Global warming opens the door for invasive macrophytes in Swedish lakes and streams

Master´s thesis, 20 credits.

by

Simon Hallstan

Department of Environmental Assessment
Swedish University of Agricultural Sciences
Box 7050 SE 750 07 Uppsala

Supervisor: Eva Willén
Assistant supervisor: Daniel Larson

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Simon Hallstan
shallstan@spray.se

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ABSTRACT

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The increased travelling and transporting by man has caused more species to be moved to new areas, e.g. in ballast water. These species are called introduced species or alien species. Some alien species manage to reproduce and grow rapidly in their new environment. They are then called invasive species. Invasive species is a threat against biodiversity and an economical problem. They compete with other species and can change the environment for these species. In this study aquatic plants (macrophytes) are treated. Some invasive macrophytes have such an immense growth that they are an obstacle for swimmers and anglers. Examples of aquatic species that has been introduced to Sweden and caused problems are the water weed (*Elodea canadensis*) and the fringed water lily (*Nymhopides peltata*).

Due to the emissions of so called greenhouse gases, the scientist believes that the climate is changing. They estimate that the annual mean temperature in Sweden will rise with 2.5–4.5°C. The consequences are that species that previously was not able to survive in Sweden might be able to survive in the future. In this study I have compiled a list of aquatic vascular plants introduced somewhere in the world. I have examined if the species described as invasive could establish in Sweden, both at the current climate, and in the future climate predicted by two different models from the Swedish Metrology and Hydrology Institute (SMHI). By matching the species distribution with current climate using the computer program GARP (Genetic Algorithm for Rule-set Prediction), I have created a niche for each species. These niches have been projected onto the future and current climate. The results show that the risk of introductions of invasive species to Swedish freshwater habitats will increase in the future. Many of the invasive species are also able to establish at the current climate. The results show that the species which have the biggest possibility to establish in Sweden are: *Azolla filiculoides, Crassula helmsii*, *Lagarosiphon major*, *Lemna minuta*, *Myriophyllum aquaticum* and *Zizania aquatica*. They can establish at both the current climate, and a future warmer climate.

SAMMANFATTNING

Klimatförändringar möjliggör etablering av nya makrofyter i svenska sötvatten

Människans ökade resande och transporterande har medfört att fler arter förflyttas till nya områden, t ex i barlastvatten. Dessa arter kallas för främmande arter eller introducerade arter. En del främmande arter klarar sig väldigt bra i sin nya miljö och får en snabb och kraftig tillväxt. De kallas då för invasionsarter. Invasionsarter är ett hot mot biodiversiteten och ett ekonomsikt problem. De kan konkurrera ut andra arter och förändra livsmiljön för dessa arter. I detta arbete behandlas akvatiska växter (makrofyter), som växer i sötvattensmiljö. En del makrofyter tillväxer så kraftigt att de hindrar människor från att bada och fiska. Exempel på akvatiska växter som introducerats till Sverige och blivit problem är vattenpest (*Elodea canadensis*) och sjögull (*Nymhopides peltata*).

På grund av utsläpp av så kallade växthusgaser tror forskare att vårt klimat håller på att förändras. Man uppskattar att årsmedeltemperaturen i Sverige kommer öka med 2,5–4,5°C. Det innebär att arter som förut inte kunde överleva i landet nu kommer att kunna göra det. I den här studien har jag sammanställt en lista över introducerade akvatiska kärlväxter i hela världen. Jag har undersökt om de som beskrivs som invasionsarter någonstans i världen kan etablera sig i Sverige i dagens klimat och i det klimat som förutspås inträffa år 2100 av två olika klimatsimuleringar gjorda av SMHI. Genom att jämföra klimatet med utbredningsdata för växterna har jag, med hjälp av datorprogrammet GARP (*Genetic Algorithm for Rule-set Prediction*), skapat nischer för varje art. Nischerna har sedan projekterats på nutida och framtida (år 2100) klimat. Resultatet visar att *Azolla filiculoides, Crassula helmsii, Lemna minuta*, *Lysichiton americanus*, *Myriophyllum aquaticum* och *Zizania aquatica* är de arter som har störst möjlighet att etablera sig i Sverige, både i dagens klimat, och i ett framtida varmare klimat.

1 Introduction

The introduction of non-indigenous species to new areas is a large threat to biodiversity. Wilcove et al. (1998) consider it to be the second worst threat to biodiversity. So far, this has not been a big problem in Sweden, partly because the cold climate limits many species' northern distribution. However, scientists believe that because of the emission of greenhouse gases, the climate will get warmer in the future. This means that the risk of new species establishing in Sweden will increase. In this study I have investigated the risk of establishment for some known problematic macrophytes, both at current climate and at two simulations of a future warmer climate.

1.1 Alien species

Species spread naturally, but with human involvement they can be introduced to places otherwise unreachable. The introductions can be intentional because of economical or esthetical reasons, or they can be accidental, as when species are transported in ballast water. Species introduced to new areas by Man are called alien or non-indigenous species. Invasive species are non-indigenous species that manage to reproduce rapidly and become a problem. Some species can totally dominate a habitat, even if they do not do so as native species. There are several theories on why some alien species become invasive. The perhaps most accepted one is that they have escaped from their natural enemies, and therefore have a big competitive advantage over the native species (see e.g. Clay 2003; Keane and Crawley 2002; Mack et al. 2000; Torchin et al. 2003).

Invasive species are problematic in several ways: they are a threat against biological diversity, an economical problem and an obstruction for recreational activities. They threaten the biological diversity by competing with native species and altering habitats. Many aquatic invasive plants can grow in dense floating mats that limit light availability for other organisms. When the biomass is degraded at the end of the growing season, oxygen is consumed at the bottoms of the lakes. The low oxygen conditions increase the internal loading of phosphorus, which may cause toxic phytoplankton blooms. Some species can also form hybrids with native species and reduce genetic diversity. The formation of dense mats of floating plants or dense stands of submerged or emergent macrophytes can be an obstacle for boating, fishing and swimming.

In some places in southern Sweden, 30-40% of the wild vascular plants have arrived since 1700 (Jonsell 2004). Many of them are originally garden plants that escaped. Some are invasive and might be a threat against native vegetation. Examples are sycamore (*Acer pseudoplatanus*) and the garden plants garden lupin (*Lupinus polyphyllus*), japanese rose (*Rosa rugosa*), red-berried elder (*Sambucus racemosa*), canadian goldenrod (*Solidago canadensis*) and giant hogweed (*Heracleum mantegazzianum*) (Jonsell 2004). Giant hogweed is a large perennial herb introduced from Caucasus that now is common in south and middle Sweden. This species is not only a very strong competitor that outcompetes other species (Lundström 1984, 1990), but also poisonous and harmful to humans. Therefore, the Swedish Environmental Agency has recommended it to be eradicated (Swedish Museum of Natural History 2005b).

In Sweden there are at least 30 alien species of vascular plants established in connection to freshwater habitats (Wallentinus 2002). Of these species, only three can so far be considered invasive: *Elodea canadensis*[1], *E. nuttallii* and *Nymphoides peltata* (Larson and Willén 2006).

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[1] Authors and commons name in English and Swedish (where available) for all aquatic alien species are available in appendix 1, page 40.

The first finding of *E. canadensis* in Sweden is from 1871 (Almqvist 1965). It is originally a North-American species that is believed to have escaped from aquarium (Josefsson 1999) or been introduced with imported timber (Cook and Urmi-König 1985). *E. canadensis* forms large stands that are obstructing water activities like boating and fishing. When the large amount of biomass is degraded at the bottom in the autumn, oxygen is consumed. The anoxic conditions lead to a release of phosphorus from the sediment, which increases the eutrophication process. *E. canadensis* is a dioecious species, and since only male plants are found in Sweden the reproduction is strictly vegetative (Larson and Willén 2006).

E. nuttallii was not discovered in Sweden until 1991 (Anderberg 1992), but is spreading, and has the potential of becoming a big problem. It has been found to outcompete *E. canadensis* in nutrient rich environments (Barrat-Segretain and Elger 2004; Simpson 1990).

N. peltata is a floating leaved plant with attractive yellow flowers. It has been introduced to Swedish waters on several occasions, the first time in 1892. The introductions were made because of the plants esthetical value, but also because it was believed to give protection for fish fries and thereby increase fish populations (Eckerbom 1940). It has spread and is spreading to sites downstream the original introduction place (Larson and Willén 2006). Since *N. peltata* is used as an ornamental plant and is available at plant nurseries, further introductions could easily take place.

Glyceria maxima is another species that is considered a pest in some areas. It is a grass native to southern Sweden, but has been introduced in other regions to be used to feed cattle (Larson and Willén 2006). It has spread throughout the country and is common from Skåne to *Limes norrlandicus* (Mossberg and Stenberg 2003). *Glyceria maxima* form dense stands in shallow waters and outcompete other emergent macrophytes and contribute to an overgrowth of open waters (Josefsson 1999). *Glyceria maxima* and *E. canadensis* have negatively influenced the populations of several emergent macrophytes (*Ranunculus reptans, Zannichellia palustris, Alisma wahlenbergii* and *Callitriche hermaphroditica*, among others) in the Ekoln bay of Lake Mälaren (Almqvist 1965; Martinsson 1989).

1.2 Predicting invasive species

It is of great value to be able to predict which species that could become invasive. By creating legislation and raising public awareness it is possible to minimize the risk that potentially invasive species will be introduced. Trade can be controlled and if the alien species are spotted in nature, eradication could start immediately. There are a few different approaches for predicting potential invasive species. The most straightforward way is to compile a list of species that are invasive or pest species somewhere else. This approach has the advantage that species already introduced have traits that make them likely to be introduced and invasive again, e.g. they are used commercially (and therefore transported all over the world) or have the ability to reproduce rapidly. However, a big disadvantage with this method is that it only highlights species that already are considered invasive, which will have the consequence that future, but not yet, invasive species are classified as safe (Mack 1996).

There are certain characters that are believed to be associated with invasive species. Baker (1974) constructed a now classic list of weed species characters. This could be used to find potentially invasive plants. However, according to Mack (1996) this method has a low prediction value for two reasons. Firstly, the list compiled by Baker focuses on weeds, defined as species growing at places disturbed by man. These traits are therefore not useful explaining why species can invade natural areas. Secondly, it does not consider the advantage an introduced species might have because of lack of native enemies, parasites and competitors. It is also evident that no species have all these listed characters, and that not all species with several of the characters are invasive (Mack 1996).

Another approach is to focus on a habitat to see if it is sensitive to invasions, i.e. how invasible it is. Alpert et al. (2000) list factors that might decrease the invasibility of a habitat, including a low disturbance and different kinds of stress. In northern parts of the world, cold winter temperature is a stress factor that limits the distribution of many plant species. Since the global temperature is predicted to increase, there is a risk that new species will be able to establish in Sweden (Larson and Willén 2006).

1.3 Climate change and invasive species

During the 20th century, the temperature at the surface of the earth increased with 0.6 °C. According to the Intergovernmental Panel on Climate Change (IPCC) the temperature will keep rising with 2.3–3.4°C until the year of 2100. SweClim (Swedish Regional Climate Modelling Programme, http://www.smhi.se/) predicts that the Swedish annual temperature will increase with 2.5–4.5°C (Bernes 2003) during the same period. The temperature increase in Sweden will thus be larger than the world average (Bernes 2003).

The human induced climate and atmospheric changes will and are affecting several species' physiology, phenology and distribution (Hughes 2000). To investigate the effect of global warming on European plant diversity, Thuiller et al. (2005) simulated the distribution of 1350 European plant species in the year 2080 under seven different climate change scenarios, based on their present distribution. In the worst case scenario 22% of the species will become critically endangered and 2% extinct. Southern Scandinavia was predicted to have a high species turnover, losing boreal species and gaining Euro-Siberian species. New species will not only be able to survive in Sweden, but they might also have a competitive advantage over the natives, who cannot tolerate the increased radiation and drought or take full advantage of the increased temperature.

1.4 Modelling species distribution

By matching species distribution data with environmental data it is possible to model a species niche, i.e. the environmental limits where a species can survive and reproduce. The modelled niche can then be used to detect geographical areas with suitable habitats for the species. This is an effective way to investigate which species that have the potential to invade a particular area, and by projecting the constructed niche on future climate scenarios it is also possible to see the effect of global warming on habitat invasibility.

There are several different approaches and methods to model species distribution from its realized niche. The simpler ones, such as BIOCLIM (Nix 1986), look at species occurrences at different environmental dimensions (excluding a given proportion of the tails, commonly 5%) to produce a niche, while more advanced ones uses logistic regression (e.g. Austin et al. 1990). The rules produced can then be applied to environmental layers to get a modelled distribution. The general process of ecological niche modelling is explained in figure 1.

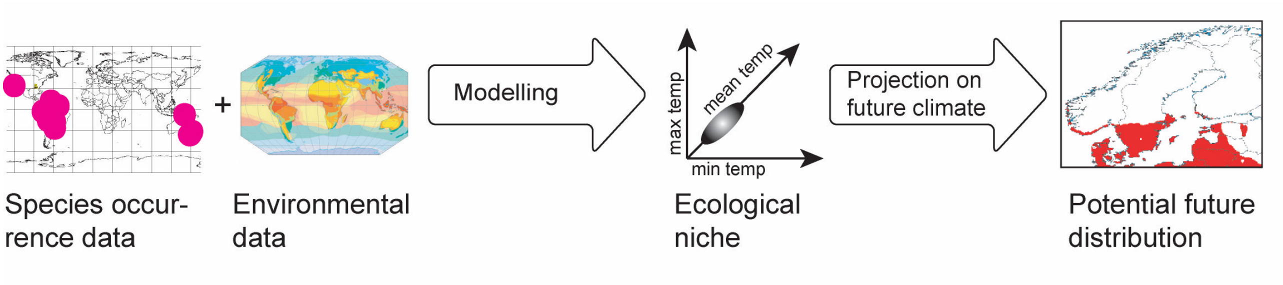

Figure 1. Schematic explanation of the modelling process.

In this study, a model called *Genetic Algorithm for Rule-set Prediction* (GARP) has been used. GARP uses several algorithms to produce a rule-set, and should therefore always have better predictive ability than other methods using individual algorithms (Peterson 2001). Is has been shown in several studies that GARP have a good predictive ability (e.g. Anderson et al. 2002; Mau-Crimmins et al.; Peterson et al. 2003; Peterson 2001; Peterson and Vieglais 2001; Sánchez-Cordero and Martinez-Meyer 2000).

1.5 Aim

There is a knowledge gap regarding invasive aquatic plants in general and their response to climate change in particular. The main focus of invasive species research has been on agricultural weeds, and in those few cases where aquatic species have been studied, invertebrates or fish have been prioritized on the expense of plants. The only previous study with climate-model simulation for aquatic alien plants is to my knowledge Peterson et al. (2003), who simulated the potential distribution of *Hydrilla verticillata* in North America.

In this study I have collected information about freshwater species that are introduced or considered invasive in other parts of the world, mostly in Scandinavia, central Europe, United Kingdom, North America, Australia and New Zealand. With current climate data and simulated climate data for Sweden, a modelled future potential distribution for these species where created. The purpose was to study the effect of climate changes on invasiveness of Swedish freshwater habitats and to raise awareness about particular species that might become invasive in Sweden.

2. Methods

2.1 Species list

A list of non-indigenous freshwater vascular plant species was created by searching various sources, i.e.: Internet sites of governmental agencies, universities and other organizations, and literature for information on introduced species in different countries. The focus was on Europe and the temperate parts of the world, but accessible information from others areas is included. The list can be found in appendix 1. It contains 145 species that are non-indigenous somewhere in the world.

