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Seed bank and emergent vascular flora of ballast areas in Reposaari, Finland

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I studied the seed bank and emergent flora of ballast areas in Reposaari, SW Finland (61°30´N, 21°28´E). Altogether 2 180 seedlings germinated from 104 samples (depth mean = 9.2 cm) making 11 205 seeds per 1 m^2 area. 26.5% of the seedlings were monocots and 73.5% were dicots. I identified 70 taxa in the seed bank. The most common species were *Potentilla argentea* L., *Tanacetum vulgare* L., *Poa trivialis* L., *Festuca rubra* L., *Agrostis capillaris* L. and *Poa pratensis* L. Of all germinated seeds 25.3% were annuals or biennials and 62.7% were perennials (the rest not recognized to species level). Sixty-nine individuals of 9 ballast species germinated from seed bank samples: *Artemisia absinthium* L., *Astragalus glycophyllus* L., *Carum carvi* L., *Cirsium arvense* (L.) Scop. ssp. *arvense*, *Lamium album* L., *Medicago lupulina* L., *Melilotus alba* Medicus, *M. altissima* Thuill. and *Senecio jacobaea* L. This accounted for 13.2% of the species in the seed bank, but only 3.2% of all germinated seedlings. In the emergent flora of the study sites I found 134 vascular plant species, of which 30 were ballast species. The emergent flora and seed bank shared 49 taxa: 10 monocots, 38 dicots (of which 3 were trees or bushes) and one pteridophyte. The emergent flora was richer in ballast species than the seed bank (22.4% vs 13.2%). The number of seeds in the seed bank decreased with depth and after cold treatment. The densest and richest seed bank was encountered in sand and the sparsest and poorest in fine sand. The amount of stones was positively correlated with the number of germinating seedlings and species. A thick organic layer seemed to diminish the number of viable seeds.

Key words: ballast plants, emergent flora, organic layer, seed bank, soil matrix

INTRODUCTION

Ballast plants are species that were distributed in ballast soil to new areas of the world during the sailing ship era (approximately A.D. 1400–1880). If the exported material was light or if there was no cargo, ballast soil was loaded in the ship's hold to keep the ship steady. In another harbour the soil or part of it was unloaded if a new, heavier cargo was taken. The heaps of unloaded ballast soil were composed of stone, gravel, sand, organic soil, they and included also seeds, vegetative reproductive organs of plants, whole plants and small terrestrial animals (insects, etc.).

Especially at the end of the sailing ship era, the total amounts of soil moved from harbour to harbour and from continent to continent were bigger than ever before or ever since. Ballast soil allowed overseas migrations, which were crucial for many plant species that were not capable of spontaneous long-range dispersal. At present water rather than soil is used as ballast and not too many plant species are hydrochores.

Reports of alien species believed to have been introduced in ballast to various countries were published especially between the end of the 18th century and the First World War (review by Ridley 1930). Actually there has been more transportation of ballast soil from Europe than to Europe. More ballast plants (and also animals) migrated from Europe to, for instance, North America than vice versa (Lindroth 1957).

The ballast plants attracted numerous botanists in the Nordic countries because the species did not belong in the native flora. Also the nature of international trade of those countries, namely exporting heavy materials and importing lighter ones back, lead to accumulation of large amounts of ballast soil. With various kinds of import and export products some other countries were even losing ballast soil and/or recycling it. Also the shallowness of the Finnish coast fairly quickly led to a restriction that it was no longer allowed to dump ballast soil in the sea.

Even though many herbarium specimens have been collected and the knowledge of ballast flora has been relatively good, surprisingly few studies have been published concerning the ballast flora in Finland or elsewhere. In Norway, Tore Ouren has published, particularly during the 1960–70's (mainly in Norwegian), a group of studies concerning ballast flora (Ouren 1959, 1968, 1972, 1977, 1979ab, 1983, Bjorndalen & Ouren 1975). The data on the subject are scattered throughout many publications (e.g. Hogg 1867, Lousley 1953, Lindroth 1957) and some works were not effectively published, but written only in the form of graduate studies. Concerning the ballast flora of Reposaari, the situation improved in the 1980's when a summary of the ballast species (altogether 140) found on the island was published in Finnish (Kalinainen 1987). Subsequently an article, mainly based on that study, was written for a Finnish botanical magazine (Kalinainen & Lampolahti 1994).

The seed bank of ballast areas has not been studied anywhere in the world. Assumptions that some plants have emerged from a seed bank have been presented in certain studies (e.g. Kalinainen 1987), but serious research has not been carried out. In general, seed bank studies in Finland have been relatively few, some dealing with forests (Vieno *et al.* 1993, Komulainen *et al.* 1994), some with arable lands (Paatela & Erviö 1971, Kiirikki 1993) and some with shore meadows (Jutila 1994). The prospects of using seed bank to save threatened species have rendered seed bank studies urgent.

The aim of the present study was to find answers to the following questions:

1) What is the size, species composition and proportion of perennials vs annuals and biennials of the seed bank in the 'cultural meadows' of the ballast area?
2) What are the main differences in the emergent flora and the seed bank?
3) How do environmental factors such as soil depth and matrix influence the seed bank? What consequences follow for the management of these areas in general?
4) Which ballast species can be found in the seed bank and in what amounts?
5) How important is the seed bank for the survival of ballast species?

STUDY AREA

The study area is situated on the western coast of Finland, by the Gulf of Bothnia, on the island of Reposaari, belonging to the town of Pori (61°30´N, 21°28´E). In the end of the 19th century Reposaari was one of the most important harbours in Finland and the ballast areas grew very large; in fact some of the eastern streets and houses were built on ballast soil. The historical course of time was different in Reposaari than in most other Finnish harbours. In the beginning of this century the main harbour moved to Mäntyluoto, and Reposaari was an isolated, quiet island until 1952 when the road was built. Accordingly, the ballast flora had the opportunity to become established. In many other big Finnish harbours the development led to steam ships, asphalted lawns and the invasion of a railway flora, which resulted in extinction of the ballast flora. The smaller harbours were left unused and the vegetation succession continued quickly to forest (Kalinainen 1987). The extinction of ballast flora was typical. Currently Reposaari is the single important refuge for ballast flora in Finland.

The most exotic plants came from South America, but most of the plant material that survived longer originated from

Central and South Europe (Laine 1981). Alien species were easily recognized as ballast plants, but also species native to Finland were well represented. Sometimes those species could be regarded as representing different races, but often the identification of these species as ballast plants is based on the statements of former botanists, e.g. "growing on ballast". Many neophytes that were readily recognized as being of ballast origin as they came to Reposaari (Kalinainen 1987) have later dispersed in Finland, similarly to the railway flora in the beginning of this century.

Currently the ballast flora of Reposaari includes 50–75 species (Kalinainen 1987, Kalinainen & Lampolahti 1994). Several species are threatened (Rassi *et al.* 1992) and precise data are needed for their management.

METHODS

Sampling design and techniques

I took 104 seed bank samples from five different sites in Reposaari. The greatest distance between the sites was 800 m. All of them were located in places where ballast species are or have previously been growing. In four sites I established a lattice from which I randomly selected the sampling places. The fifth site, by sea shore of Lontoo (Finnish for London) was established by drawing a circle around an individual of *Astragalus glycophyllus* (the other of the two known individuals growing in mainland Finland). I randomly selected the distance and the direction of the sampling places measured from the middle of the plant. This different sampling method was chosen to find out if *A. glycophyllus* can produce germinable seeds to the bank.

