenström & Risberg 1999). The first vegetation consisted of a herbaceous flora (e.g. Poaceae, *Artemisia, Rumex*) together with birches. The opening of the Närke Strait to the west resulted in the intrusion of saline water into the Baltic basin as reflected by the presence of a cold-water marine ostracods and foraminifera benthic fauna (Schoning 2001). The earliest human influence (hunter – gatherers) has been traced in the archipelago formed by the regressive shore displacement during the Mesolithic – Early Neolithic, i.e. until ca. 5300 cal yr BP (Åkerlund et al. 1995a, Åkerlund 1996). The highest areas in south-eastern Uppland, north of Stockholm, emerged during the Late Mesolithic and Neolithic, before 3800 cal yr BP, and it has now been concluded that shore displacement in this area was regressive but with two early still-stands. In contrast, transgressive phases (L1-L4) characterised the Litorina Sea, 9200–3800 cal yr BP, in areas south of Stockholm (Tab. 1). The dating of these phases is, however, ambiguous (Fig. 2). Important new results support the idea that irregular isostatic rebound occurred in the area during the last ca. 8000 calendar years (Hedenström 2001, Risberg et al. 2004), and that the isobases for the Litorina Sea had a different pattern compared with the present ones.

The isolation of Mälaren from the Baltic Sea started during the end of the Viking Age, i.e. AD 1000, but was prolonged because of a stand-still in the shore displacement (Ambrosiani 1981, Risberg et al. 2002a). The final isolation took place during Medieval times ca. AD 1300 and was partly caused by the construction works connected with the foundation of Stockholm, which closed the sailing routes passing the town (Miller & Robertsson 1982, Miller 1989, Risberg et al. 2002a).

The oldest indications of anthropogenic influence in the Stockholm region close to the Neolithic/Mesolithic settlements (e.g. Korsnäs and Kyrktorp) are ambiguous, since the find of a few pollen grains from apophytes could emanate from natural sea-shore vegetation including for example *Artemisia, Urtica,*

Table 1. Examples of sites and range of the deposits investigated highlighting new interpretations according to the methods applied

Site/area Investigated time period (cal yr BP)	New interpretations	Age Cal yr BP/AD	Methods	References
Lake Ådran 11 500–0	Transgressive Litorina sea (L1)	8900–7800 BP	Mineral magnetic parameters	Sandgren et al. (1990), Sandgren & Risberg (1990)
Stockholm archipelago 11 500–0	Reservoir age	6000 BP	AMS versus bulk sediment dating	Hedenström & Possnert (2001)
	Configuration of Litorina sea isobases	11 500–0 BP	Siliceous microfossils	Hedenström & Risberg (1999)
	Recent pollen rain and pioneer vegetation	1950s	Pollen	Miller & Wenner (1968)
	Maritime deciduous forest of natural origin	2000–0 BP	Pollen	Karlsson (1998)
Älgpussen bog 9200–0	Transgressive Litorina sea (L4)	3800 BP	Lithostratigraphy, diatoms	Björck et al. (1995)
	Cultivation of *Linum usitatissimum* (flax)	2900 BP	Pollen	Karlsson et al. (1995)
Björkö island (Birka) 9000–0	Accumulation of waste deposits in Lake Mälaren	AD 750–975	Pollen, macrofossils, parasites, phytoliths	Risberg et al. (2002a)
	Presence of humans, cattle, sheep/goat	AD 750–975	Microfossils, coprolites (pioneer studies)	Karlsson (2000)
	Thickness of cultural layers	AD 750–975	Shallow seismic refraction	Andrén & Lindeberg (1997)
	Modern analogues of flora and mollusc fauna composition	Recent	Inventories of flora and mollusc fauna	Engblom & Lennevi (1999) Johansson (1997)
Grödinge area (Korsnäs, Eklundshov, Kyrktorp, Smällan) 9000–1000	Transgressive Litorina sea (L2, L3, L4) Pioneer studies of phytoliths	7000 BP (L2) ca. 5700 BP (L3) 4200–3800 BP (L4)	Pollen, siliceous microfossils (diatoms, phytoliths, cysts) macrofossils	Miller & Robertsson (1981) Åkerlund et al. (1995a) Åkerlund et al.(2004)
	Settlement locations	9000 BP to recent	Palaeogeographical maps	Åkerlund et al. (1995b) Åkerlund (1996)
Arlanda area 7800–0	Comparison between central areas and outlying land	4500–0 BP	Pollen	Karlsson & Risberg (1998)
	Weak traces of a transgressive Litorina sea (L4)	3200 BP	Diatoms	Karlsson & Risberg (1998)
Northern Uppland 6500–0	Regressive sea level with still stands	6500–0 BP	Siliceous microfossils	Hedenström & Risberg (2003)
Vendel, N Uppland 5700–0	Vegetation and land use, reconstruction of the Vendel Period	1500–1200 BP	Pollen, charcoal particles	Arrhenius et al. (1990) Atkinson (1990) Karlsson (1999a)
Helgö island 5000–1000	Land use	2600–1400 BP	Pollen, diatoms	Miller & Hedin (1988)
	Palaeo field		Pollen, spores	
	Prehistoric manuring	1400 BP	Pollen	
	Retting of *Cannabis*	1400–950 BP		
Lake Fatburssjön 3800–300	Accelerating pollution	AD 16th century	Diatoms, Cladocera	Robertsson et al. (1992, 1995)
	Intense human impact	1100 BP	Pollen, macrofossils	
Lake Laduviken 2500–500 BP	Clear human impact	AD 700–1600	Pollen, diatoms	Miller & Robertsson (1982) Karlsson & Robertsson (1997) Robertsson & Miller (1997)
	Shore displacement Preconditions for settlement location	2500–1300 BP		
Helgeandsholmen island 1400–100	Clear human impact First notes of phytoliths	AD 700–1300	Pollen, diatoms, phytoliths (initial)	Miller & Robertsson (1982)
	Isolation of Mälaren	AD 1000–1300	Diatoms	Miller & Robertsson (1982)
	Erosion through construction works	AD 1000 to modern time	Siliceous microfossils	Miller & Robertsson (1982)