2.2 Species distribution data

The distribution data was collected form the Global Biodiversity Information Facility (GIBF, GBIF 2005) and Atlas Florae Europeae (AFE, Jalas and Suominen 1972-1996). GBIF is a non-profit organization with the aim of making scientific data on biodiversity electronically available. It has 78 participants, 47 countries and 31 organizations. From the GBIF portal it is possible to access distribution data from institutes, like museums and universities, from the entire world. AFE is a project for mapping the distribution of vascular plants in Europe. The maps have been digitalized at the Botanical Museum of the Finnish Museum of Natural History. See table 2 for detailed species distributions references.

2.3 Climate Data

The temperature variables used were mean, minimum and maximum air temperatures 2 meters above ground. Mean temperature is the mean from 4 moments every 6th hour while minimum and maximum temperatures are the monthly mean of daily minimum and maximum temperatures. Both the climate prognoses for the period 2071-2100 and the dataset of the current climate (i.e. 1961-1990) are based on simulations and not on actual measurements. The current climate data correspond to the experienced conditions in terms of statistics such as averages and variability. Three different temperature data sets were used:

- Current climate data for the entire world included in GARP was used to create niches. The data derives from IPCC and the original resolution is 0.5 degree cells, but has been generalized to 1 km cells.

- Current climate data in a higher resolution, covering Scandinavia, was obtained from SweClim (SMHI 2003) and used for predictions of current potential establishment.

- Climate prognoses were obtained from SweClim (SMHI 2003) and used for prediction of future establishment possibility.

The future climate depends on the levels of greenhouse gases emitted. Therefore, IPCC has created several different emission scenarios based on different possible political, technological, demographic and economical development. There are four main types of emission scenarios. Firstly they are characterized by focusing either on economical development (A-scenarios) or a more environmental friendly sustainable development (B-scenarios). Secondly they consider the level of globalization, which can be increasing with an extensive global trade (1-scenarios), or a shift toward regional self-support (2-scenarios). The scenarios used in this study are A2 and B2. In both, the world population is still increasing by the year 2100, but slower in the B2 scenario. The economical development is increasing in both models and the economical difference between the rich and poor countries is decreasing (Bernes 2003).

Table 1. Schematic overview of emission scenarios. From Bernes (2003).

	Globalization and extensive world trade	Regional self-reliance
Economical development	A1	A2
Environmental sustainability	B1	B2

2.4 Computer Models

The distribution simulations were made with the computer program Desktop-GARP (version 1.1.6) (http://www.biomapper.org/GARP). GARP creates a rule-set for a species' distribution based on non-random correlation between species presence and environmental variables. The program works in an iterative process of rule selecting, evaluation, testing and incorporating or rejecting the rule (Peterson et al. 1999). First the program chooses one out of four types of rules: atomic, logistic regression, bioclimatic envelope, and negated bioclimatic envelope rules. Then the rule is evaluated from training points. The change in accuracy from one iteration to the next is used to determine if the rule should be incorporated in the rule-set or not. The program was set to do 1000 iteration or until new rules did not increase the intrinsic accuracy measurement. Fifty percent of the occurrence points were used for training. The model process is explained schematically in figure 2.

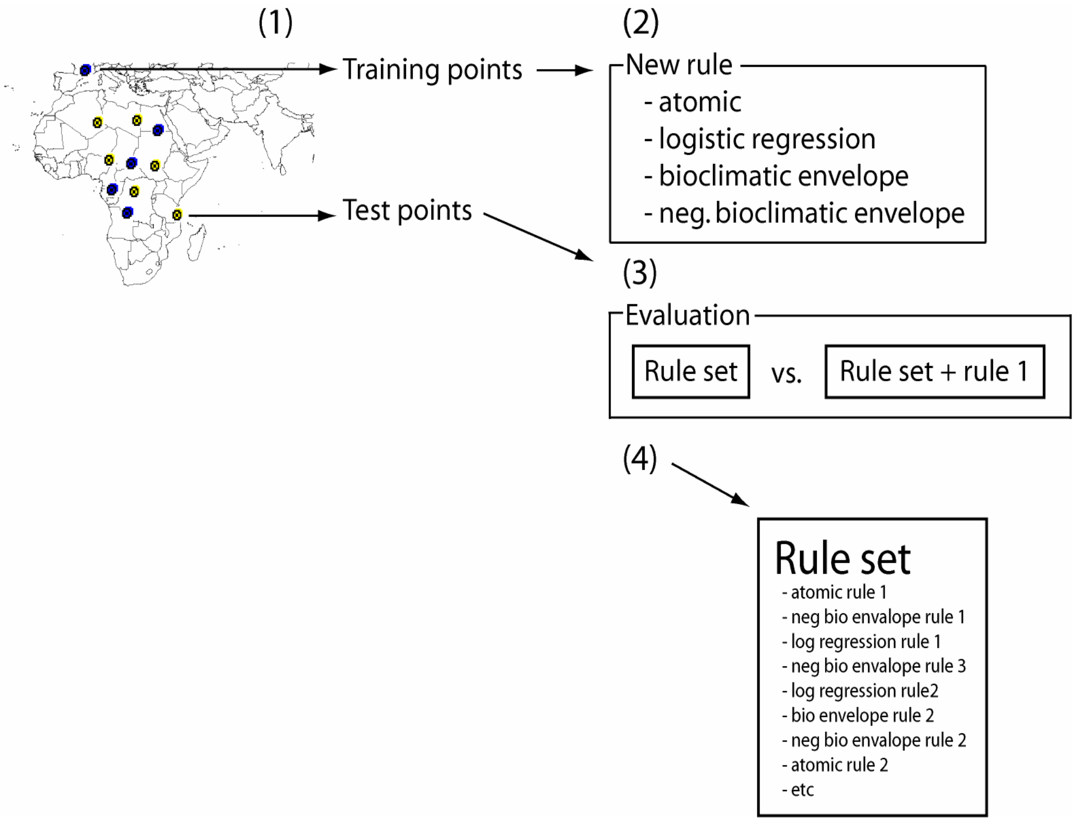

Figure 2. Schematic explanation of GARP. (1) 50% of the occurrence points are randomly set aside as test points. The other 50% is used as training points. (2) The training points are used to create a detection rule. (3) The rule is evaluated with the test points. If the model is more accurate with the new rule, it is included in the rule-set. Step 2 and 3 are repeated 1000 times or until convergence is reached.

To capture the random effect of different model "runs", 21 rule-sets were made for each species. From the rule-sets, digital maps in the format of ARC/INFO grid files were created by projection onto the present and future climate. The grid files were imported into ArcView 3.3 (ESRI 2002), using the Spatial Analyst Extension, were the 21 projections for each species were summarized and projected as four different categories: no predicted establishment possibility; predicted establishment possibility in 1 to 7 of the models; predicted establishment in 8 to 15 of the models and predicted establishment in 16 to 21 of the models. The categories were named "no", "low", "intermediate" and "high" probability of establishment possibility, respectively.

The potential establishment possibility was modelled for five species already established in Sweden as well as for all species in the created list described as invasive by at least one source (n=21). By including already established species, the ability of the model and the chosen environmental parameters to simulate the distribution of aquatic plant species can be assessed. In order to make this assessment, the known occurrences in Sweden, Norway and Finland of these five species were excluded from the model and compared with the modelled distribution. The species chosen for this task were: *Ceratophyllum demersum*, *Nuphar lutea*, *Nymphoides peltata*, *Potamogeton natans* and *Typha latifolia*, all except *N. peltata* are indigenous to Sweden. For the 21 invasive species, potential establishment possibility were modelled both at current and future climate.

Table 2. Number of occurrence points used in simulations and references for the distribution data. * Scandinavian occurrences excluded.

Species	Number of occurrences in model	References
Alternanthera philoxeroides	88	1-6
Azolla filiculoides	2925	1, 4-5, 8-10, 15-18, 28
Azolla pinnata	77	1, 4-5
Cabomba caroliniana	31	1, 4-6, 15
Ceratophyllum demersum	9608	1, 3-10, 15-19, 21, 25, 28
Crassula helmsii	1580	1, 5, 8, 15, 28
Eichhornia crassipes	171	1-6, 15-18, 21, 23
Elodea canadensis	17083	1, 3-4, 6-8, 10, 12, 15, 17-19, 29
Elodea nuttalii	4184	4, 7-8, 10-11, 15, 29
Hydrilla verticillata	43	1, 4-6, 15, 18-19, 21
Hydrocotyle ranunculoides	109	1, 4, 6, 15, 17-18, 21
Lagarosiphon major	937	15
Lemna minuta	1671	3-4, 6, 8, 11, 15, 17-18, 23
Ludwigia uruguayensis	12	4, 9
Lysichiton americanus	382	4, 10, 15, 25
Myriophyllum aquaticum	573	1, 3-6, 8, 15, 17, 18, 26
Nuphar lutea	15632	3-4, 6-8, 10, 15, 19, 25, 28
Nymphoides peltata	2404 (2353*)	7-8, 10, 15, 18
Pistia stratiotes	173	1, 4-6, 8, 15, 17, 21, 23
Potamogeton natans	20988	1, 3-4, 6-8, 10, 11, 13, 15, 18-19, 25
Salvinia molesta	11	1, 5-6, 18
Spartina anglica	1030	1, 15
Trapa natans	12	4, 7, 10, 17, 19
Zizania aquatica	10	3-4, 6
Typha latifolia	15631	1, 3-4, 6-7, 9-11, 15, 18-19, 25

1. Australian National Herbarium (2005); 2. Herbier de la Guyane (2005); 3. Utah State University (2005b); 4. Missouri Botanical Garden (2005); 5. National Herbarium of New South Wales (2005); 6. University of Alabama Herbarium (2005); 7. Biologiezentrum der Oberoesterreichischen Landesmuseen (2005); 8. Bundesamt für Naturschutz / Zentralstelle für Phytodiversität Deutschland (2005); 9. GBIF-Spain (2005); 10. Swedish Museum of Natural History (2005); 11. Herbarium RNG (2005); 12. University of Vienna (2005); 13. Icelandic Institute of Natural History (2005); 14. Fachbereich Wald und Forstwirtschaft (2005); 15. UK National Biodiversity Network (2005); 16. Bernice Pauahi Bishop Museum (2005); 17. AAU (2005); 18. International Institute for Sustainability (2005); 19. PAS (2005); 20. Institute of Marine and Coastal Sciences, Rutgers University (2005); 21. INBio (2005); 22. Botanic Garden and Botanical Museum Berlin-Dahlem (2005); 23. KU (2005); 24. Steiermärkisches Landesmu Joanneum - Herbarium GJO (2005); 25. University of Alaska Museum of the North (2005); 26. GBIF-NZ (2005); 27. Danish Biodiversity Information Facility (2005); 28. Jalas and Suominen (1972-1996); 29. Larson and Willén (2006).

3. Results and discussion

3.1 Predicted potential distribution of test species

To test the GARP model's ability to predict establishment possibility for aquatic species in Sweden, simulations were made for species native or already introduced to Sweden. These simulations show that the GARP model seems to have a good accuracy and can be used to simulate the distribution of aquatic plants in Sweden with the selected temperature variables. Comments about the five test species modelled follows below:

- *Ceratophyllum demersum*

Ceratophyllum demersum is a submerged species. It is quite common in southern Sweden, and occurs sporadically all over the country (fig. 3c). The modelled distribution of *C. demerum* fits well with the distribution reported by Jonsell (2001), Hultén (1971) and Mossberg et al. (2003) (fig. 3b). A few known occurrences in the far north of Sweden and Finland are not included in the modelled distribution.

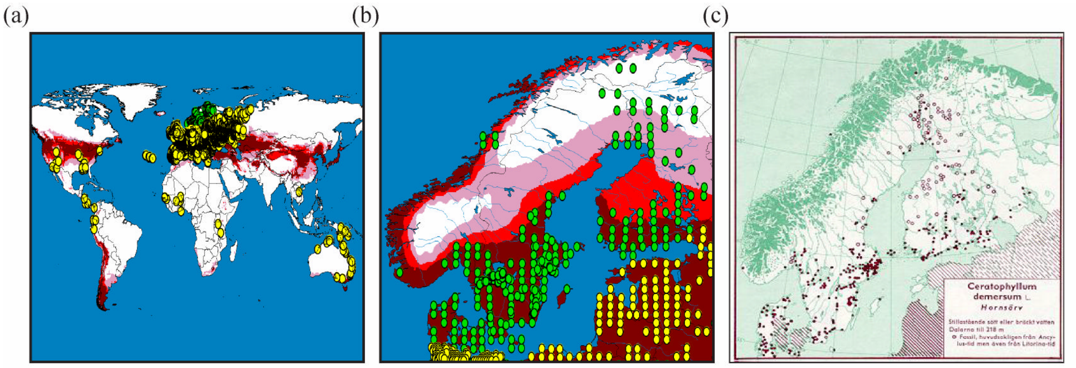

Figure 3. Predicted potential distribution of *Ceratophyllum demersum* for current climate for (a) the world and (b) Scandinavia. ○ actual occurrences included in the model; ● actual occurrences excluded from the model; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability. (c) Actual distribution (from Hultén (1971)). Densely hatched areas - common or very common; sparsely hatched areas - quite common to less common; black dots - single occurrences.

- Nuphar lutea

Nuphar lutea is common from Skåne to Norrbotten, except in the mountain regions (fig. 4a). It is a floating-leaved plant. The intermediate and high classifications coincide with the classifications "quite common to less common and" "common or very common" by Hultén (1971) (fig. 4b-c).

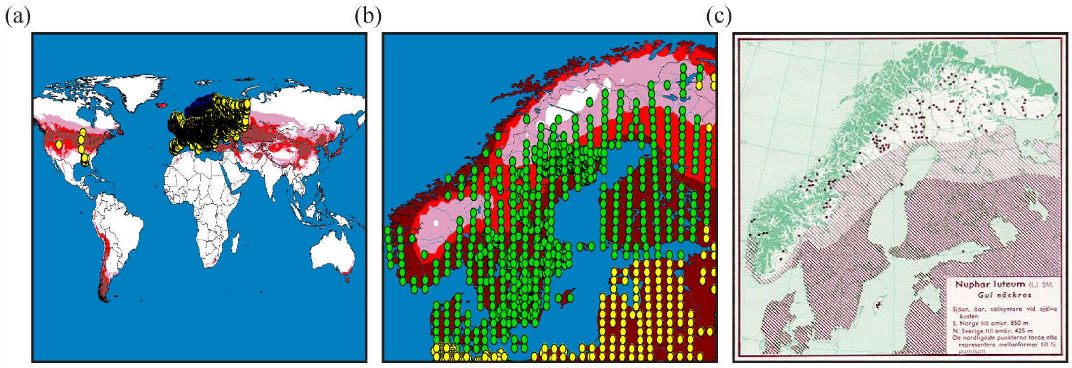

Figure 4. Predicted potential distribution of *Nuphar lutea* for current climate for (a) the world and (b) Scandinavia. ○ actual occurrences included in the model; ● actual occurrences excluded from the model; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability. (c) Actual distribution (from Hultén (1971)). Densely hatched areas - common or very common; sparsely hatched areas - quite common to less common; black dots - single occurrences.

- Nymphoides peltata

Nymphoides peltata is an introduced floating leaved plant. It has a limited but expanding distribution (fig. 5c). Since its current Swedish distribution is very well known it provides an excellent opportunity to test the GARP model. All of its confirmed occurrences fall within the model (fig. 5b). Most are in the high probability area, and a few in the intermediate. No known occurrences are within the area of low or no probability.