I took the samples with a corer of 4.8 cm diameter from a depth of up to 10 cm (in some places less than that; $n = 86$) and where possible (mainly in the church meadow; $n = 18$) I took another sample from 10–20 cm. The data of both profiles were fused, but also tested separately where indicated in the text. Because the soils were stony, I was not able to get whole samples every time. The average depth of the samples was 9.2 cm (2–14 cm) (Table 1). Although some samples were fairly shallow they were used for data similarly as the others. Kruskal-Wallis test did not indicate any difference in the number of species or seedlings in the two sample depth groups, which were 0–5 cm and 5–10 cm. There was also no difference of monocots, dicots, ballast species and ballast seedlings separately.

The samples were taken in the dock area in autumn 1993 and in the other sites in spring 1994 (Table 1). The samples may include both transient and persistent seed bank. When I took the samples I recorded the presence of stones, the matrix type and the plant species within 30 cm distance from the sampling place.

Treatment of seed bank samples

The samples were spread out in a 0.5 cm layer to germinate on a mixture of fertilized peat and sand (volume 1:1). Most of the samples were put to germinate as soon as possible after sampling (the short preservation before sample han-

Table 1. Seed bank sampling data. *n* is the number of seed bank samples, soil volume is the total volume of seed bank samples, depth is the sampling depth and (in parentheses) the number of samples from different depths. Gathering is the date when the samples where taken (the number of samples in parentheses if several dates). Halving means halving the sample in longitudinal section. Preservation time between the gathering and germination is shown (the number of samples is in parentheses if not all were treated likewise) for those samples given a cold treatment. Depth of the organic layer is presented based on observations from soil samples. In the church meadow all samples were wholly organic so the depth of the organic layer was deeper than the sample depth. The longest distance between the samples taken in one site is given in column distance. × = mean.

Site	*n*	Volume (l)	Depth (cm)	Gathering	Halving	Cold treatment (days)	Sampling depth (cm)	Depth of the org. layer (cm)	Distance m
A. glycophyllus site	8	1.167	0–10	21.4.-94 (4) 13.5.-94 (4)	no	0	×= 8.1 (5–10)	×= 2.4 (0–6)	5
Church meadow	34	5.854	0–10 (19) 10–29 (15)	10.5.-94	yes, 17 samples	219 (17)	×= 9.5 (6–10)	> 10	45
Lontoo meadow	23	3.782	0–10 (20) 10–20 (3)	13.5.-94	no	0	×= 9.1 (5–12)	×= 5.6 (0–10)	47
Dock area	20	3.085	0–10	22.10.-93	no	131	×= 8.5 (2–14)	×= 2.3 (0.5–6)	45
Old harbour	19	3.348	0–10	21.4.-94	no	0	×= 9.7 (9–10)	×= 2.9 (0–8)	50
Total	104	17.236							

dling and germination was 2–4 days in a cold room at + 5°C). All samples from the dock area and 17 samples from the church meadow were kept in a cold room for several weeks (Table 1), then given a two-week – 1°C treatment in a refrigerator and then placed for two more weeks in a cold room and then germinated. The cold treatment given to the dock area samples ensured that the seeds would enter winter dormancy. The seedlings germinating from the treated church meadow samples represented a persistent seed bank.

Greenhouse methods

The samples were germinated in the greenhouse of the Environmental Research Centre of Satakunta. Samples were given a photoperiod of 16 hours of light and 8 hours of dark. The temperature was programmed to 20°C by day and 15°C by night. A mesh was used in the hatches to prevent seeds from entering the greenhouse. Samples were watered once or twice a day depending on the temperature. On very hot days (temperature in the greenhouse > 30°C), a sprinkler was used to lower the temperature.

All the samples were allowed to germinate for at least 130 days, after which time the germination had clearly slowed down. The first seedlings emerged in less than a week. I observed the sample pots every week and made an inventory at least twice (max. four times) during the experimental period (the last one in the end of the experiment). I identified most of the seedlings to species level, but some to genus level. The scientific names of the plants follow Hämet-Ahti *et al.* (1986). The plants were divided into monocotyledons, dicotyledons and pteridophytes and, according to life history types, into annuals, biennials and perennials (modified according to Hämet-Ahti *et al.* 1986: if several strategies, the shortest was chosen). In the statistical tests annuals and biennials were combined.

Study of the established vegetation

I observed the vegetation of the study sites for 3 years and recorded especially the occurrences of ballast plants. I made a complete list of the vascular plant species in study sites in August 1995, and I also estimated visually the abundance of species on the 1–7 scale of Norrlin. These data were, like the seed bank data, divided into systematic and life history groups.

Statistics

The statistical analyses were performed using the Statistical Analysis System (Anonymous 1988). Since the data did not in most cases show a normal distribution I had to use nonparametric statistics (the Kruskal-Wallis test). Pairwise *t*-test was used to compare the amount of monocots vs dicots and annuals + biennials vs perennials.

I used PATN (Pattern Analysis Package; Belbin 1993) to run several classifications and ordinations for the seed bank data. The environmental data were fitted to these analyses as well. The association measure of Bray and Curtis (Belbin 1993) was used for samples and two-step measure for species (Belbin 1993) and the fusion was based on the flexible UPGMA (the default in the package). Semi-strong hybrid multidimensional scaling (SSH; Belbin 1991) was used as an ordination method.

RESULTS

Seed bank density

Altogether 2 180 seedlings germinated from the 104 seed bank samples. On the average, 22.0 (0–119) seedlings germinated per sample. Of these, 5.6 (26.5%) were monocotyledon species and 15.4 (73.5%) were dicotyledon species. Pairwise *t*-test proved that there were significantly more dicot seedlings than monocot seedlings in the whole material. Predominance of dicots was also significant for each study site, except for the *Astragalus glycophyllus* site. On the average, 0.3 fern prothallus was detected per sample. The average number of seeds in 1 m^2 (with the average sample depth 9.2 cm) was 11 205. When the deeper samples and also the cold-treated samples were excluded, the seed density estimate increased to an average of 28.0 germinable seeds per pot ($n = 56$), thus 14 235 seeds in 1 m^2.

The germinable seed banks in the study sites differed significantly in terms of total, monocot and dicot seedling numbers (Fig. 1a). The most abundant seed bank was detected in the old harbour (mean = 23 739 seedlings/m^2 for 10 cm sample depth justified) and the smallest in church meadow (mean = 4 666 seedlings/m^2), where there were also samples from 10–20 cm depth and part of the samples were given cold treatment like all the dock area samples. When the cold-treated and deep soil samples were excluded, the mean of seedling number of the church meadow increased to 9 830 /m^2. The largest seedling number in one pot was 119 (65 761 seedlings/m^2); 118 for dicots and 23 for monocots. The first two of these maximum numbers were observed in samples from the Lontoo meadow and the last one in a pot from the old harbour area. Only four samples, all from the church meadow, were totally devoid of germinating seeds (Fig. 1a).