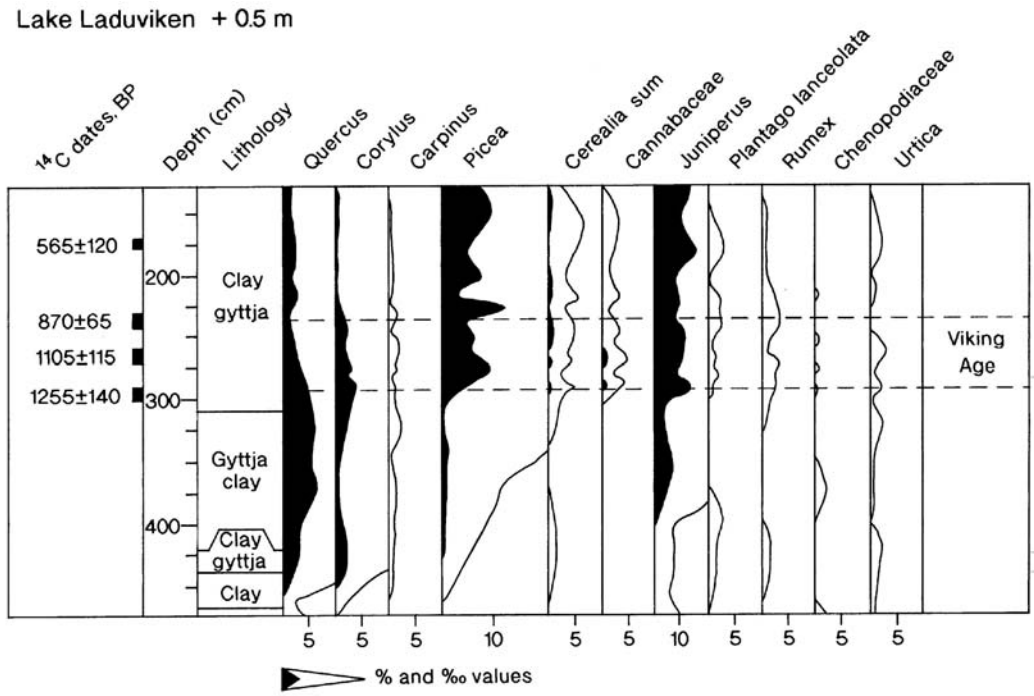

Fig. 3. Pollen diagram from the Lake Laduviken with selected taxa, illustrating that the landscape was opened up and more intensively used during the Viking Age (simplified after Robertsson & Miller 1997)

Chenopodiaceae (Miller & Robertsson 1977, 1981, Åkerlund et al. 2004).

Clear indications of grazing and cereal cultivation are found in pollen diagrams and as phytoliths in soils from old field systems, representing sediment deposition during the Bronze Age and Iron Age (Miller & Hedin 1988, Björck et al. 1995, Robertsson et al.1995, Karlsson et al. 1997, Karlsson & Risberg 1998, Borgmark 1998). At the Hallunda Bronze Age settlement finds of pollen grains (*Triticum* and *Hordeum*) and macrofossils confirm cultivation of cereals (Robertsson 1988).

A clear increase in human impact can be seen in the sediments studied in the Lake Mälaren area during the Viking Age. An evaluation of pollen diagrams from 20 different sites representing lakes, mires and settlement areas showed some general trends (see compilation by Karlsson & Robertsson 1997, Tabs 1 and 4). The landscape was opened up and more intensely used for grazing, reflected by a marked increase in *Juniperus*. Cultivation of cereals, especially *Secale* became more evident than earlier. *Cannabis* was an important crop, which expansion is reflected in the pollen flora (e.g. Miller & Hedin 1988). The forest composition changed by a marked decrease of *Quercus* and *Corylus,* which was followed by a major spread of *Picea* (Fig 3).

The foundation of Stockholm in the 13th century AD, and the agricultural activities to supply the medieval town with food, is clearly reflected in the Lake Laduviken and Lake Fatbursjön sediments (Miller & Robertsson 1982, Robertsson et al. 1995, Robertsson & Miller 1997).

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