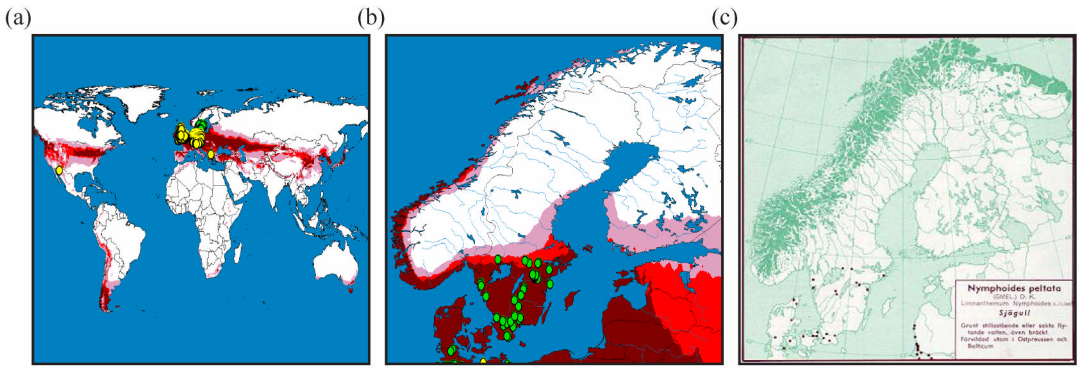

Figure 5. Predicted potential distribution of *Nymphoides peltata* for current climate for (a) the world and (b) Scandinavia. ○ actual occurrences included in the model; ● actual occurrences excluded from the model; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability. (c) Actual distribution (from Hultén (1971)). Densely hatched areas - common or very common; sparsely hatched areas - quite common to less common; black dots - single occurrences.

- Potamogeton natans

Potamogeton natans is a floating-leaved plant that can be found throughout Scandinavia, except in the mountain regions (fig. 6c). The model gives a good picture of its distribution, but seems to underestimate the northern distribution (fig. 6b). Several of the known occurrences are included in the low probability area.

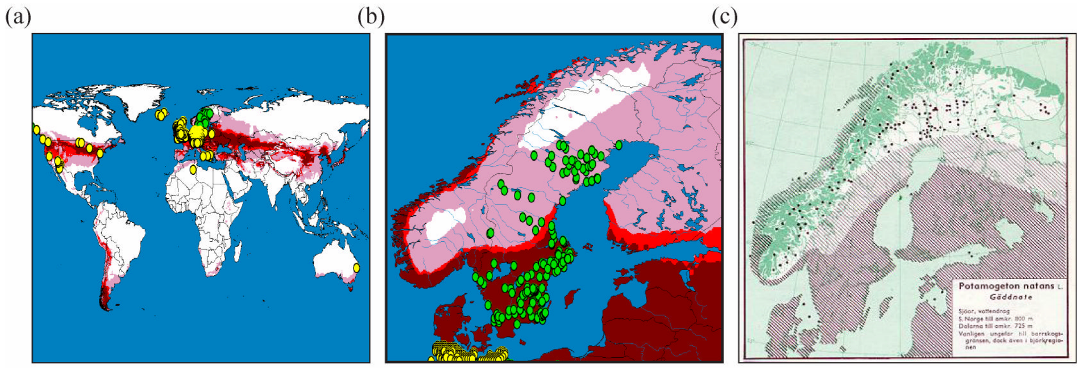

Figure 6. Predicted potential distribution of *Potamogeton natans* for current climate for (a) the world and (b) Scandinavia. ○ actual occurrences included in the model; ● actual occurrences excluded from the model; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability. (c) Actual distribution (from Hultén (1971)). Densely hatched areas - common or very common; sparsely hatched areas - quite common to less common; black dots - single occurrences.

- Typha latifolia

Typha latifolia is an emergent species. It is common in southern Sweden, but can also be found in many places further north (fig. 7c). The areas of high probability of establishment possibility coincide well with the category ”quite common to less common” by Hultén (1971) (fig. 7b-c). The Swedish and Finnish coasts of the northern Baltic, where a few occurrences are reported, are included in the model as low probability.

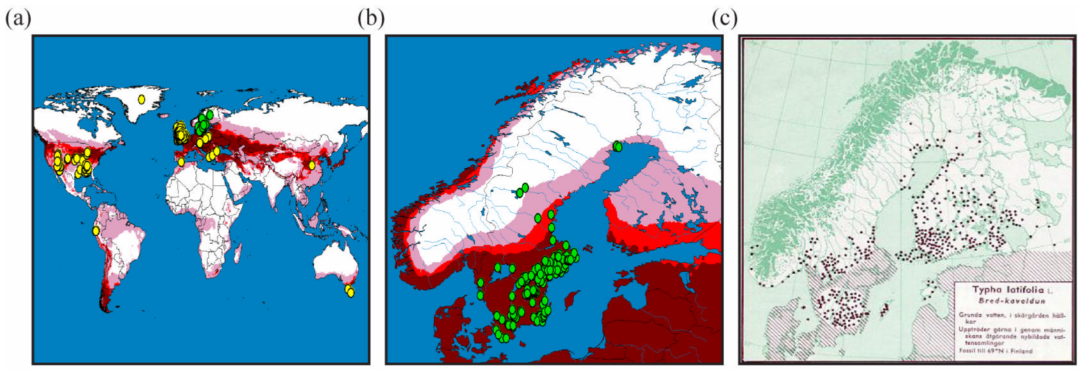

Figure 7. Predicted potential distribution of *Typha latifolia* for current climate for (a) the world and (b) Scandinavia. ○ actual occurrences included in the model; ● actual occurrences excluded from the model; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability. (c) Actual distribution (from Hultén (1971)). Densely hatched areas - common or very common; sparsely hatched areas - quite common to less common; black dots - single occurrences.

3.2 Predicted potential distribution of invasives

Simulations of the potential distribution were made for 21 species. All where described as invasive somewhere in the world by at least one source. Only *Trapa natans* is native to Sweden, but six of the species have been introduced to the country. The modelled distribution and comments of each species is presented on the following pages.

- *Alternanthera philoxeroides*

A. philoxeroides is an emergent aquatic plant, which also can grow in terrestrial habitats (CDFA 2005). The model predicts that it can establish in southern Sweden (fig. 8). The risk is, according to the simulations, higher in the future, both with A2 and B2 emission scenarios. There is some risk of an establishment in Sweden, but the probability is higher than "low" only in the southern nemoral zone with a future warmer climate. *A. philoxeroides* forms dense mats, which can become dense enough to support the weight of a human being (CDFA 2005). Even if there is some risk of an establishment in Sweden, the probability is low.

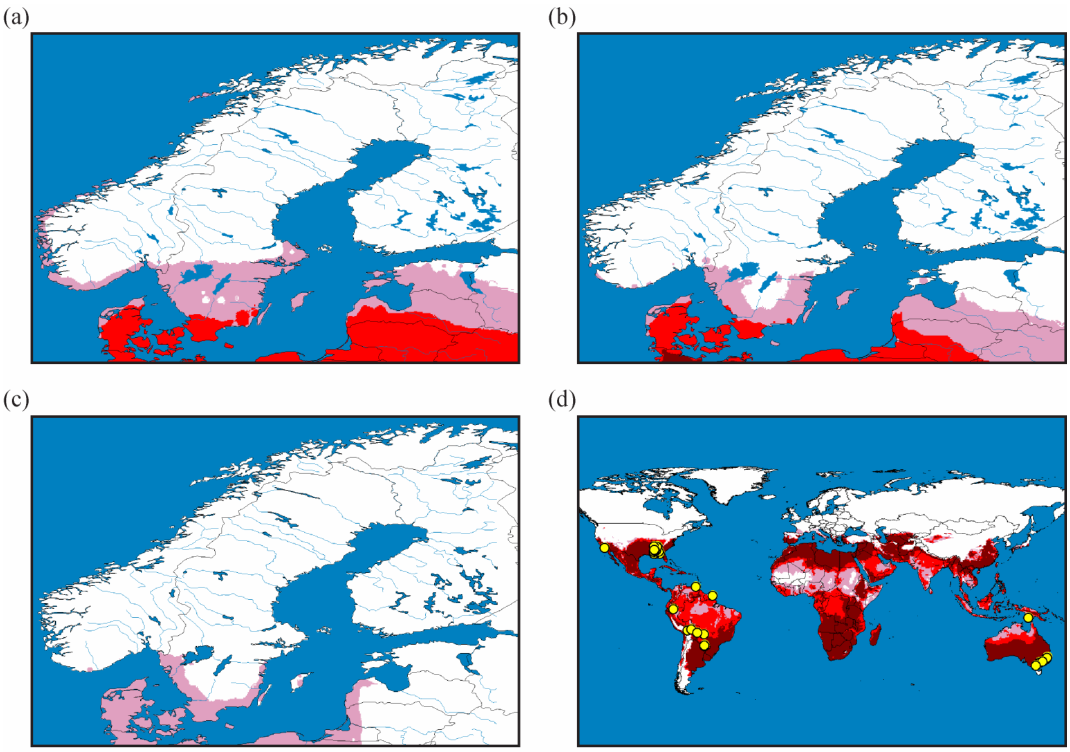

Figure 8. Modelled establishment possibility for *Alternanthera philoxeroides* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Azolla filiculoides*
A. filiculoides has been known as an alien in Europe for the last 100 years and is becoming established in increasing parts of Western Europe. It forms dense mats and the species is considered a serious weed (Janes 1998). It is reported to appear occasionally in Sweden, but seldom survives the winter season (Jonsell 2000). Milder winters might change this. One locality is known from Skåne, and according to the simulations, *A. filiculoides* can establish in southern Sweden (fig. 9). The simulations with the A2 scenario predict that the species could establish in the entire Scandinavia. With the B2 scenario, all of Sweden, except parts of the alpine zone, is predicted to be suitable for *A. filiculoides*.

A. filiculoides is the most frost tolerant of the *Azolla* species. In laboratory experiments, it has survived temperatures down to -4°C, and ice-encasement for more than one week. In Worcester (UK), where minimum air temperature reaches -10°C, *A. filiculoides* successfully overwintered (Janes 1998). Wong et al. report that *A. filiculoides* can survive temperatures down to -10 to -15°C (1987). It seems likely that *A. filiculoides* could survive in Sweden, in the whole country at a future warmer climate and in the southern part at the current climate. Since *A. filiculoides* is described as a serious weed, and is used in the aquarium trade, it is a species to be concerned of.

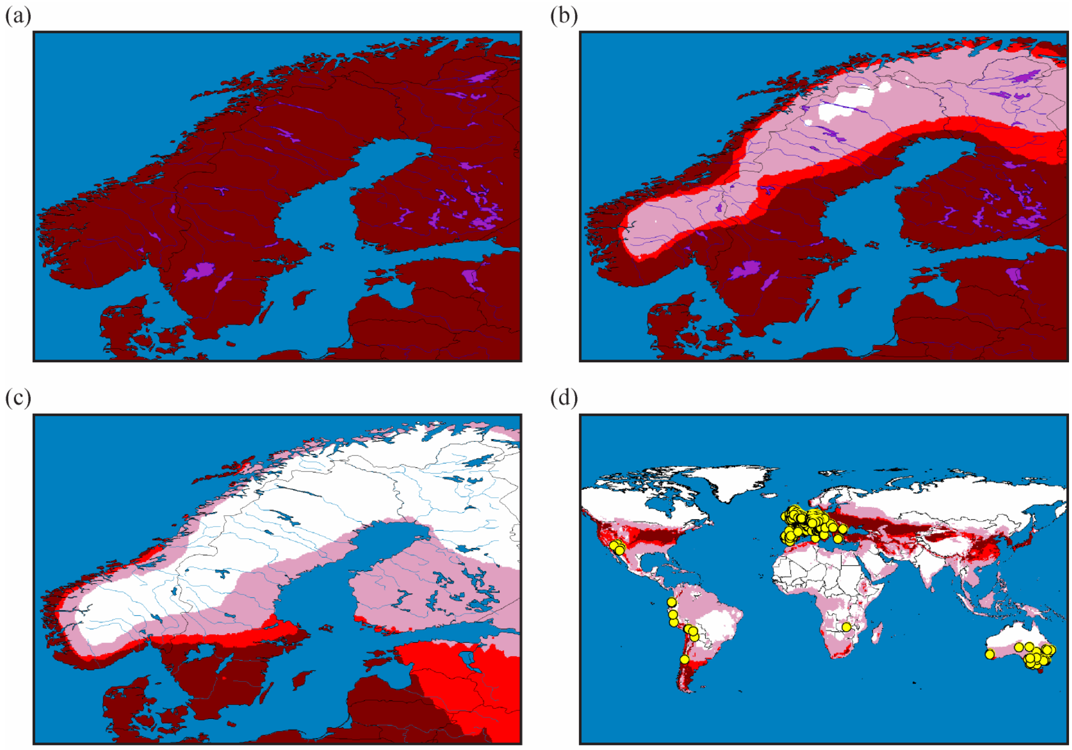

Figure 9. Modelled establishment possibility for *Azolla filiculoides* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Azolla pinnata*

A. pinnata is a free floating plant. It grows and spread quickly and can form dense mats, which limits light availability. The predicted current potential distribution is Africa, South America, except the mountains, south and Middle America, Australia and south Asia. This coincides well with native and introduced occurrences reported by ISSG (2005). The chances of *A. pinnata* establishing in southern Sweden is small. The results from the two future simulations show an establishment possibility at the coasts and about 55 km inland, up to the boreo-nemoral zone (fig. 10).

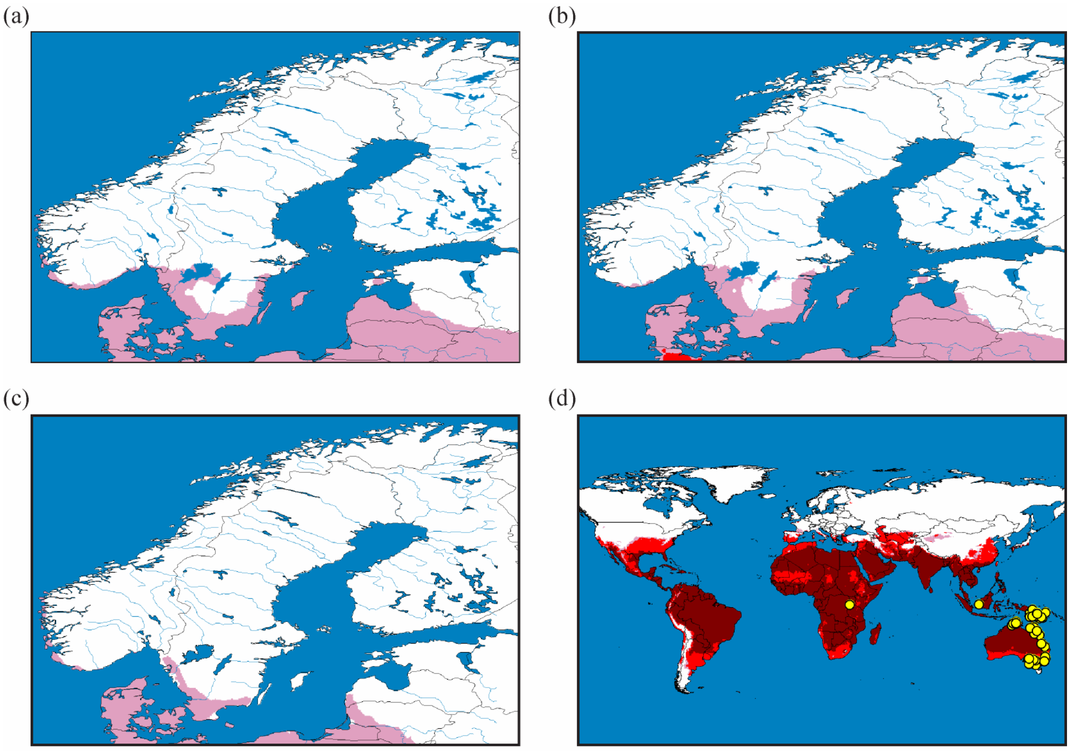

Figure 10. Modelled establishment possibility for *Azolla pinnata* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Cabomba caroliniana*

C. caroliniana is a submerged plant, except for occasional floating leaves and emergent flowers. It is native to southern Brazil, Paraguay, Uruguay, and northeast Argentina. It is used in aquariums and has been introduced to North America, Asia, Australia and Europe (ISSG 2005). *C. caroliniana* has been found in a pool in an old quarry in Skåne (Gladsax) and in a ditch in Sörmland (Huddinge) (Jonsell 2001). The simulations show a potential distribution in Sweden at the current climate. The northern limit is the same for the two future simulations (fig. 11). The West coast is predicted to have a lower probability of establishment in the warmest scenario, but it seems unlikely that it would become to warm for the plant to establish since *C. caroliniana* prefers a warm, humid climate with a temperature range of 13-27°C. However, it can survive temperatures of less than 0°C (Agriculture & Resource Management Council of Australia & New Zealand 2000). The known sites in Sweden have been known for 10 (Skåne) and 20 (Sörmland) years, but *C. caroliniana* does not seem to have spread. This could be because it has not been able to spread from the lakes where it is growing today and has not been introduced in other places. It might also be because very few other places have a suitable habitat. With a warmer climate there is a risk of more establishments and a further spread from the existing populations. *C. caroliniana* can form dense stands and outcompetes other aquatic plants (ISSG 2005).