Both monocot and dicot seedlings exhibited high-

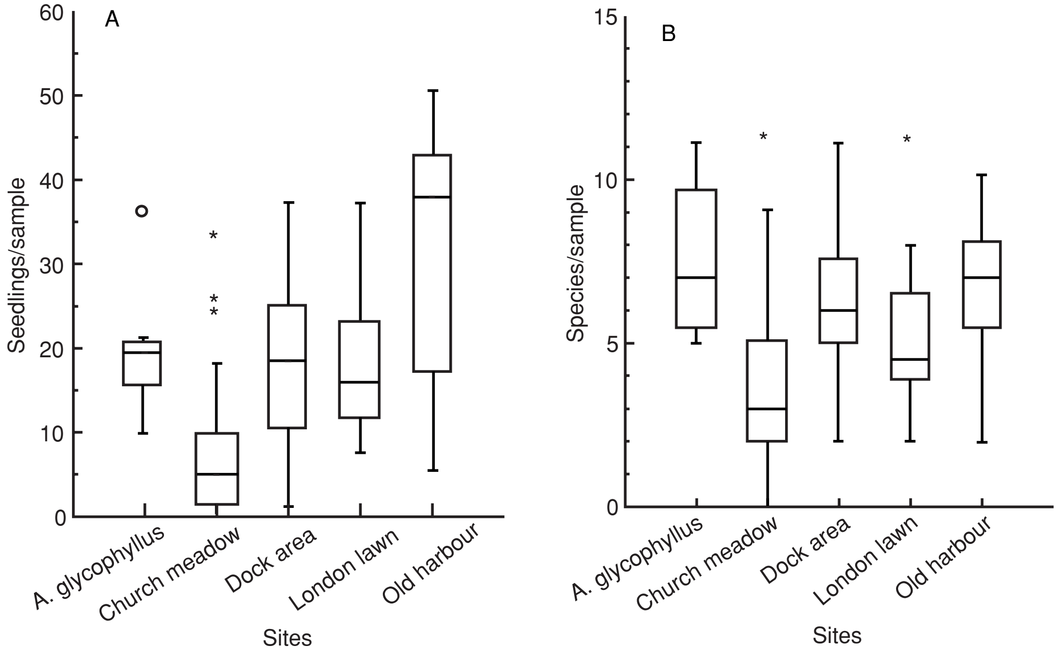

Fig. 1. Mean numbers of germinating A) seeds and B) species per sample in the seed bank of the study sites. The scatter of the data is shown with a box plot. Horizontal line = median; box = data within upper and lower quartiles; ends of vertical lines = 10% and 90% fractiles of the data; circles and stars = the extreme values: star = value used in counting other parameters, circle = left out of the calculations.

est germination in the samples from the old harbour area, 9.2 and 28.5 seedlings/pot, respectively. The lowest numbers of monocot and also dicot seedlings were from the church meadow, 2.0 and 6.2 seedlings/pot, respectively. Proportionally the most monocot-rich seed bank was in the dock area (5.1 seedlings/sample; 26.9% of all seedlings) and the most dicot-rich seed bank in the Lontoo meadow (17.3 seedlings/sample; 79.3% of all seedlings). There were significantly more germinating dicot than monocot seeds in the seed banks of each site except in the *Astragalus glycophyllus* site, where the difference was not significant.

Seed bank flora

In the germinating seed bank, I identified 70 taxa of which 3 to genus and the rest to species level. A mean of 5.3 species was found per sample, of which 1.6 were monocots and 3.7 dicots. The minimum species number was 0, recorded for 4 pots and the maximum was 11, recorded for 4 pots. The mode (the value with the highest frequency) was 6 species. The maximum for monocots was 4 species and for dicots 9 species. There were significantly more species of dicots than of monocots (tested by pairwise *t*-test) in the whole data as well as separately in each site. The predominance of dicot species and seedlings differed significantly between the study sites. The predominance of dicot species was highest in the Lontoo meadow and the predominance of dicot seedlings was highest in the old harbour. In the whole data there were 1.1 (5.6%) leguminous seedlings and 0.54 leguminous species per sample.

The germinating seed bank in the study sites differed significantly in the total number of species (Fig. 1b), and in that of monocot species and dicot species separately. The samples around *Astragalus glycophyllus* ($n = 8$) were the most species-rich, mean of 7.5 species, of which 2.5 were monocots and 5 dicots. On the average, the species-poorest were the samples from the church meadow: 3.6 species, of which 1.2 were monocots and 2.5 dicots, even though the maximum species number in the sample was 11 (Fig. 1b).

Most of the leguminous seeds (2.25) and species (1.25) per sample germinated in pots from the

Astragalus glycophyllus site and this was also the relatively most leguminous-rich site on the basis of species (16.7%). Proportionally the largest number of germinating leguminous seeds was found in the pots from the church meadow.

The richest seed bank flora was found in the samples of the Lontoo meadow (Table 2: 40 species), where also the number and proportion of dicot species was highest (33 and 82.5% respectively). In other sites the total number of seed species was around 30. The proportion of monocots in the total seed bank flora was highest in the old harbour (33.3%) and the church meadow (27.6%) (Table 2).

The most abundant species in the seed bank (Table 3) were *Potentilla argentea*, *Tanacetum vulgare*, *Poa trivialis* and *Festuca rubra*, all represented by more than 100 seedlings. The most frequent species in the samples were *Tanacetum vulgare*, *Potentilla argentea*, *Poa trivialis*, *Agrostis capillaris*, *Poa pratensis* and *Festuca rubra*, all found in 30 or more pots. Also *Artemisia vulgaris*, *Elymus repens*, *Plantago major*, *Sagina procumbens*, *Trifolium repens* and *Urtica dioica* can be regarded as common species in the individual sites (Appendix).

Life history strategies of the seed bank species

25.3% of the germinating seeds were annuals or biennials and 62.7% were perennials; the rest were not recognized to species level and could thus not be placed in either of these groups. A mean of 1.0 annual or biennial species (18.8%) and 4.3 perennial species (81.4%) were found per sample.

The richest annual and biennial seed bank was found in the Lontoo meadow, where on the average 36.2% of the germinating seeds (8.4) and 21.9% of the species (1.4) per sample were annuals or biennials. In the old harbour there were in absolute terms more numerous, but relatively fewer, annuals and biennials: a mean of 10.5 (27.1%) germinating seeds of annuals + biennials per sample representing an average of 1.4 (21.2%) species. Due to the abundant seed bank in the harbour there was also the highest number of perennial seeds per sample (19.6). The mean of perennial species was highest in the seed bank of the *Astragalus glycophyllus* site (6.3), but the old harbour was not far behind in species richness per sample (5.1). In relative counts, the numbers of perennial species (88.5%) and seedlings (82.8%) were highest in the dock area.

I used pair-wise *t*-test to find out if there was a difference in the number of annual + biennial vs perennial species or seedlings. In the whole data there were significantly more perennials both in terms of seedlings and species. This was also true in the different sites when the species number was tested. Significantly more perennial seedlings than annuals + biennials were found in the samples of the *Astragalus glycophyllus* site, the dock area and the old harbour. The predominance of perennials was not significant in the church meadow or in the Lontoo meadow.

The predominance of perennial species and seedlings was significantly different when the investigation sites were compared. The predominance of perennial species was highest in the *Astragalus*

Table 2. The total number of taxa identified to species or genus level in the emergent vegetation (= EV) and germinating from the seed bank (= SB) of the study sites. Species column indicates the total number of seed plant species, which is in the next two columns divided into mono- and dicots. Only one pteridophyte could be identified to species level (*Equisetum arvense*). The number of tree and bush species and ballast species are indicated in the last two columns and the number of these species is also included in the first three columns. Stars indicate that those ballast species found in the emergent vegetation during last three years, but not in summer 1995, were included in the number of taxa. Compare with the Appendix.