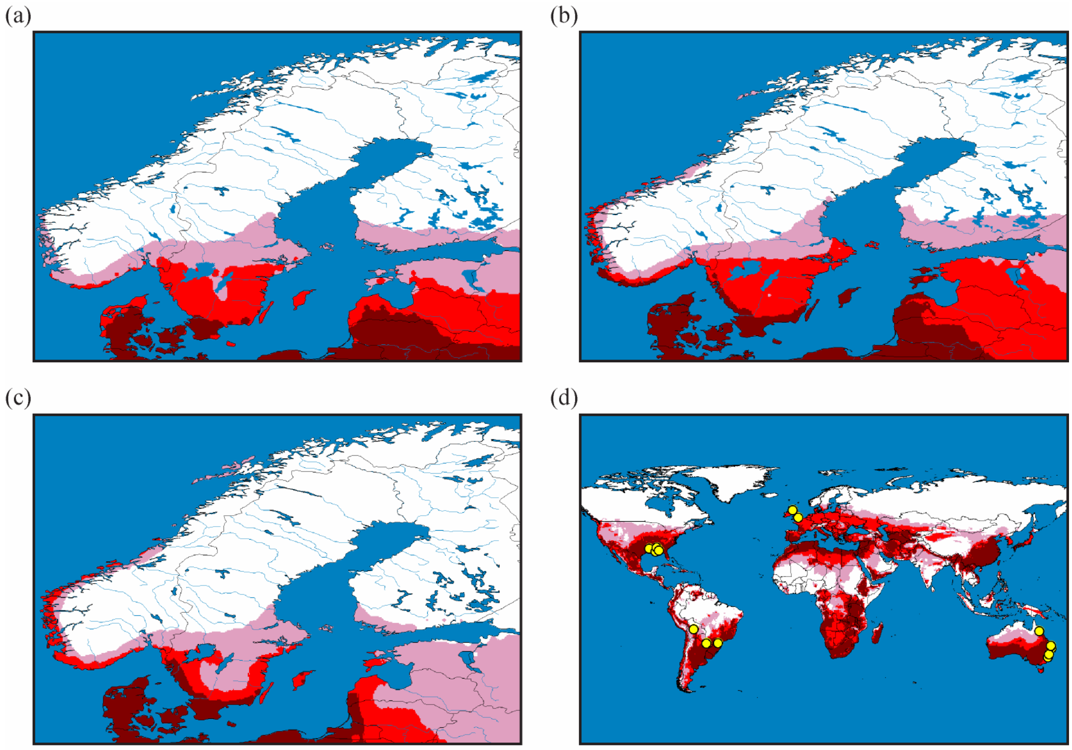

Figure 11. Modeled establishment possibility for *Cabomba caroliniana* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Crassula helmsii*

C. helmsii can grow both in a submerged and emergent form. It grows in wetlands, standing or slow-flowing water. *C. helmsii* has been introduced to the United Kingdom, probably before 1914. It has been found to be a very strong competitor, and has suppressed native plants in managed ponds within a few years. In one lake the dominant species shifted from invasive *Elodea* spp. to *C. helmssi* in two years (Dawson and Warman 1987). The model predicts that *Crassula helmsii* can establish in southern Sweden. Simulations with the A2 future climate scenario show that all Scandinavia is at risk of an invasion (fig. 12). The risk is lower with the B2 future climate scenario, but still practically the entire Scandinavia is at risk. It is reported to be able to survive mean winter temperatures of –6°C (EPPO 2005), so it seems likely that it could establish in Sweden with the current climate. It is sold as a garden pond plant (as *Crassula recurva*) and is reported to survive Swedish winters (Aqua Interiör 2005). There are three reasons for being especially concerned about this species: (1) both the prediction and other sources of information states that *C. helmsii* could survive in Sweden; (2) it has been described as an aggressive invasive species and has caused problems in e.g. the United Kingdom (Dawson and Warman 1987) and (3) it is available in nurseries and could easily be introduced.

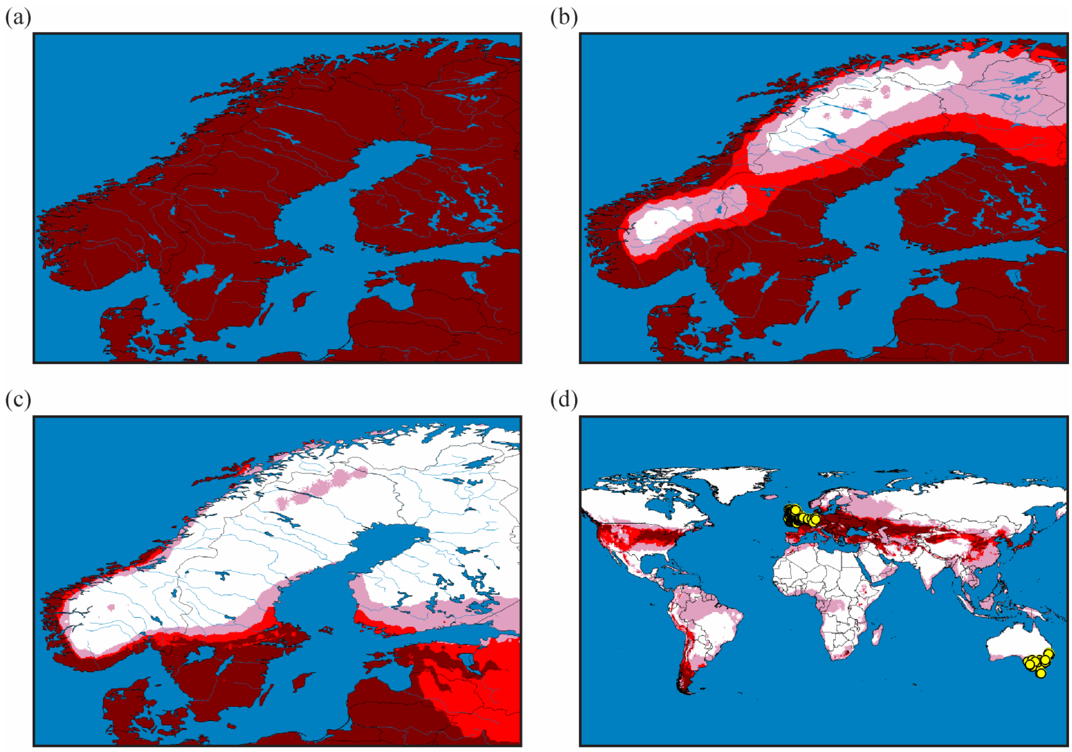

Figure 12. Modelled establishment possibility for *Crassula helmsii* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Eichhornia crassipes*

E. crassipes is considered one of the world's worst invasive species. It originates from the Amazons, but has been introduced to Asia, Africa, Australia, Europe and North America (ISSG 2005). In Europe it has been found as high north as United Kingdom (Applied Vegetation Dynamics Laboratory 2005) (EPPO 2005) and occasionally in the Netherlands (Wallentinus 2002). The possibility of an establishment seems low, both in current climate and in the future climate simulations (fig. 13). Skåne, the south coast of Blekinge, the West coast and parts of Gotland is predicted to have a low probability of establishment. *E. crassipes* is a popular ornamental plant and is often used in Swedish garden ponds. According to Kasselmann (1995), its minimum growth temperature is 12°C. Its leaves suffer permanent frost damage at air temperatures of -1 to -4°C (Sakai and Larcher 1987; Urbanc-Bercic and Gaberscik 1989). The temperatures will probably be this low at some point every winter, even with the predicted temperature increase. Still, it seems possible that *E. crassipes* could become established in the coastal areas of southern Sweden. Even if it is less likely than many other plants to become invasive in Sweden, there is still a need of concern since the consequences of an invasion in other countries are so severe.

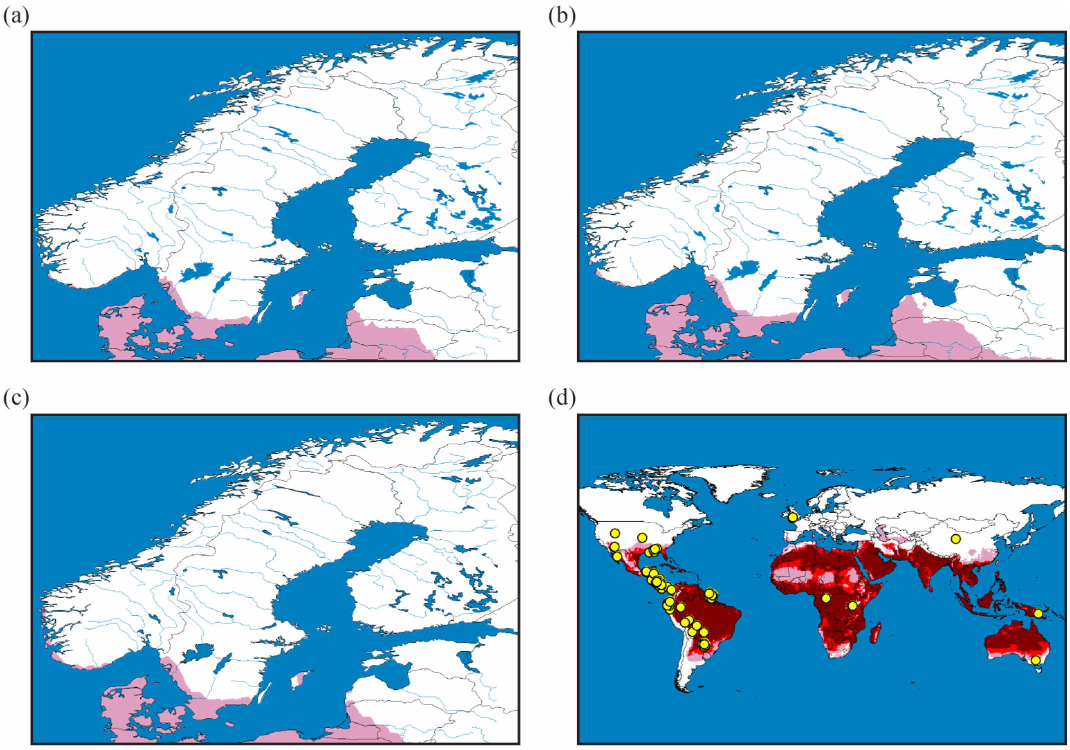

Figure 13. Modelled establishment possibility for *Eichhornia crassipes* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ● actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Elodea canadensis*

E. canadensis was introduced to Sweden over 100 years ago. It has since become invasive and is one of the few aquatic alien plant species that is a problem in Sweden today. *E. canadensis* outcompetes other aquatic species and forms large stands that interfere with fishing and boating. The simulations coincide with the reported occurrences (fig. 14). The establishment possibility is higher for the B2 scenario than the A2 scenario, according to the model. The B2 emission scenario predicts a warmer climate, and, according to the model, the warm climate will lower the probability for a further spread of *E. canadensis*. However, such an outcome seems unlikely, since *E. canadensis* is common in southern Europe, where temperatures are even higher. If the climate gets warmer, it seems likely that *E. canadensis* will be able to spread further.

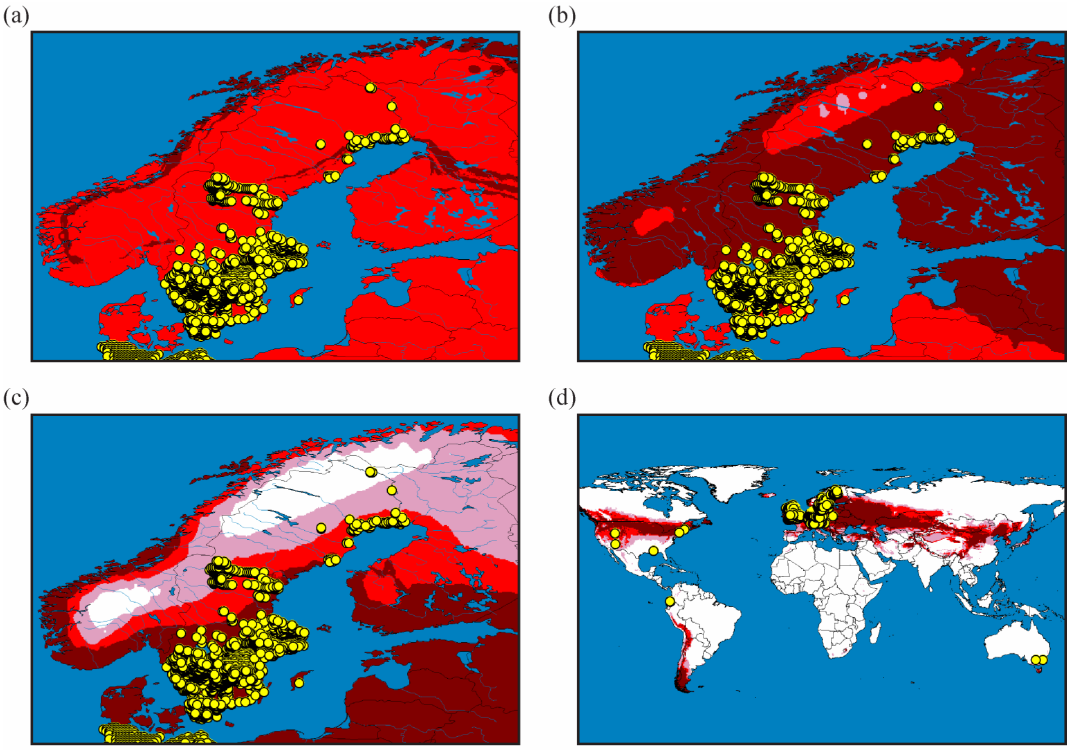

Figure 14. Modelled establishment possibility for *Elodea canadensis* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Elodea nuttallii*

E. nuttallii was introduced to Sweden over 100 years later than *E. canadensis*. It was first found in Sweden in 1991, in Lake Mälaren. Two years later it was found as far north as Norrbotten (Swedish Museum of Natural History 2005a). It is a submerged plant, and just like *E. canadensis* it forms large and dense stands that interfere with boating and fishing and affects other lake biota. *E. nuttallii* has been found to outcompete *E. canadensis* in nutrient rich environments (Barrat-Segretain and Elger 2004; Simpson 1990). The modelled establishment possibility fits well with the current one reported by Larson & Willén (2006), except for the localities in the north east middle boreal sub-zone, which is not included in the model (fig. 15). Almost all of the occurrences used in the simulations are found at the same longitude: in the United Kingdom, Germany, southern Sweden and middle United States. The occurrences in the north are too few to have an impact on the modelled niche. Since *E. nuttallii* has been introduced to Sweden recently, it is probably still expanding its distribution. According to the simulations it will be able to establish in almost all Scandinavia in the future, and since it is invasive and already present it is a species that is a conspicuous threat.