Site	Species		Monocots		Dicots		Pteridop.		Trees, bushes		Ballast sp.	
	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB
A. glycophyllus-site	57	29	14	6	42	23	1	0	7	0	6	6
Church meadow	45	28	10	7	34	21	1	2	6	1	7	3
Lontoo meadow	77	40	12	6	64	33	0	1	13	1	18*	3
Dock area	68	34	17	7	50	27	1	0	16	2	8	5
Old harbour	31	27	9	8	22	19	0	0	2	1	4*	0
Total	134	68	26	11	107	53	1	2	23	3	30	9

glycophyllus site and that of perennial seedlings was highest in the same site and also in the dock area. Even when the *A. glycophyllus* site was excluded from the analysis, the predominance of perennial species and seedlings still remained significantly different in the individual sites.

Ballast species in the seed bank

Nine species that can be regarded as being of ballast origin germinated from samples: *Artemisia absinthium*, *Astragalus glycophyllus*, *Carum carvi*, *Cirsium arvense* ssp. *arvense*, *Lamium album*, *Medicago lupulina*, *Melilotus alba*, *M. altissima* and *Senecio jacobaea*. These accounted for 13.2% of the species in the seed bank, but only 3.2% of all germinated seedlings. Twenty-four samples (23% of all samples) had ballast plants, altogether 69 individuals. Of the ballast species in the emergent flora 30% had a seed bank, which is actually less than for the other species. The average was 0.31 ballast plant species and 0.65 ballast seedlings per sample. Maximum values were 3 ballast species and 8 seedlings per pot.

It appeared that there was a significant difference in the number of ballast plant species and seedlings among the sites (this was also true after considering the influence of depth layer and cold treatment): from the old harbour, where the seed bank was most abundant, no ballast seedlings germinated. The most ballast-species rich seed bank was in the *Astragalus glycophyllus* site, where 16.7% of the species and 7.5% of seedlings can be regarded as ballast plants. In total, 6 different ballast plant species were found in the seed bank of this site (20% of all seed bank species in this site) (Table 2). In pots from the dock area a mean of 0.4 ballast species (7.7%) and 1 seedling (5.2%) were observed. In total, 4 different ballast plant species (8.7% of all seed bank species in this site) were found in the germinating seed bank of this site. In the seed bank of the Lontoo meadow and the church meadow, the average proportion of ballast species was between 5% and 6% and the proportion of ballast seeds was about 4% of all seeds.

Table 3. The most abundant taxa in the seed bank: total amount and percentage.

Species	Seedlings	Percentage
Potentilla argentea	430	19.2
Tanacetum vulgare	228	10.2
Poa trivialis	123	5.5
Festuca rubra	102	4.6
Agrostis capillaris	91	4.1
Artemisia vulgaris	86	3.8
Poa pratensis	85	3.8
Plantago major	83	3.7
Trifolium repens	63	2.8
Sagina procumbens	54	2.7
Urtica dioica	45	2.4
Elymus repens	43	1.9
Unrecognized dicots	254	11.4
Unrecognized monocots	89	4.0
Other species	458	20.5

Classification and ordination of the seed bank data

I made several classifications for the original data and the transformed data ($\ln(x+1)$). The empty samples were considered to form a separate group, but the differences in the other sample groups were less evident (Fig. 2). This was the general result of the ordinations as well. All samples (except the empty ones) had seeds of at least one of the species in the first species group, i.e. the most frequent species such as *Tanacetum vulgare*, *Potentilla argentea*, *Poa trivialis*, *Agrostis capillaris*, *Poa pratensis* and *Festuca rubra*. A multiple-linear regression of the explanatory variables, fitted to the ordination of the whole data showed that the number of perennial seeds had the highest correlation with the ordination axis (PCC: $r = 0.5875$). The next important explanatory variables were the number of seeds, the number of perennial species and the number of dicot seeds (all > 0.5). When the empty samples were excluded from the analysis the ordination was more difficult to interpret and the correlations of all explanatory variables with the ordination axes were less than 0.5. The number of annual species, depth of organic layer and number of perennial species had the highest correlations.

Established vegetation and germinating seed bank

The average number of vascular plant species in a 30 cm diameter around the sampling place was 5.1

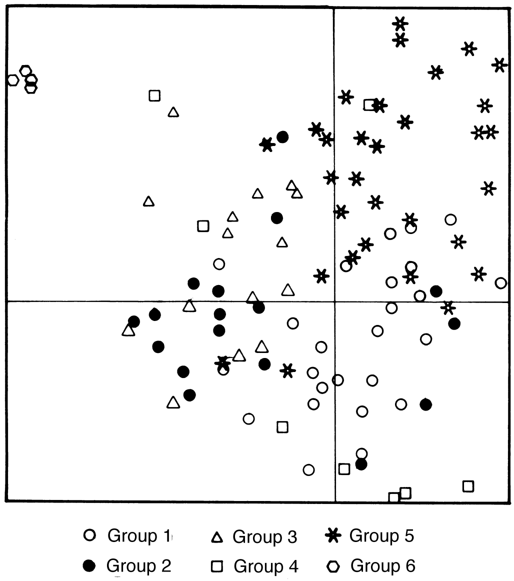

Fig. 2. Ordination of the seed bank data. The classification groups are shown. In all groups, except group 6, all samples have species from the first species classification group. **Group 1** includes samples (*n* = 31) from all sites. Numerous species from the first species classification group, also species from groups 2–4. *Tanacetum vulgare* the most frequent species. **Group 2** includes samples (*n* = 33) from all sites but the old harbour. Fairly numerous species from the first species classification group, also species from groups 2–6. *Tanacetum vulgare* the most frequent species. **Group 3** includes samples (*n* = 5) from the church meadow and one sample from the dock area. A few, infrequent species from the first species classification group, also two species from group 2. No *Potentilla argentea* or *Tanacetum vulgare*. **Group 4** includes samples (*n* = 19) from all sites but the *Astragalus glycophyllus* site. Numerous species from the first species classification group, also species from groups 2 and 4. *Potentilla argentea* the most frequent species, *Tanacetum vulgare* fairly frequent. **Group 5** includes samples (*n* = 12) mainly from the church meadow, three from the old harbour and one from the Lontoo meadow. Few, infrequent species from the first species classification group, also species from group 2. *Potentilla argentea* the most frequent species, no *Tanacetum vulgare*. **Group 6** includes samples (*n* = 4) from the church meadow. These samples were empty.

(1.6 monocots and 3.5 dicots). The proportion of ballast plant species was 7.5% (0.38), which is lower than the percent of ballast species in the germinating seed bank. The number of plant species in the sampling circle of 30 cm differed significantly among the study sites. Sampling places were most diverse in the dock area (mean 7.6 species) and the poorest in the old harbour (mean 2.5 species). Also the ballast species richness of the sampling circle was highest in the dock area (0.58 species; 7.6% of all the species), but the *Astragalus glycophyllus* site was almost as rich (0.50 species; 12.1% of all the species). In sampling circles of 30 cm, I found a maximum of 12 vascular plant species, 4 monocots, 10 dicots (all in the dock area) and 2 ballast species (in the dock area and the Lontoo meadow).

There were altogether 134 species in the whole emergent flora of the study sites. The richest emergent and seed bank flora were found in the Lontoo meadow with 77 and 40 species, respectively. Altogether 30 ballast species occurred in the study sites. Most ballast species were found in the Lontoo meadow vegetation, while the seed bank had only 2 ballast species; the highest number of ballast species in a seed bank was 6 species, in the *Astragalus glycophyllus* site.