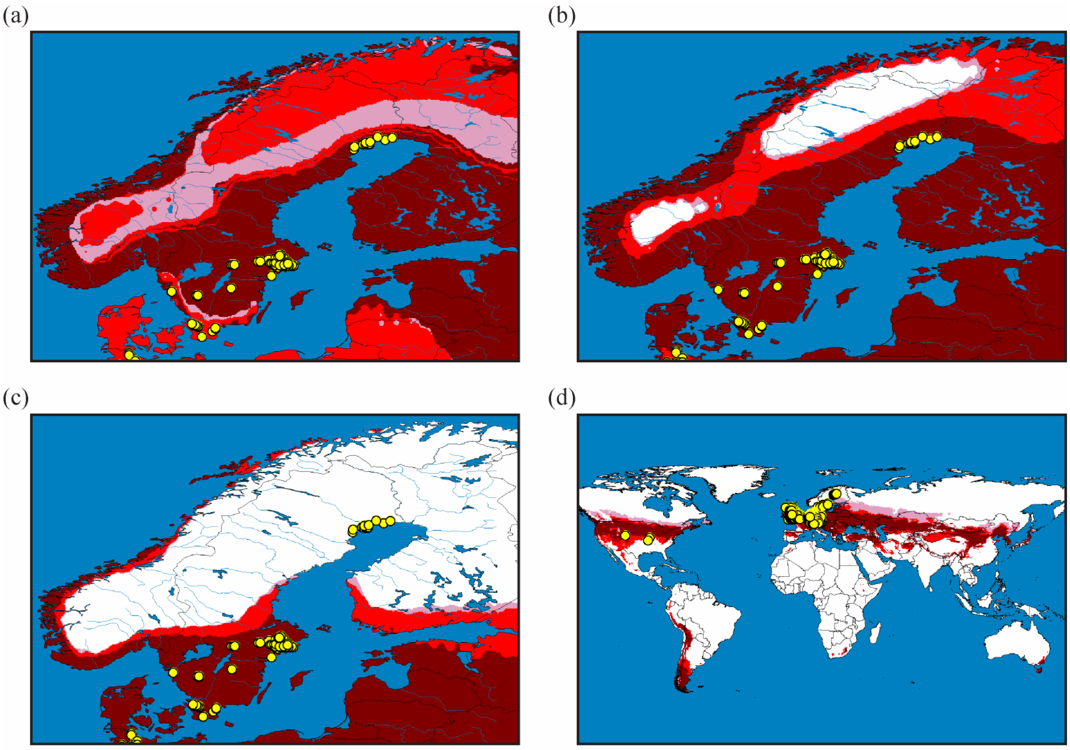

Figure 15. Modelled establishment possibility for *Elodea nuttallii* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Hydrilla verticillata*

H. verticillata is a submerged plant species, but can also grow as free floating, and form dense mats. As submerged, it can form dense stands that decrease light availability for other organisms and obstruct recreational activities like fishing and boating (ISSG 2005). The model predicts that *H. verticillata* could establish in Sweden at the current climate (fig. 16). There are similar possibilities for establishment in the two future simulations, although the probability is a little bit higher in the B2 model. *H. verticillata* prefers temperatures between 20 and 27° (ISSG 2005) so it seems unlikely that it would be too warm in A2 scenario. There is a risk that *H. verticillata* can be able to establish in Sweden at both current and future climate.

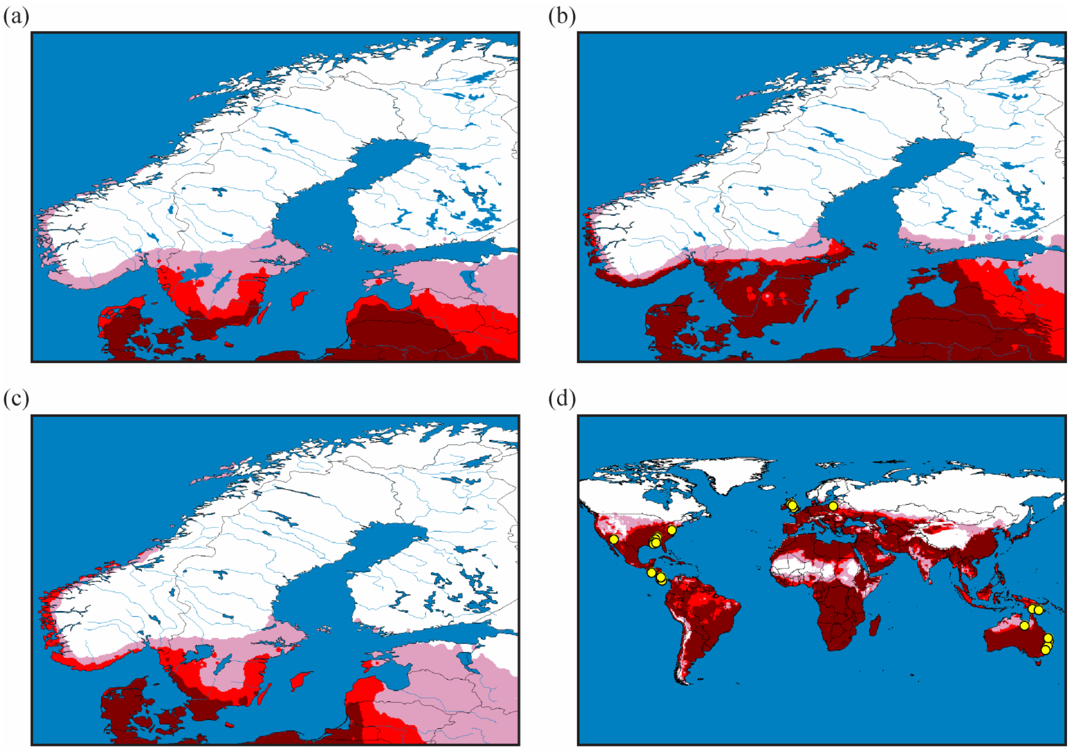

Figure 16. Modelled establishment possibility for *Hydrilla verticillata* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Hydrocotyle ranunculoides*

H. ranunculoides is native to North America and has been introduced to e.g. South America, Great Britain and the Netherlands. It is a floating-leaved plant that grows very quickly (Invasive Non-Native Species in the UK, 2005). According to the simulations it could establish in southern Sweden at the current climate (fig. 17). With a warmer climate, the risk would be higher. It is hard to explain why the model's predictive power is higher for the Boreo-nemoral zone in the B2 model than in the A2 model, when it at the same time is lower in northern Sweden. Relatively few (109) occurrences were used for the model, which might have caused the unexpected result.

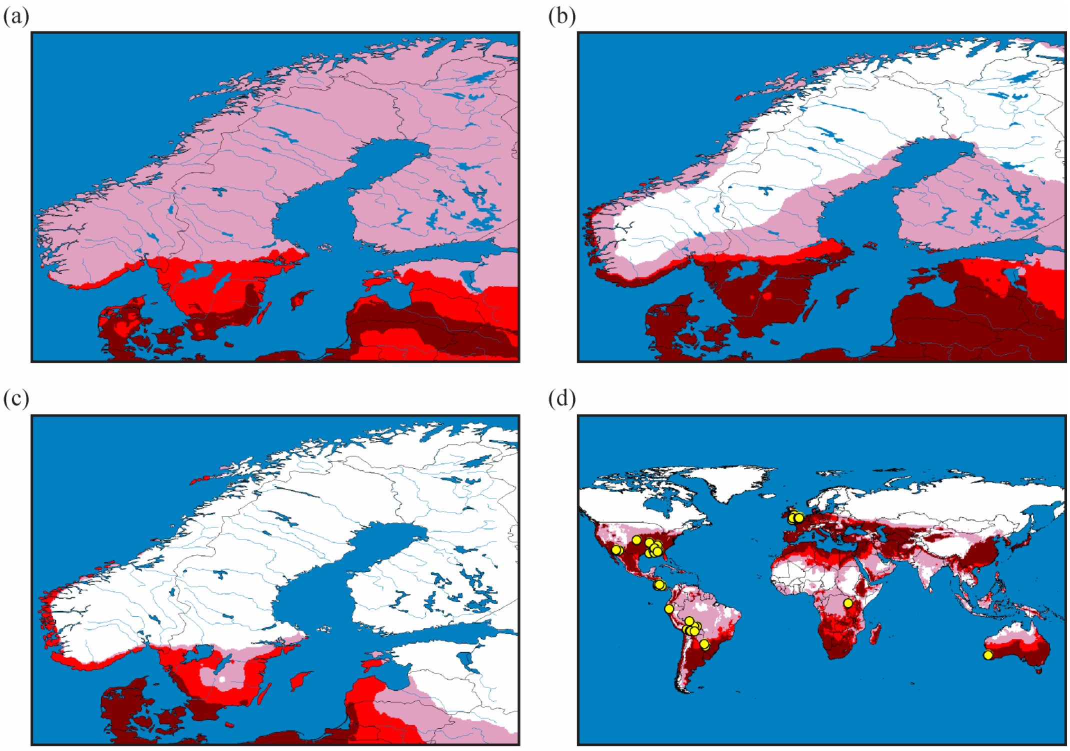

Figure 17. Modelled establishment possibility for *Hydrocotyle ranunculoides* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; □ low probability; □ intermediate probability; □ high probability.

- Lagarosiphon major

L. major is a member of the same family (*Hydrocharitaceae*) as *Elodea spp*. It is a submersed water plant that dominates in standing or slow-flowing water. It has been introduced to the UK and has often replaced *E. canadensis* and *E. nuttallii*, particularly in alkaline waters where *L. major* has a greater ability to photosynthesize (Invasive Non-Native Species in the UK, 2005). The model predicts that *L. major* can establish in southern Sweden at the current climate (fig. 18). If the A2 scenario climate simulation comes true, *L. major* could establish in entire Scandinavia.

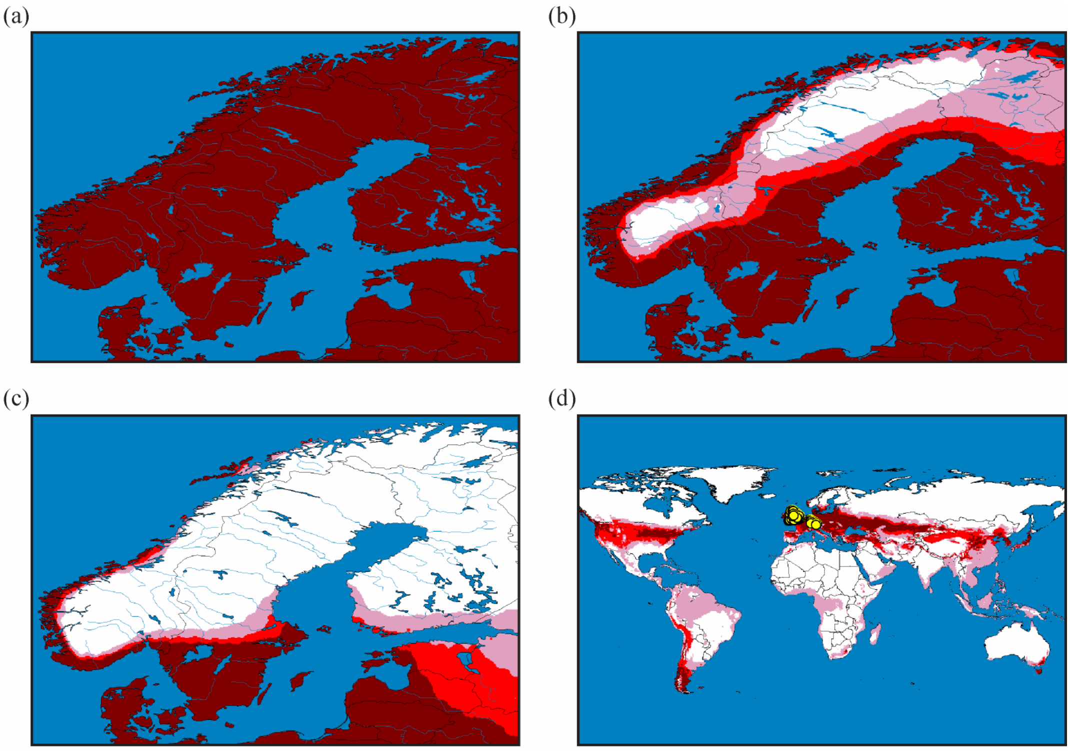

Figure 18. Modelled establishment possibility for *Lagarosiphon major* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- Lemna minuta

L. minuta is a free-floating plant. There are three other *Lemna* species native to Sweden. According to the simulations, *L. minuta* could establish at the current climate (fig. 19). In the A2 scenario, the entire Scandinavia is at risk for an establishment.

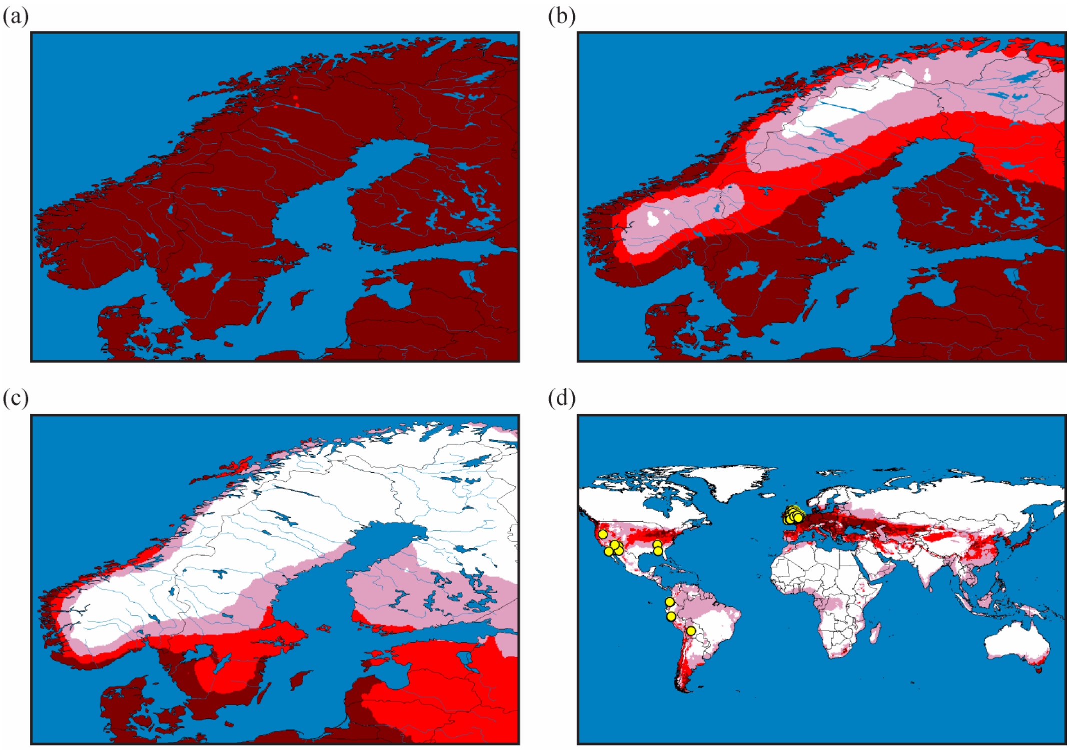

Figure 19. Modelled establishment possibility for *Lemna minuta* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Ludwigia grandiflora*
L. grandiflora is emergent plant native to South America. Sometimes *L. grandiflora* and *L. uruguayensis* are considered synonyms, and sometimes they are considered to be different species (see ITIS 2005; Zardini et al. 1991). Only a small part of south Sweden is predicted to be warm enough (in the B2 scenario) for an establishment of the species (fig. 20). The risk of an invasion is low.

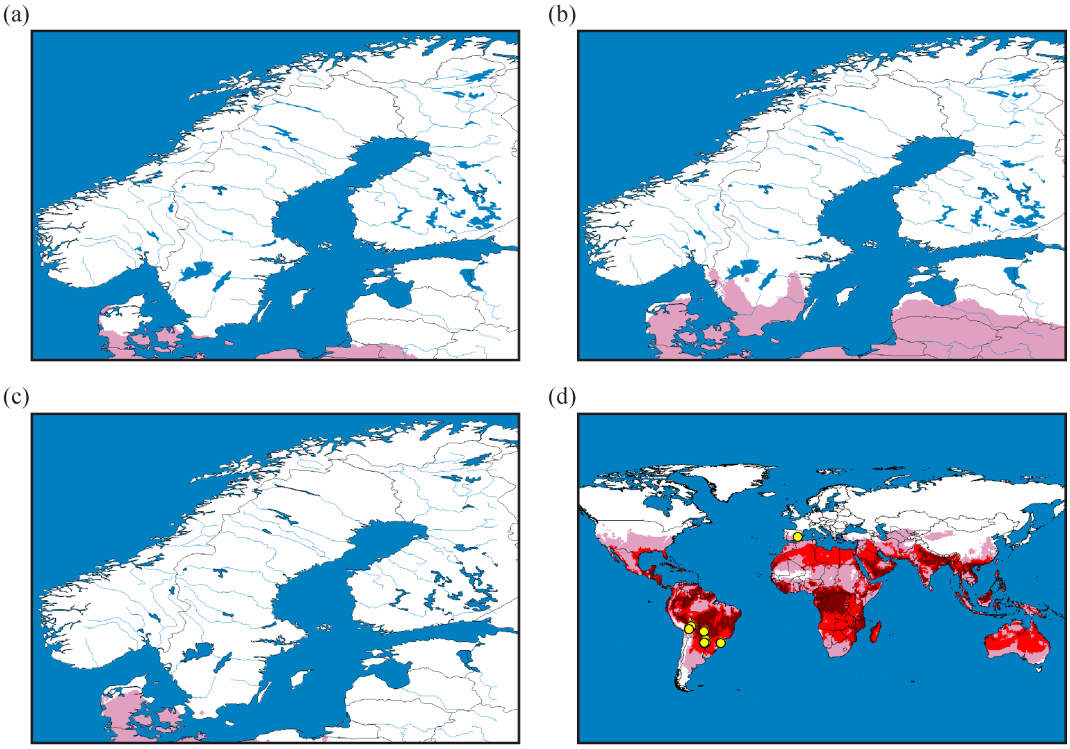

Figure 20. Modelled establishment possibility for *Ludwigia grandiflora* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Lysichiton americanus*

L. americanus is an emergent plant that has been introduced to Sweden from North America. It is used as a garden plant. It grows in marches, along ditches and in wet woods and similar habitats (Swedish Museum of Natural History 2005b). The northern limit of the high establishment possibility coincides with the most northern confirmed occurrence places (fig. 21). The future simulations show a higher probability in the north, but a lower in the south. Still, entire Scandinavia is covered in all three models. There is a risk that *L. americanus* will spread further.

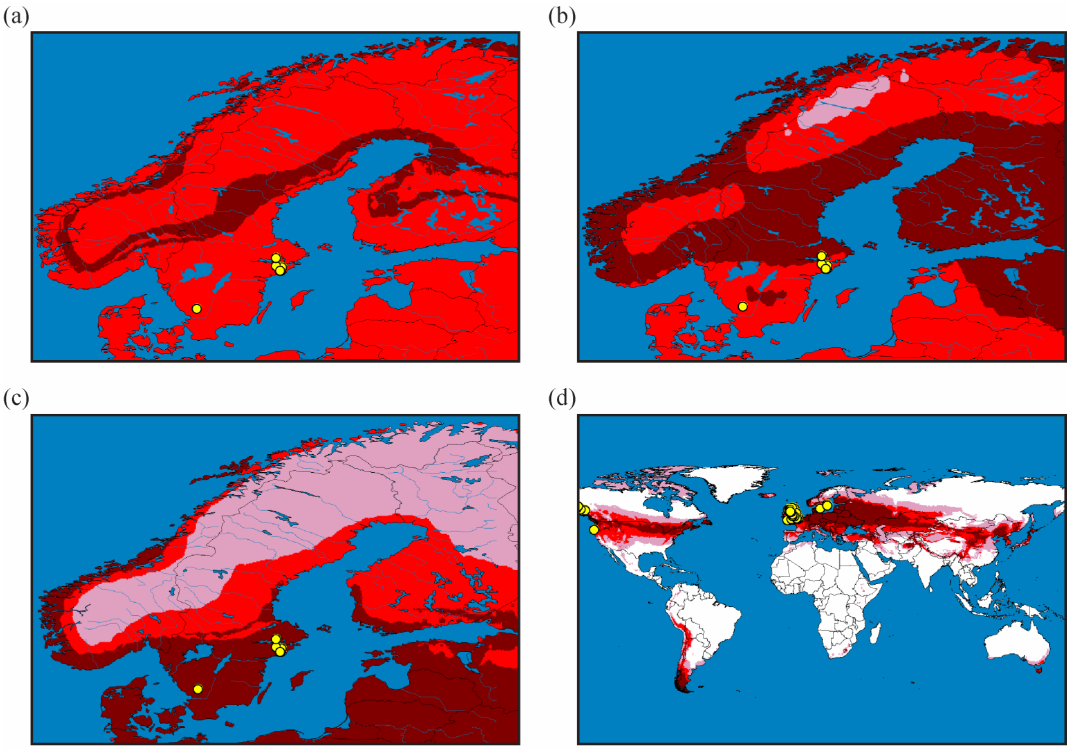

Figure 21. Modelled establishment possibility for *Lysichiton americanus* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- Myriophyllum aquaticum

M. aquaticum is native to South America and has been introduced to North America, Australia, New Zealand, Java, United Kingdom and Ireland. It is used as an ornamental plant and has caused big problems where introduced. It can grow both in submerged and emergent forms. *M. aquaticum* can form dense mats and stands. The Longview Diking District in Washington estimates that it spends $50,000 a year on control of *M. aquaticum* in drainage ditches (Washington State's Department of Washington State's Department of Ecology 2003). Commercial traders state that it can tolerate (aquarium) temperatures between 10-29 ° (Tropica 2005). This means that it probably could grow during a large part of the year in Sweden. However, this data is not scientifically acquired, and it does not say anything about survival at low (freezing) temperatures. The results from the simulations show a possible establishment potential in southern and middle Sweden at the current climate (fig. 22). The model predicts a high chance of a future establishment possibility in all Sweden (A2) and a high probability up to *Limes Norrlandicus*, and then low further north (B2). *M. aquaticum* is predicted to be able to establish in Sweden if introduced. It is also known to be a costly problem elsewhere, so it is important to prevent introductions.

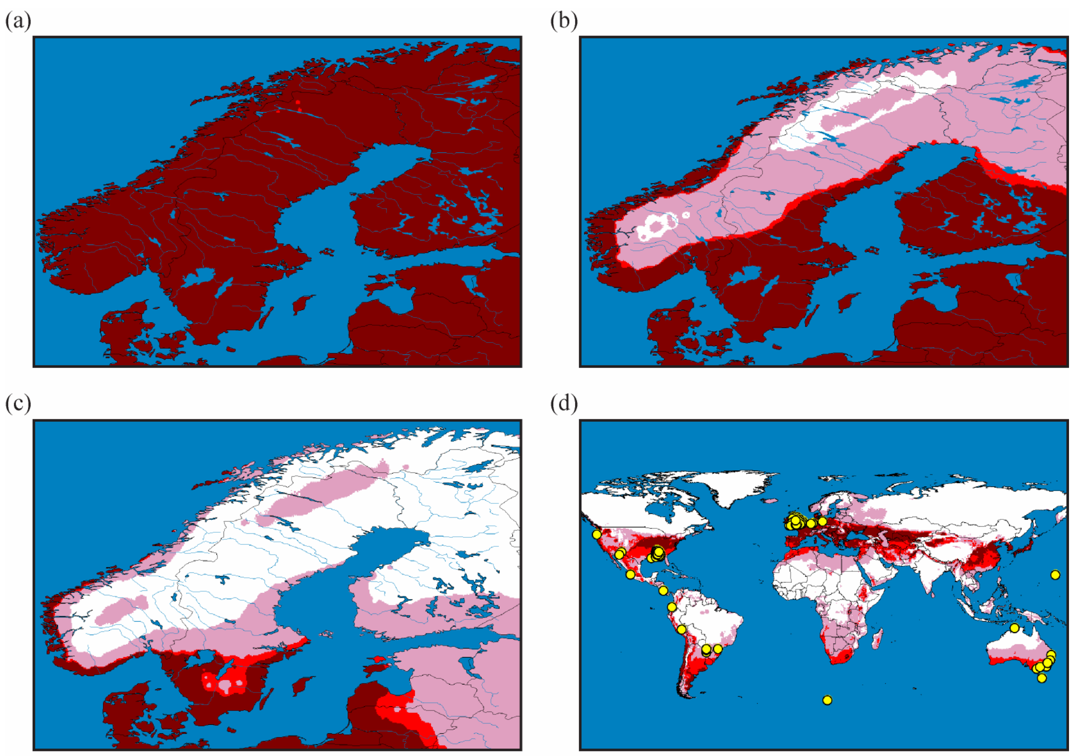

Figure 22. Modelled establishment possibility for *Myriophyllum aquaticum* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Nymphoides peltata*

N. peltata was first introduced to Sweden in 1892. It has been introduced several times and spread further, and is now known in several places in southern and middle Sweden. *N. peltata* is a big problem locally. It forms dense mats and is an obstacle for recreational activities like boating and fishing (Larson and Willén 2006). *N. peltata* is used as an ornamental pond plant and is available at plant nurseries. The simulation for the current climate coincides well with the present northern distribution (fig. 23). With a warmer climate, all but the mountain regions can be invaded, according to the simulations. *N. peltata* is already spreading in the lake systems where it has been introduced and a warmer climate could facilitate a northern spread. Since it is available at plant nurseries there is a risk of further introductions, and *N. peltata* could become a problem in more lakes and streams.

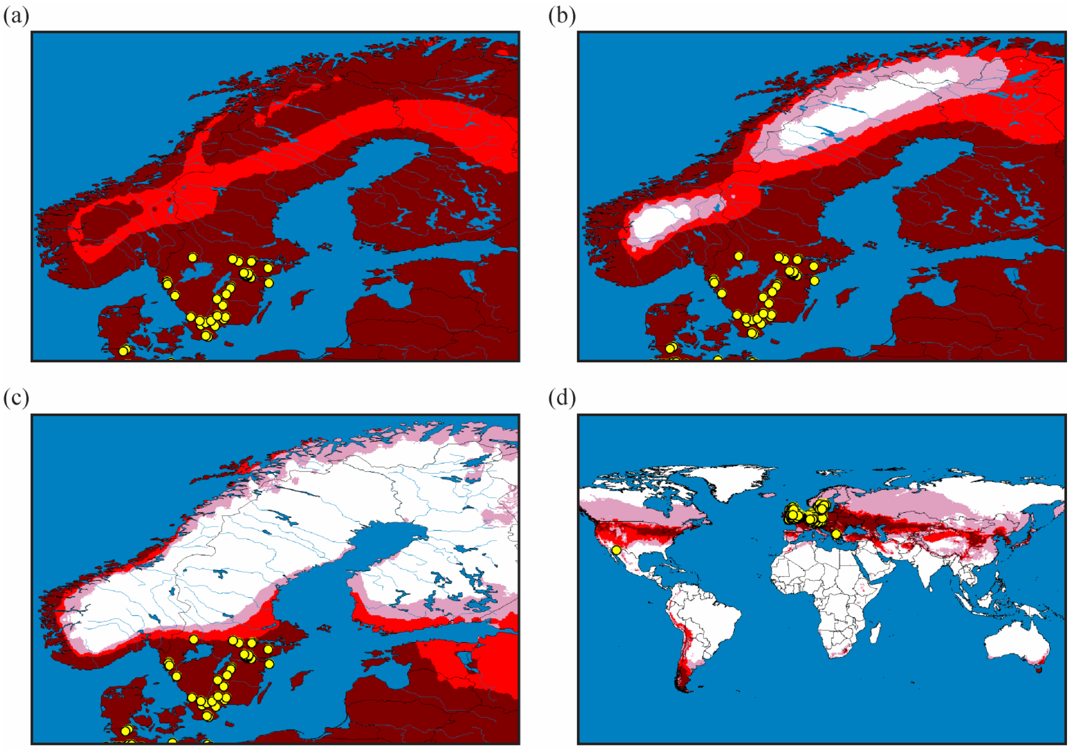

Figure 23. Modelled establishment possibility for *Nymphoides peltata* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; ☐ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Pistia stratiotes*

P. stratiotes is a free floating plant used as an ornament in aquariums and ponds. It is available at Swedish nurseries (Aqua Aqua Interiör 2005). *P. stratiotes* is native to South America, and has been introduced to e.g. the United States and New Zealand. According to Rivers (2002) it can not survive temperatures below 15°C. The results of the simulations show that it cannot establish in Sweden, neither at current or a warmer future climate (fig. 24).

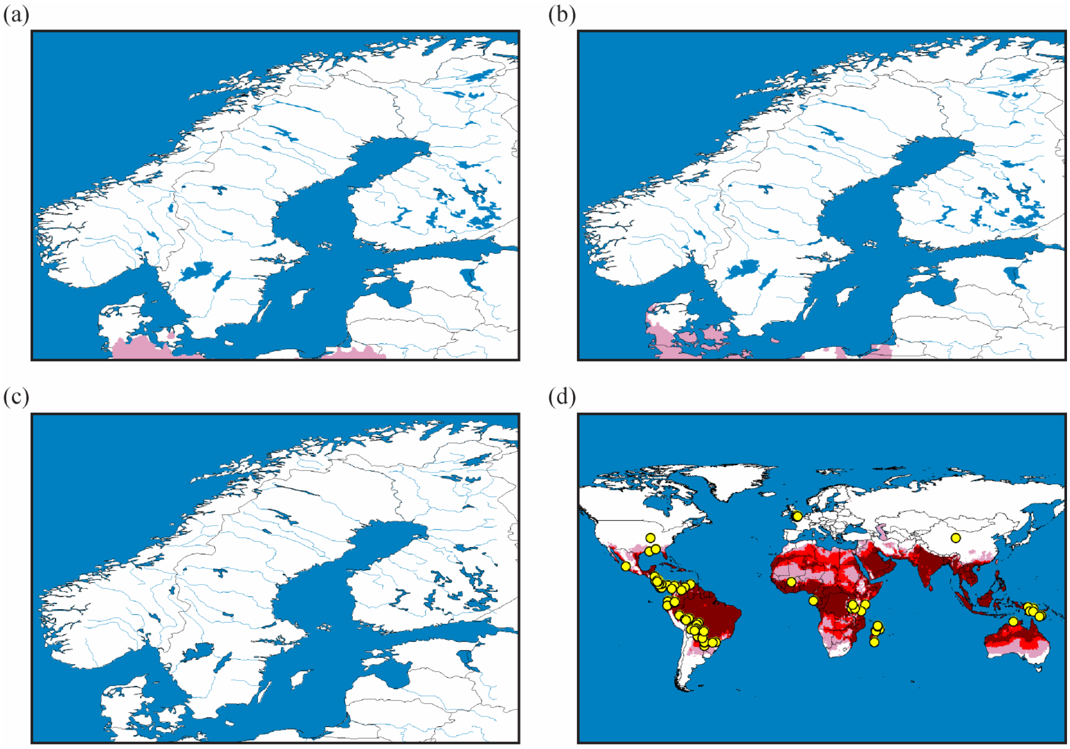

Figure 24. Modelled establishment possibility for *Pistia stratiotes* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ● actual occurrences; ☐ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Salvinia molesta*

S. molesta is a free floating plant. It is native to South America, and has been introduced to Australia-Pacific region, North America, Asia, Africa and the United Kingdom. *S. molesta* is one of the world's worst invasive species (NAS 2005). It forms dense mats that can be up to 60 cm deep. The mats decrease light availability, and decomposition of the mats can cause oxygen depletion (ISSG 2005). According to the simulation, there is a low probability of *S. molesta* establishing in the nemoral zone at a current climate (fig. 25). With a warmer climate the risk is intermediate in the nemoral zone and low in the boreal-nemoral zone. *S. molesta* has no perennating organs or dormant spores, so its persistence depends on survival of the meristematic tissues in buds on the rhizome (Whiteman and Room 1991). Therefore, *S. molesta* is sensitive to low winter temperatures. Whiteman and Room (1991) found that *S. molesta* is killed when exposed to temperatures below -3°C for more than a few hours. The risk of an establishment and invasion of *S. molesta* in Sweden is low.