The emergent vegetation of the old harbour is dominated by grasses like *Agrostis capillaris* and *Festuca rubra*. The most common forbs are *Trifolium repens*, *Achillea millefolium* and *Potentilla argentea*. All these species were also represented in the seed bank, but also *Plantago major* and *Tanacetum vulgare* had high seedling densities. In the emergent vegetation of the *Astragalus glycophyllus* site the most common species were *Elymus repens* and *Tanacetum vulgare*, which both were also found in the seed bank, but only *T. vulgare* and also *Poa pratensis* can be regarded as dominants in the germinating seed bank.

The vegetation of the church meadow is dominated by *Phleum pratense*, a grass that was not found in the seed bank of this site. The most common forbs were *Achillea millefolium*, *Senecio jacobaea* and *Tanacetum vulgare*, all of which were represented in the seed bank, but only *T. vulgare* can be regarded as a seed bank dominant. Other seed bank dominants were *Potentilla argentea*, *Trifolium repens* and *Poa trivialis* of which the last mentioned was not represented in the emergent vegetation. This has perhaps resulted from difficulty in identifying sterile specimens of *Poa*.

The emergent vegetation of the Lontoo meadow was dominated by *Dactylis glomerata*, *Galium verum* and *Medicago lupulina*; of these only *M. lupulina* was present also in the seed bank. The dominant in

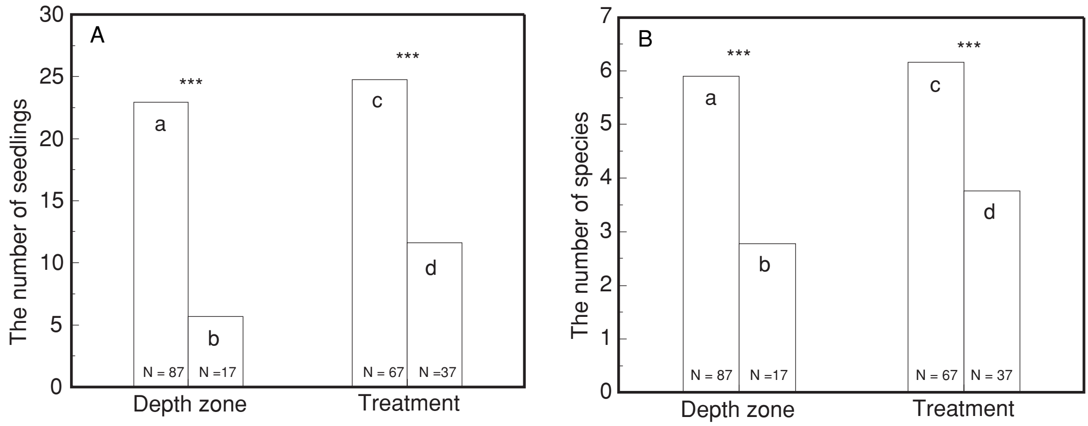

Fig. 3. Number of germinating A) seeds and B) species in seed bank samples taken from two different depth zones and given two treatments; a = 0–10 cm, b = 10–20 cm, c = immediately germinated samples and d = samples germinated after cold treatment.

the seed bank was again *Potentilla argentea*. *Sagina procumbens*, an annual species not found in the emergent vegetation, had the second densest seed bank.

The emergent vegetation in the dock area is dominated by *Tanacetum vulgare*, *Agrostis capillaris* and *Potentilla argentea*, all of which had a seed bank, but interestingly, *P. argentea* only in small numbers. *Artemisia vulgaris*, *Tanacetum vulgare* and unidentified dicots were dominants of the seed bank. Also *Elymus repens* germinated from the seed bank, in contrast to the samples from the *Astragalus glycophyllus* site where it was dominant in the emergent vegetation, but did not germinate in seed bank samples (Appendix).

The majority of the species both in the emergent and seed bank flora were dicots (79.9% vs 77.9%) and perennials (77.6% vs 76.5%). There was clearly a larger percentage of tree and bush species in the emergent flora (16%) than in the seed bank (4.4%). The emergent flora was also richer in ballast species than the seed bank (22.4% vs 13.2%).

The flora of the vegetation and the germinating seed (+ spore) bank had 49 shared taxa, i.e. 10 monocots, 38 dicots (of which 3 tree and bush species) and one pteridophyte. The total number of species identified in this study was 154. The nine ballast species found in the seed bank were also represented in the vegetation. However, it is possible that some ballast species germinated from the seed bank of a certain site where that ballast species was not seen in the emergent vegetation during the study (Appendix).

Influence of depth zone on the seed bank

The Kruskal-Wallis test indicated highly significant differences in the numbers of seedlings and species between the samples from different depth profiles, when the whole data were used (Fig. 3a and b). There were significantly more seedlings in the samples of the upper 10 cm than in those of the deeper ones. This was also true when the numbers of monocot and dicot species as well as numbers of seedlings were tested using the whole data. The predominance of dicot species and seedlings was significant in both depth layers. The predominance of dicot seeds was significantly greater in the upper soil layer than in the lower, but there was no significant difference in the predominance of dicot species. There was no significant difference in the amount of ferns between the depth zones in the whole data. I achieved similar results also when I tested the significance of depth profile separately in the two treatment groups.

The influence of depth on the viability of seeds of individual species was tested excluding the effect of treatment and even site. The numbers of seedlings of *Agrostis capillaris*, *Plantago major* and *Poa trivialis* were significantly lower in the deepest profile. *Epilobium angustifolium* and *Equisetum arvense* showed the opposite condition.

There were also significantly more ballast plant species and seedlings in the samples from the upper 10 cm layer than from the lower one. This result was obtained for the whole data as well as separately in each of the almost immediately germinated and cold treated groups.

More perennial than annual + biennial species and seeds germinated in both soil layers . The differences were significant in all cases, except for viable seeds in the lower soil layer. According to the Kruskall-Wallis test, the predominance of perennial species and seedlings was significantly greater in the upper soil layer than in the lower.

Influence of cold treatment on the seed bank

The Kruskal-Wallis test with the whole data indicated that there were very significantly more species and seedlings in the almost immediately germinated group of samples than in the preserved and cold-treated samples (Fig. 3a and b). For mono- and dicots the difference was significant. The predominance of dicot species and seedlings was significant in both treatment groups and it was significantly greater in the immediately germinated group than in the cold-treated group. In the amount of fern prothalli no significant difference was observed between the preservation groups.

I also studied the influence of cold treatment separately for the two groups of sample depth. In both depth groups all differences were significant (except for ferns) and similar to those in the whole data. To eliminate the influence of site, I tested the influence of cold treatment on seedling amount with the church meadow data. There were fewer species and seedlings in the cold-treated samples. The same result was obtained for mono- and dicot seedlings separately, dicot species and the amount of fern prothalli, but not quite so for monocot species. When the church meadow data were further divided into two depth groups and the influence of cold treatment was tested in these separately, the differences remained significant and similar for the amount of species and seedlings. The result was in all cases the same for mono- and dicot species separately, except when the depth group was the upper 10 cm and the monocot species and seedling numbers were tested. There were no significant differences in the number of fern prothalli between treatment groups when the church meadow data, divided into two depth groups, were tested.

According to the pairwise *t*-test, there were significantly more perennial than annual seedlings and species in both treatment groups. The Kruskal-Wallis test showed that the predominance of perennial species was significantly smaller in the cold-treated group than in the immediately germinated group. No significant difference was detected in the number of germinating seeds. There was no significant difference between the treatment groups in the amount of ballast plant species or seedlings.

The influence of cold treatment on individual species was studied with several statistical tests. In the group of samples collected in spring cold treatment significantly decreased the germination of several species. Seeds of *Betula*, *Festuca rubra*, *Poa pratensis* and *Plantago major* were not able to germinate after treatment, indicating a transient seed bank. Also the number of seedlings of *Tanacetum vulgare* and *Trifolium repens* was significantly reduced with the treatment.

Influence of matrix on the seed bank

In most samples (78) the matrix was classified as sand, which was found in all sampling sites. Seven samples from the church meadow and one from the old harbour were classified as fine sand. Altogether 18 samples from the church meadow (11), the Lontoo meadow (2) and the old harbour (5) were classified as organic mould. The Kruskal-Wallis test indicated that there were significant differences between the matrix type groups in the number of both monocot and dicot species and seedlings. In all cases the number of species and seedlings was highest in sand and lowest in fine sand. Matrix type does not seem to influence the amount of fern prothalli. When the deeper samples were excluded, the significant difference between the matrices remained only in the number of dicot species and individuals.

Stones were present in 19 samples. The amount of stones seemed to increase the number of species and seedlings significantly when the whole data were used. This holds also for monocots, but the result was not significant for dicots. When I used the data of rapidly germinated seeds and samples collected from the uppermost 10 cm, the result was that the seedling number was still significantly higher in stony samples (also for mono- and dicots, but not ferns). The same result was obtained for the number of monocot species, but not for all species or dicot species. The amount of ballast plant species or seedlings did not significantly differ whether there were stones in the sample or not.

The depth of the organic layer showed slight negative rank correlation with the amount of all germinating seeds and dicot seeds. After that the depth of the organic material in the samples was divided into two classes: under 5 cm (60) and over 5 cm (38). There were significantly more species and seedlings in the samples with a thinner organic layer (< 5 cm). This also holds true for dicot species and number of mono- and dicot seedlings. There was a significant difference in the number of species and seedlings (divided also into mono- and dicots) between 5 groups, based on the depth of the organic layer in the samples. No significant differences were detected in ferns. When I made the analysis without the cold-treated samples and those taken from 10–20 cm, significantly more species and seedlings were present when the organic layer was less than 5 cm thick. The depth of organic layer did not seem to affect the number of ballast species or seedlings: no significant difference was detected.

DISCUSSION

Seed bank density

The seed bank density in the ballast area of Reposaari (11 749 seeds/m^2 in the upper soil layer) was on the average higher than in most grasslands (Rice 1989: 220–221, Graham & Hutchings 1988b). The seed numbers were higher than in a limestone grassland (Milberg & Hansson 1994: 10 060 seedlings/m^2) or in a road verge (Milberg & Persson 1994: 5 800 seedlings/m^2) in Sweden, but it should be remembered that both the transient and persistent seed banks are included in my results while the studies cited above concerned only the persistent seed bank.

There are no other seed bank studies in an urban environment, except my own studies in the centre of the town of Pori (Jutila in prep.). The seed bank in Reposaari was slightly larger than that in the town of Pori, but clearly smaller than, for example, in the abandoned fields of Karkali (50 000 viable seeds m^2 to a depth of 25 cm; Kiirikki 1993) or in the cultivated soils of Finland (a seed counting method, 43 850 seed/m^2 in a 20-cm surface layer; Paatela & Erviö 1971) or in the seashore meadows of Pori (20 000 seeds per m^2; Jutila 1994).

The dicot species dominated the seed bank accounting for 73.5% of the seedlings. The dominance of forbs in grassland seed banks has been noticed e.g. by Roberts (1981), who examined several communities. Seashore meadows and wet grasslands have, on the contrary, more mono- than dicots in the seed bank (Milberg 1993, Jutila 1994). The pioneers in the boreal zone are mainly forbs, but include also certain grasses. In life history strategies, grasses lean mainly to the perennial strategy while forbs have more possibilities. Most of the vegetation in a boreal environment is perennial, but also some annuals and biennials belong in the natural vegetation, for instance, in seashore meadows. In 'cultural' and also seminatural meadows, short life strategy is more common than in natural environments.

The dominance of grasses and certain tall forbs in cultural or seminatural meadows in the boreal zone quite often indicates that the management of the site has ceased and the number of forbs is declining. This means that especially small, often annual forbs are even more dramatically decreasing. When some disturbance, such as grazing, mowing, burning and especially digging in an urban environment, leads to a restart in secondary succession or at least prevents it from continuing, ruderal forbs, because of their faster life strategy and better dispersal mechanism in time (seed bank), take over.

The seed bank of these 'cultural meadows' on ballast soil in Reposaari is dominated by dicots. Only in the *Astragalus glycophyllus* site, which is situated in the immediate vicinity of by the sea, the number of dicot seeds was not significantly higher than that of monocots. This is due to the fact that seashore meadows and also their seed banks are dominated by grasses. The sandy site was probably suitable for the seeds of many species to survive. Proportionally the majority of the grass seeds was found in the dock area where the succession has in many places led to grass-dominated vegetation and also to the dominance of tall forbs that are less well represented in the seed bank. It was interesting to observe that the old harbour had the highest numbers of germinating seeds. That site is nowadays mown twice a year.

Seed bank flora

Concerning the species richness it is more difficult to make comparisons than for the seed density, for the sampling intensity (both the individual sample size and the total volume) varies in different studies. The seed bank of Reposaari was, on the average, quite species-rich compared to some grasslands (Rice 1989). It was also species-richer than the cultural meadows and ruderate places in the centre of Pori (Jutila in prep.). The seed pool was also richer than in arable land (Paatela & Erviö 1971: 41 species in 97.8 dm^3) or in the boreal hardwood forest (Vieno *et al.* 1993, Komulainen *et al.* 1994: 8 taxa in 1.1 dm^3). The fairly small amount of samples probably restricted the species found in the seed bank in Reposaari. The seed bank flora in different study sites was fairly similar and the ten most common seed bank species accounted for 75% of the seed bank.

Even though the whole flora and dicot flora was richest in the Lontoo meadow, the number of species per sample in this area was the biggest in samples of the *Astragalus glycophyllus* site and of the old harbour. In the Lontoo meadow the horizontal variation or patchiness of species in seed bank was greater than in the old harbour, where the species composition from place to place varied less than in the Lontoo meadow. Because the sampling area of the *A. glycophyllus* site was clearly smaller than in the other sites, it was excluded from these comparisons.

These results showed that the seed bank data was fairly homogenous and only the samples that had no seedlings could be separated to a distinct group. Also the correlations of the used explanatory variables were poor. In the future the vegetation of ballast sites should be more carefully studied to allow classification and ordination of the emergent data and correlation with the seed bank.