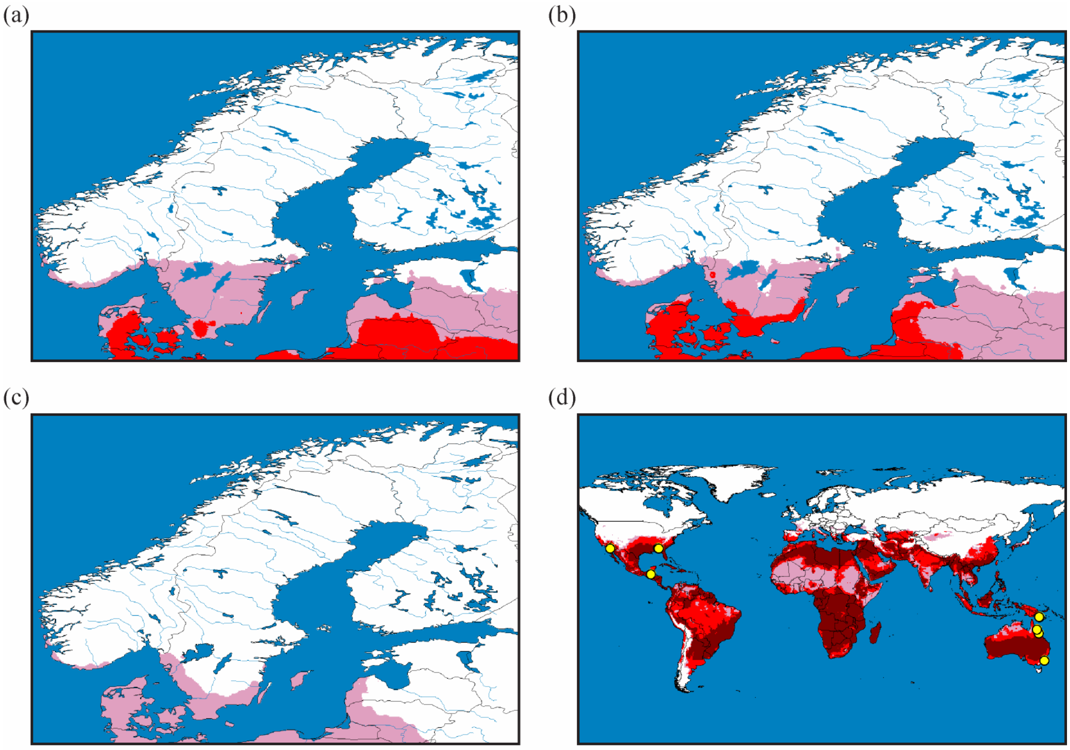

Figure 25. Modelled establishment possibility for *Salvinia molesta* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; ☐ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Spartina anglica*

S. anglica is a salt marsh grass species. It has been used to stabilize tidal mud flats and has been introduced to many places. It has been classified as one of the 100 worst invasive species in the world by ISSG (ISSG 2005). According to the results from the simulations it could establish in southern Sweden today and entire Sweden with a warmer climate (fig. 26). The most northern findings today are in Denmark (Jylland). However, since *S. anglica* grows on salt marches, a habitat very rare in Sweden, the risk of an establishment is low.

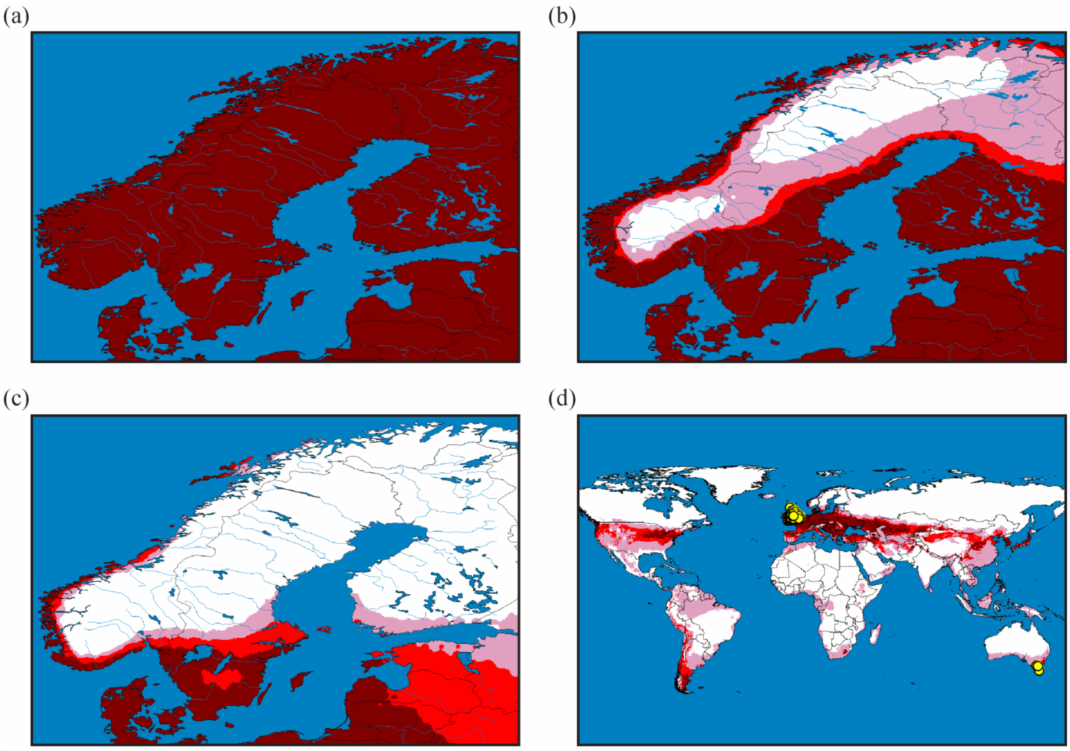

Figure 26. Modelled establishment possibility for *Spartina anglica* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Trapa natans*

Trapa natans was last found in Sweden in Skåne in 1916. The species had its widest distribution a couple of thousands years ago. It became extinct because of a climate change and due to collecting and harvesting of the plant (Swedish Museum of Natural History 2005b).In the United Kingdom it is considered invasive (Applied Vegetation Dynamics Laboratory 2005). According to the results of the simulations it could become established in southern and middle Sweden (fig. 27). In the future, it could establish in entire Sweden, if climate warming proceeds as in the A2 scenario. Since *T. natans* is a native species, an establishment might be considered positive. *T. natans* is included in the red-list of threatened species in Sweden (Gärdenfors 2005). It is categorized as “regional extinct”. However, since it is a problem in other places, it might become invasive and problematic also in Sweden in the future, even though it is native.

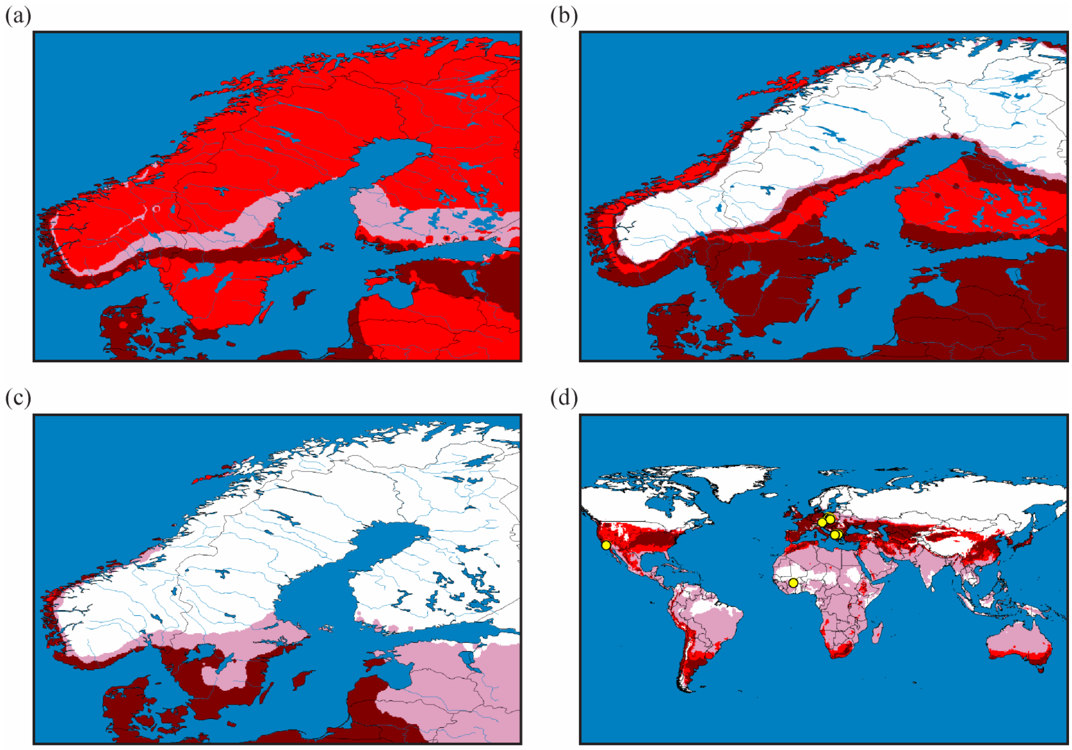

Figure 27. Modelled establishment possibility for *Trapa natans* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

- *Zizania aquatica*

Z. aquatica is a grass in the family of *Poaceae*. It is native to North America, but is considered an invasive species in the state of Washington. It has also been introduced to Latvia (Latvian Alien Species Database 2005; NAS 2005). The results from the simulations show that it could establish in Scandinavia (fig. 28). In the future, the entire Scandinavia is at risk.

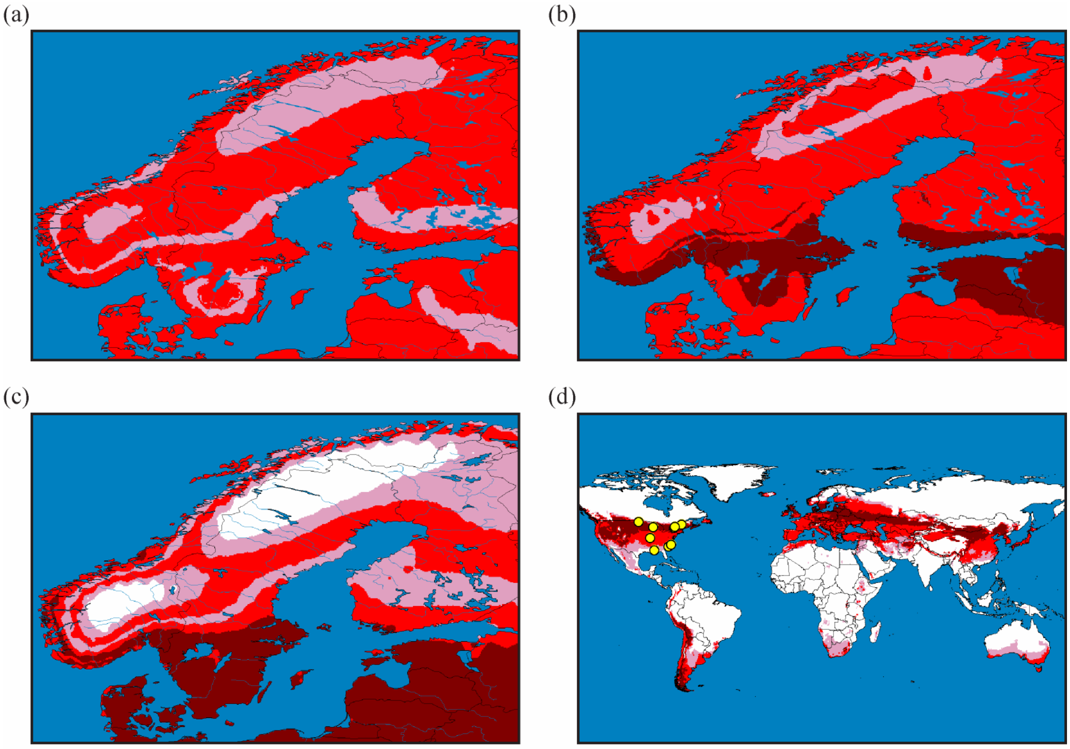

Figure 28. Modelled establishment possibility for *Zizania aquatica* for (a) 2071-2100 climate, A2 emission scenario; (b) 2071-2100 climate, B2 emission scenario; (c) 1961-1990 climate (SweClim) and (d) 1961-1990 climate (IPPC). ○ actual occurrences; □ no probability; ■ low probability; ■ intermediate probability; ■ high probability.

3.3 Invasibility of Swedish freshwater habitats

The simulations show an increased possibility for many invasive species to establish in Sweden if the climate gets warmer (table 3). The increase in temperature will allow many species to extend their northern distribution. This was also found in a study by Beerling (1993), who examined the effect of a temperature increase on the northern distribution of terrestrial plants *Fallopia japonica* and *Impatiens glandulifera*. The results are also confirmed by laboratory experiment acquired minimum survival temperatures, where such are available.

According to the results of this study, the nemoral zone is the area most sensitive to invasions. As expected, the further north, the less risk of an establishment. The sub-alpine and the alpine zones are the least sensitive. Even if the temperatures would be sufficient in these zones for a particular species, the risk of its establishment is still low for four reasons not reflected in the model: (1) these zones have harsh environment, with poor conditions for macrophytes; (2) they often have very few contributories, from where seeds or propagules could come; (3) these areas are sparsely populated, which lower the risk of human induced introductions; (4) they are protected from air born seeds, even though that is the most likely vector of introduction.

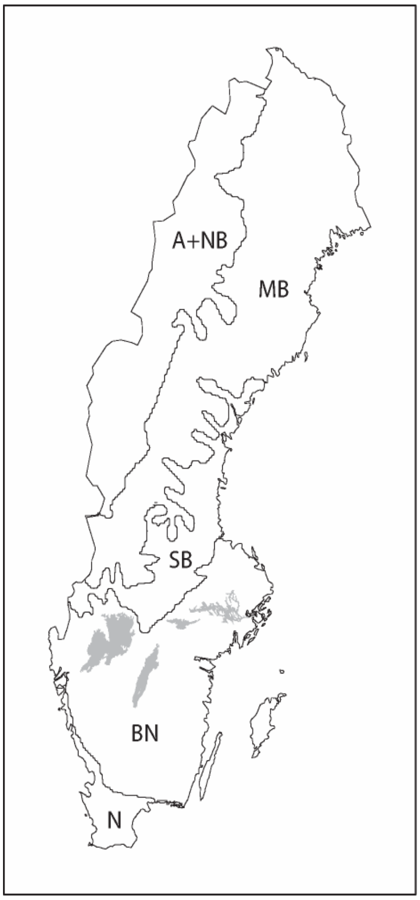

Figure 29. Vegetational zonation. N - Nemoral zone; BN - Boreo-nemoral zone; SB - Southern boreal sub-zone; MB - Middle boreal sub-zone; A+NB Alpine, sub alpine and northern boreal sub-zone.