Ballast species in the seed bank

Nowadays, about 75 plant species can be included in the ballast flora of Reposaari (Kalinainen & Lampolahti 1994). In this study nine ballast species germinated, which is 12% of all still existing ballast species and 30% of the ballast species found in the emergent vegetation of the study sites. The proportion of ballast seeds of all germinating seeds was even smaller than the proportion of ballast species of all species. All ballast species found in the seed bank, i.e. *Artemisia absinthium*, *Astragalus glycophyllus*, *Carum carvi*, *Cirsium arvense* ssp. *arvense*, *Lamium album*, *Medicago lupulina*, *Melilotus alba*, *M. altissima* and *Senecio jacobaea*, were also growing in the study sites. Half of these species were fairly short-living (1 annual or biennal, 3 biennials and 1 perennial or biennial) for whose dispersal the capability to form a persistent seed bank is an important adaptation. Almost half were leguminous species, which are known to have a hard seed coat. Seeds of *Medicago lupulina*, for instance, have a dormancy that can last for many years. Still due to the short non-dormant phase in their development they can germinate rapidly under favourable conditions (Sidhu & Cavers 1977). The perennial (or biennial) *Senecio jacobaea*, which is a well-known weed in many areas of the world, has both effective seed dispersal by wind and a persistent seed bank from which it germinates mainly in spring (Roberts 1986). It is likely that the small sample size in my study hindered discovering all rare species. The ballast species that were found in the seed bank are also the most common ballast species in the vegetation.

Still, the seed bank is known to be important for many rare ballast species since their seeds can be preserved there for centuries. In Reposaari the long time-scale of records shows that numerous species have germinated from the seed bank. During the last three years I have recorded germination of *Carduus nutans*, *Euphorbia helioscopia*, *Filipendula vulgaris*, *Hyoscyamus niger*, *Papaver dubium*, *Plantago lanceolata*, *Trifolium arvense* and *Vicia tetrasperma* from the seed bank after disturbance, like digging or burning. *Diplotaxis muralis*, *Malva sylvestris*, *Geranium pusillum*, *Erodium cicutarium* and *Conyza canadensis* are further ballast species that are also considered to depend on seed bank in the flora of Reposaari (Kalinainen & Lampolahti 1994). At least *Carduus nutans* (Popay *et al.* 1987), *Erodium cicutarium*, *Hyoscyamus niger* (Roberts 1986), *Papaver dubium* (Odum 1978), *Plantago lanceolata* and *Filipendula vulgaris* (Milberg 1991) have been shown to have a persistent seed bank. The seed bank of all the aforementioned species is likely to be small and concentrated in patches of earlier plant locations, and their seeds may have certain germination requirements that were not fulfilled in this study.

The seed bank of Reposaari is activated now and then by water-pipe construction and various other kinds of disturbances. The importance of seed bank was evident in 1992, for example, when a water-pipe channel was built in the side of the Lontoo meadow, one of the richest ballast flora places in Reposaari. In the following summer there was a dense vegetation comprised of common ruderates, but also numerous ballast plants germinated from the seed bank, some of which had not been seen in the place since the beginning of the 20th century. *Papaver dubium*, for instance, flowered there vigorously but the following summer it had disappeared. *Hyoscyamus niger*, a biennial plant, lasted in the place for two years and *Euphorbia helioscopia* only one summer. It is likely that these plants are now preserved in the seed bank of the site and will germinate when some other disturbance activates the seeds.

Emergent vegetation and seed bank

About 72% of the seed bank flora was also found in the emergent vegetation of the study sites, and only 20 species were found exclusively in the seed bank (Appendix). Dicots dominated the emergent flora and the seed bank, but the species' abundance relations were more unequally distributed in the latter. The percentage similarity of the emergent and seed bank flora of each site was clearly lower, varying from 43.3% in the *Astragalus glycophyllus* site to 69% in the church meadow. The *A. glycophyllus* site can be regarded as the successionally youngest site and the grass-dominated church meadow as the successionally oldest site. It has been shown in many studies (e.g. Chippendale & Milton 1934, Donelan & Thompson 1980) that the seed bank of grasslands becomes smaller in number and more similar to the established vegetation as the succession proceeds. The species poverty of the emergent vegetation (both in the 30 cm diameter of sampling points and in the flora of the sampling site) in the old harbour was apparently reflected in the total seed bank poverty, but not in the number of species per sample.

The percentage of species found in the emergent vegetation and in the seed bank as compared with the number of all species in the emergent flora was 36.8%, and varied from 23.2% in the *Astragalus glycophyllus* site to 48.4% in the old harbour. It is evident that the number of species having a seed bank will raise with a higher sampling intensity or some other methods. From these figures, it can be suggested that maybe 40% of the emergent flora has a seed bank of any importance.

Generally the dominant species in the emergent vegetation seem to have a seed bank, but those species dominated the seed bank only rarely. *Potentilla argentea* was the most abundant species in the seed bank in three out of the five sites. In all places *Tanacetum vulgare* was included in the group of the four most abundant seed bank species. One grass species was also always included in the four most abundant seed bank species.

Influence of depth zone and matrix on seed bank

The seed bank density seemed to diminish with soil depth, as has been shown in many studies (Nicholson & Keddy 1983, Graham & Hutchings 1988a). It was intriguing to find that the predominance of perennials and dicots decreased with depth. It can be suggested that annuals and biennials retain their viability longer than perennials, which is logical because opportunistic germination is essential in their strategy. The decline in the predominance of dicots is more difficult to explain and may it be an artefact.

The number of species and seedlings was highest in sand, which is in agreement with the results of Paatela and Erviö (1971), who found that greatest abundance of weed seeds occurred in coarse mineral soils. They also found that certain species were frequent and abundant in mineral soils and others in organic soils.

Cold treatment

The cold treatment seemed to decrease the amount of germinating seeds and species. Although most species in the boreal zone have at least a transient seed bank, they too suffered losses. Birches and many grasses have a good ability to disperse in space due to large seed sets, but only a small proportion of their seeds has the ability to disperse in time (Kiirikki 1993).

Even though there was a predominance of perennials (species and seeds) in both treatment groups, the predominance of perennials was significantly smaller in the cold-treated group than in the rapidly germinated group. This means that annual species survived the cold treatment better, but also they seemed to loose some seeds.

Management of ballast areas: examples and implications of a seed bank

The results of this study are not too encouraging as regards the practical use of seed bank, but on the other hand many previous observations point to its significance. More information is needed to clarify this. The management should be based on the present study and also on other observations.

In general it can be argued that moderate disturbance of soil is beneficial for a ballast flora. This was noticed also in one part of the dock area where a horse pasture was established a year and a half before. After heavy grazing pressure, even during the winter, the area seemed almost plantless, only some *Rumex longifolius* being found. The following summer the site was flowering with a rich and tall growing ballast flora including species like *Carduus nutans*, *Melilotus alba*, *Medicago lupulina*, *M. falcata* and *Anchusa officinalis*, but also many weed species like *Arctium tomentosum* and *Urtica dioica*. Also the church meadow, i.e. one of the best ballast places, was grazed by cattle 50 years ago. It was later used as a playground for children of the village.

In the management of ballast areas one should have a good knowledge of the established vegetation, its succession and the life strategies of the constituent species. Then one should decide which species should be protected and where. Mowing (and removing of mown hay) in late season when these species have flowered and produced seed favours small and annual species. Places that have lost their ballast vegetation, but still have these species in the seed bank, should be disturbed by digging, burning or heavy grazing. The areas to be managed should be small and mosaic to avoid expansion of some ruderate species.

Total lack of ballast species in the largest seed bank of the sites, i.e. the old harbour, would suggest some other management than seed bank activation, but also the emergent vegetation did not have any ballast species (in 1995). Seeds of ballast species could be collected and delivered to this place. There is still the possibility that the seeds of a few ballast species can be in the soil, but they were not found in the small sample. Small scale soil disturbance would also be justified to enable the collected seeds and the seeds of many well-dispersing species to establish themselves on the site.

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APPENDIX

Abundance of species in the seed bank and vegetation. Figures indicate the numbers of germinated seedlings in the seed bank (SB) and estimated abundance of species (in log. scale 1–7) in the emergent vegetation (EV). Ballast species are marked with an asterisk (*). Symbol + means that the species was growing in the emergent vegetation during some of the years 1992–94, but not in summer 1995.

Species	*A. glycophyllus* site		Church meadow		Lontoo meadow		Dock area		Old harbour	
	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB
Species present only in the vegetation										
Acer platanoides	1		1		1		1		(1)	
Alopecurus pratensis			2		1		3		1	
Agrostis gigantea	3									
Alnus glutinosa	1				1					
* *Anchusa officinalis*			2							
Anthriscus sylvestris	1		1		2					
* *Anthyllis vulneraria* ssp. *fennica*							1			
Arabis glabra					1					
Arctium tomentosum	1				2		1			
* *Artemisia campestris*					2					
Atriplex prostrata							1			

(continues)

Species	*A. glycophyllus* site		Church meadow		Lontoo meadow		Dock area		Old harbour	
	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB
Avenula pubescens					3					
Bromus inermis	2									
Calamagrostis epigejos	1				1		2		1	
* *Campanula rapunculoides*					2					
Capsella bursa-pastoris	1		1							
* *Carduus nutans*							2		+	
Centaurium pulchellum	1									
* *Cerastium arvense*					2					
Dactylis glomerata			1		5					
Deschampsia cespitosa							1			
Deschampsia flexuosa					3		2			
Eleagnus commutata							1			
Elymus arenarius	1						1		2	
Epilobium adenocaulon							1			
* *Euphorbia helioscopia*					+					
Festuca arundinacea	2									
Festuca ovina							2		2	
Festuca pratensis			1				2			
Filipendula ulmaria	2				1		1			
* *Filipendula vulgaris*					1					
Fumaria officinalis			1							
Galium album					1				1	
Geum urbanum					1		1			
Glaux maritima	2									
Hieracium umbellatum	1				2					
Hippophae rhamnoides	2						2			
* *Hyoscyamus niger*					+					
Impatiens glandulifera					1					
Juniperus communis					1					
* *Knautia arvensis*					2					
Lathyrus pratensis	1				2					
* *Linaria repens*					1					
* *Medicago falcata*			3				1			
Milium effusum					1					
Myrrhis odorata					1					
Odontites litoralis	1									
Phalaris arundinacea	3									
* *Papaver dubium*					+					
Phleum pratense	2		6		2		3		1	
Phragmites australis	2						1			
Picea abies			1				1			
Pinus sylvestris			2		1		1			
Plantago maritima	1									
Poa annua			1		1		1			
Poa compressa							4		3	
* *Polygonum amphibium*			2							
Potentilla anserina	2									
* *Potentilla intermedia*							1			
Prunus padus	1						1			
Rhinanthus minor			1							
Rhinanthus serotinus					1					
Ribes nigrum							1			
Ribes spicatum	1				1		1			
Rosa dumalis					1					
Rosa rugosa			2							
Rorippa palustris	1									
Rubus idaeus	2				1		2			
Salix caprea					1		1			
Sambucus racemosa							1			
* *Saponaria officinalis*					2					
* *Senecio viscosus*	1									
* *Silene latifolia*					2					
Solanum dulcamara							1			

(continues)

Species	*A. glycophyllus* site		Church meadow		Lontoo meadow		Dock area		Old harbour	
	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB
Sonchus arvensis							1			
Sorbus aucuparia	2		2		2		1			
Symphoricarpos					1					
Taraxacum sp.	2		2		2		2		3	
* *Tragopogon pratensis*			2							
* *Tussilago farfara*	1									
Valeriana sambucifolia					1					
Veronica chamaedrys			1						2	
Viburnum opulus					1					
Vicia sepium	2		1		1					
* *Vicia tetrasperma*					1					
Species present both in the seed bank and emergent vegetation										
Achillea millefolium	3		4	4	3	4	3	4	5	10
Agrostis capillaris	2	7	2	1	3	11	6	17	7	47
Agrostis stolonifera			2				4	9		
* *Artemisia absinthium*					2			5		
Artemisia vulgaris	3	2	3	3	2	12	2	65	2	4
* *Astragalus glycophyllus*	2	1								
Betula pendula					2	9	3	4		
Betula pubescens			1	6			1		1	20
Calamagrostis stricta	1			1		5				
* *Carum carvi*		1						6	3	
Cerastium fontanum	1				1	2	1	1	1	4
Chenopodium album						3	1			
* *Cirsium arvense* ssp. *arvense*	2				2	1	4			
Dianthus deltoides					3	1				
Elymus repens	4	6	2	3	2	1	3	24	2	9
Epilobium angustifolium			1	1	3	2	2	1		1
Equisetum arvense	2		2	11		4	2			
Festuca rubra	3	1	3	7	3	21	4	11	7	61
Fragaria vesca							1			1
Galium verum	2		3		5			1		
Juncus gerardii	3	2		1						4
* *Lamium album*		2	2	3	2					
Leontodon autumnalis	2		2	2	1		4	2	2	
Linaria vulgaris	2		2	6	2	15	3	15	1	3
Matricaria matricarioides						1		3	1	4
* *Medicago lupulina*	1	6	2	2	4	15	2	1	2	
* *Melilotus alba*		1			1		3	5	2	
* *Melilotus altissima*	3	6				5		3		
Plantago major	2		2	3	1	1	3	23	2	56
Poa pratensis	3	26	2	5	1	36	2	14		4
Poa subcaerulea					2		5	1		
Potentilla argentea		1	2	53	2	156	5	6	5	183
Polygonum aviculare	1				1	3				2
Rumex acetosa		1			1			4		
Rumex acetosella					1	7	2		3	20
Rumex crispus	1	1	1		2		3			
Rumex longifolius		1					1	7	1	
Sagina procumbens	1	2		1		49	1	1		1
Salix phylicifolia					1		1	1		
Sedum acre					2	2			2	13
Sedum telephium					2	2				
* *Senecio jacobaea*			4	6	2		1			
Silene dioica					1	1?				
Stellaria graminea	1		1	2	1	12		1		
Tanacetum vulgare	4	42	4	30	3	30	7	64	3	61
Trifolium pratense	2		2		1	1	2	5	3	
Trifolium repens		2	3	22		21	4	5	6	12
Urtica dioica	2	14	2	2	2	27	2			
Vicia cracca	3	2			3	2	3		1	

(continues)

Species	*A. glycophyllus* site		Church meadow		Lontoo meadow		Dock area		Old harbour	
	EV	SB	EV	SB	EV	SB	EV	SB	EV	SB
Species present only in the seed bank										
Cicuta virosa		1								
Eleocharis palustris										1
Galium palustre						1				
Galium uliginosum				3		1				2
Glechoma hederacea				1						
Juncus bufonius										4
Leucanthemum vulgare						1				
Limosella aquatica				1						
Myosotis sp.		2				3				
Poa trivialis		9		31		29		12		37
Potentilla norvegica										1
Ribes alpinum		1								
Sagina nodosa		1								
Scrophularia nodosa		3		7		2				
Spergula arvensis		2								
Stellaria media				3		7				
Stellaria palustris								2		
Tripleurospermum inodorum								1		5
Viola canina						1				
Viola palustris		1						3		
dicotyledons		79		3				38		133
monocotyledons								3		86
grasses				1				11		1
pteridophytes				16						