Table 3. Establishment possibility for invasive species in different Swedish vegetation zones. - no predicted possibility; 1. low predicted possibility; 2. intermediate predicted possibility; 3. high predicted possibility. If coastal zones are different from the inland, probability for coast zones are given in brackets. N – Nemoral zone; BN - Boreo-nemoral zone; SB - southern boreal sub-zone; MB - middle boreal sub-zone; A+NB - Alpine, sub alpine and northern boreal sub-zone.

Species	Current Climate					A2					B2				
Area	N	BN	SB	MB	A+ NB	N	BN	SB	MB	A+ NB	N	BN	SB	MB	A+ NB
Alternanthera philoxeroides	1	- (1)	-	-	-	2	- (1)	-	-	-	2	- (1)	-	-	-
Azolla filiculoides	3	3	1	-	-	3	3	3	3	3	3	3	3	1	1
Azolla pinnata	1	- (1)	-	-	-	1	- (1)	-	-	-	1	- (1)	-	-	-
Cabomba caroliniana	3	1 (2)	-	-	-	2	2	-	-	-	3	2	-	-	-
Crassula helmsii	3	3	2	-	-	3	3	3	3	3	2	2	2	2	-
Eichhornia crassipes	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-
Elodea canadensis	3	3	2	1	-	2	2	2	2	2	3	3	3	3	2
Elodea nuttallii	3	3	-	-	-	2	3	3	1	2	3	3	3	3	-
Hydrilla verticillata	3	1 (2)	-	-	-	3	1 (2)	-	-	-	3	3	-	-	-
Hydrocotyle ranunculoides	1	1 (2)	-	-	-	3	2	1	1	1	3	3	1	-	-
Lagarosiphon major	3	3	-	-	-	3	3	3	3	3	3	3	3	- (2)	-
Lemna minuta	3	2 (3)	1	-	-	3	3	3	3	3	3	3	3	1 (2)	-
Ludwigia uruguayensis	-	-	-	-	-	-	-	-	-	-	1	- (1)	-	-	-
Lysichiton americanus	3	3	2	1	1	2	2	2	2	2	2	2	3	2 (3)	1
Myriophyllum aquaticum	3	2 (3)	1	-	-	3	3	3	3	3	3	3	3	1	-
Nymphoides peltata	3	3	-	-	-	3	3	3	3	3	3	3	3	2 (3)	-
Pistia stratiotes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salvinia molesta	1	- (1)	-	-	-	2 (1)	1	-	-	-	2	2	-	-	-
Spartina anglica	3	3	-	-	-	3	3	3	3	3	3	3	3	1	-
Trapa natans	3	1 (3)	-	-	-	3	2	1	2	2	3	3	2	-	-
Zizania aquatica	3	3	2	2	-	2	2	2	2	1	2	3 (2)	2	2	2

3.4 Advantages and disadvantages of the approach used in this study

Many methods exist for predictions of potential invasions. Here, a list of species introduced somewhere in the world was created, and niche based simulations for the species described as invasive was made. Using a list of species already invasive somewhere is an effective way to analyse the risks of invasions to Swedish freshwater habitat. However, it leaves out some possible invasive species for three reasons: (1) species that are not already invasive could become invasive if introduced to Sweden; (2) species native in Sweden could become invasive if the climate changes; (3) species natives in parts of Sweden could also become invasive if introduced to other parts of the country. There is also a risk that Swedish species could expand their current distribution through natural pathways, and become problematic in new places, if the climate gets warmer.

Using niche based modelling to predict invasive range of non-indigenous species is a good tool in invasive species management (Peterson and Vieglais 2001). With relatively small effort it is possible to judge the threat of individual species. However, there are some limitations. There can be two forms of errors in the results from the simulations: false positive and false negative predications. A false positive prediction means that the model predicts that a species could establish even though it cannot. A false negative prediction on the other hand means that a species could establish, but the results from the simulations suggest that it cannot.

A species' niche consists of more than temperature variables. Other abiotic variables, e.g. pH, light condition and nutrients conditions are essential. Also biotic factors, e.g. competitors, herbivores and pathogens are important for a plant species' distribution. The areas predicted suitable for a species will most likely decrease when more environmental parameters are added. Since only temperature parameters are used in this study, there is a risk of false positive results. Temperatures are the variable available on a global scale that is most important for aquatic macrophytes. By using temperatures it is also easy to study the effect of global warming.

The minimum temperature might be very important factor limiting a species distribution. The data used in this study is mean minimum temperatures, not the extreme minimum. For some species, especially floating and emergent species that is in contact with the air, the extreme temperature might be more important. It might be enough with a shorter time of temperatures below 0°C to cause freezing injuries that kill the leaves and the plant.

If the available reports of presence for a species do not represent the species' actual distribution, a false negative result could be expected. For many species, the majority of the presence reports come from Germany and the United Kingdom. Hence, the climates in those countries will have a strong impact on the modelled niche. The species might also be common in e.g. northern Russia, where climate is more like the Swedish, but distribution data are scarce. The results from the simulations will show that Sweden is too cold, even though it is not. The same situation will occur if the species has not yet reached its full potential distribution, e.g. because it has been introduced and has not had time to spread.

The predicted global climate change is more than just increasing temperatures. Wind conditions, precipitation, runoff, UV-irradiation are factors that will be affected, and in turn will influence e.g. water chemistry and ecosystem structure in a complex series of reactions. There are examples from the literature that show some of the possible effects of climate change on community structure and support the presumption that temperature is an important factor for aquatic plant species. Such a work was done by Hussner and Lösch (2005) who examined the alien flora of River Erft. River Erft receives thermal waste water from mining areas and has a temperature of at most 5°C higher than average waters. Hussner and Lösch found that 5 alien species had established between 1973 and 2003. They also noticed that *Egeria densa* repressed the native species *Potagometons natans* and *P. pectinatus*. Another work, using microcosms, was made by McKee et al. (2002). They found that the proportion of *Lagarosiphon major* in a macrophyte community consisting of *L. major*, *Elodea nuttallii* and *Potamogeton natans* increased when temperature was increased to simulate climate warming.

4. Conclusions

Introduction of alien species is a problem that is becoming more apparent in Sweden. In this study it has been found that several species could establish already at the current climate. With a warmer climate the introductions of alien species are more likely to lead to establishment and problems. Especially alerting are *Crassula helmsii*, *Lagarosiphon major*, *Myriophyllum aquaticum* and *Zizania aquatica*, which according to the simulations can establish at the current climate in large areas of Sweden, and in the entire Scandinavia in the future. These species cause severe problems in other countries. The further spread of already introduced and established species, in particular *Azolla filiculoides, Elodea nuttallii*, *Lysichiton americanus* and *Nymphoides peltata*, is also a risk to be concerned of. Since all species listed above are sold commercially as aquarium or garden plants there is a noticeable risk for introductions.

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Appendix 1: Introduced vascular plants in freshwater habitats world wide.

Area abbreviation follows ISO 3166-1. c=central; e=east; n=north; s=south; w=west; A-P= Australia-Pacific; Afr=Africa; Am=America, Eur=Europe. References are explained at the end.

Species	Author	Swedish common name	English common name	Class	Introduced in	Native distribution	References
Acorus calamus	L.	Kalmus	Calamus, Sweetflag	invasive	LT, LV, naturalized in SE	swAsia (P), Asien (N)	1, 9, 21
Alternanthera philoxeroides	(Mart.) Griseb.		Alligator weed	invasive	AU, CN, US, NZ, swFR	sAm	8, 10, 12, 25
Angelica sylvestris	L.	Strätta	Angelica	minor-invasive	CA	SE	19
Apium nodiflorum	(L.) Lag.		Water celery	non-indigenous	NZ		10
Aponogeton distachyus	L. f.		Cape pondweed	non-indigenous	NZ		10
Azolla caroliniana	Willd.		Carolina mosquitofern	non-indigenous	US		25
Azolla filiculoides	Lam.	Mossbräken	Water Fern	invasive	IE, LT, UK, US, SE	sAm	2, 18, 20, 25, 27
Azolla pinnata	R. Br.		Ferny azolla, Mosquito fern, Water velvet	invasive	PA, AU, CN, JP, VN, US, NZ	Afr, seAsia, MG, IN, CN, JP, MY, PH, PG, AU	5, 10
Bacopa egensis	(Poepp.) Pennell		Brazilian waterhyssop	non-indigenous	US		25
Blyxa aubertii	Rich.		Roundfruit blyxa	non-indigenous	US		25
Butomus umbellatus	L.	Blomvass	Flowering-rush, Water gladiolus	invasive	CA, US	SE	5, 19, 25
Cabomba caroliniana	Gray	Kabomba	Carolina fanwort, Carolina water-shield, Fanwort, Fish-grass, Washington-grass, Washington-plant	invasive	A-P, AU, CA, CN, IN, JP, MY, PE, US, sSE, RO	SO, BR, PY, UY, NO, AR	5, 8, 27
Callitriche hamulata	Kuetz. ex W.D.J. Koch	Klolånke	Intermediate Water-starwort	non-indigenous	NZ	SE	10, 29
Callitriche heterophylla	Pursh		Differentleaf waterstarwort,	non-indigenous	NZ		10
Callitriche platycarpa	Kütz.	Plattlånke	Various-leaved Water-starwort	non-indigenous	NZ	SE	10, 29
Callitriche stagnalis	Scop.	Dikeslånke	Starwort	non-indigenous	NZ, US	SE	10, 25, 29
Ceratophyllum demersum	L.	Hornsärv	Hornwort	non-indigenous	NZ	SE	10
Ceratophyllum submersum	L.	Vårtsärv	Soft Hornwort	non-indigenous	FI	SE	26
Ceratopteris thalictroides	(L.) Brongn.		Watersprite	non-indigenous	US		25
Colocasia esculenta	(L.) Schott		Coco yam, Wild taro	non-indigenous	US		25
Cotula coronopifolia	L.		Brassbuttons	non-indigenous	US		25
Crassula helmsii	T. Kirk	Vattenkrassula	Australian Swamp Stonecrop	invasive	US, UK, IE, DE, FR, NL, RU, PT, BE, FR, ES	AU, NZ	4, 8, 11, 15, 18, 20, 24
Cryptocoryne beckettii	Thwaites ex Trimen		Watertrumpet	non-indigenous	US		25
Cryptocoryne undulata	A.Wendt		Watertrumpet	non-indigenous	US		25
Cryptocoryne wendtii	de Wit		Wendt's watertrumpet	non-indigenous	US		25
Cyperus alopecuroides	Rottb.		Foxtail flatsedge	non-indigenous	US		25

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Cyperus prolifer	Lam.		Dwarf papyrus, Miniature flatsedge	non-indigenous	US		25
Dopatrium junceum	(Roxb.) Buch.-Ham. ex Benth.		Horsefly's eye	non-indigenous	US		25
Egeria densa	Planch.		Egeria, Brazilian elodea, Brazilian waterweed, Common waterweed, South American waterweed	non-indigenous	NZ, US, DE, FR, UK, NE	SA	10, 11, 17, 25
Eichhornia crassipes	(Mart.) Solms		Water hyacinth	invasive	50 countries on five continents. WS, MP, FM, GU, MH, PW, CK, Fiji, PF, NC, PG, WS, SB, VU, AU, NZ, US, JP, TW, CN, TH, KH, VN, MY, ID, PH, US, UK, PK, FR, NL, wcPT, eES, cIT.	the Amazon basin	5, 8, 10, 18, 22, 25,
Elodea callitrichoides	Rich.	Argentinsk vattenpest	South American Waterweed	non-indigenous	SE		27
Elodea canadensis	Michx.	Vattenpest	Canadian waterweed	invasive	SE		1, 18, 21, 27
Elodea nuttallii	(Planch.) St. John	Smal vattenpest	Nuttall's Pondweed	invasive	SE, NO, IE, DE, AT, UK	nAm	14, 18, 20,
Elodea spp.	Michx.		Water weed	invasive	BE		11
Frangula alnus	P. Mill.		Glossy buckthom	invasive	CA	Eur, nAfr, Asia	17, 19
Glossostigma diandrum	(L.) Kunze		Mud mat	non-indigenous	US		25
Glyceria declinata	Brébiss.		Floating sweet grass	non-indigenous	NZ		10
Glyceria fluitans	(L.) R. Br.	Mannagräs	Floating sweet grass	non-indigenous	NZ	SE	10
Glyceria grandis	S. Watson	Kvarngröe	American mannagrass	non-indigenous	SE		27
Glyceria maxima	(Hartm.) Holmb.	Jättegröe	Great manna grass, Reed sweet grass	minor-invasive	CA, NZ, US, SE	sSE	10, 19, 25, 27
Glyceria striata	(Lam.) Hitchc.	Strimgröe	Fowl manna grass	non-indigenous	SE		27
Hydrilla verticillata	(L. f.) Royle		Hydrilla	invasive	NZ, US, every continent except Antarctica.	Asia, nAU, sIN (dioecious), KN/KP (monoecious)	5, 10, 25
Hydrocharis morsus-ranae	L.	Dyblad	European frog-bit	invasive	CA, US	SE (south of Limes Norrlandicus)	19, 25
Hydrocleys nymphoides	(Humb. & Bonpl. ex Willd.) Buch.		Water poppy	non-indigenous	NZ, US		10, 25
Hydrocotyle ranunculoides	L. f.		Floating pennywort	invasive	BE, UK, IE, NL, cAm, sAm, sEur	sAm	4, 11, 15, 18, 20
Hydrocotyle verticillata	Thunb.		Whorled marsh pennywort, Whorled pennyroyal	non-indigenous	NZ		5, 10
Hydrophyllum virginianum	L.		Virginia Waterleaf	non-indigenous	NO		16, 26
Hygrophila polysperma	(Roxb.) T. Anders.		East Indian hygrophila, Indian swampweed, Miramar weed	non-indigenous	US		25
Hymenachne amplexicaulus	(Rudge) Nees		West Indian marsh grass	non-indigenous	US		25

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Ipomoea aquatica	Forsk.		Chinese waterspinach, Swamp morning glory, Water spinach	non-indigenous	US		25
Iris pseudacorus	L.	Svärdslilja	Yellow flag iris	minor-invasive	CA, NZ, US	SE	10, 19, 25
Iris sibirica	L.	Strandiris	Siberian Iris	non-indigenous	SE		27
Iris versicolor	L.	Brokiris	Harlequin blueflag	non-indigenous	SE		27
Juncus bulbosus	L.	Löktåg	Bulbous rush	non-indigenous	NZ	SE	10
Lagarosiphon major	(Ridley) Moss		Curly Waterweed, Curly Water Thyme	invasive	NZ, IE, UK	South africa	10, 18, 20
Lemna minuta	Kunth	Kölandmat	Least duckweed, Minute Duckweed	invasive	IE, UK, sFR, nIT, DE, CH, UK	nAm, sAm, Asia, Afr	8, 11, 17, 18, 23
Lemna turionifera	Landolt	Röd andmat	Turion duckweed	non-indigenous	FI	sAm	26
Limnobium laevigatum	(Humb. & Bonpl. ex Willd.) Heine		Amazon Frogbit	non-indigenous	US		25
Limnophila indica	(L.) Druce		Indian marshweed	non-indigenous	US		25
Limnophila sessiliflora	(Vahl) Blume		Ambulia, Asian marshweed, limnophila	non-indigenous	US		25
Limnophila x ludoviciana	Thieret		Marshweed	non-indigenous	US		25
Ludwigia grandiflora	(Camb.) Hara		Water Primrose	invasive	BE, UK, US, Mediterranean	sAm	11, 18, 23, 25
Ludwigia palustris	(L.) Ell.		Water purslane	non-indigenous	NZ		10
Ludwigia peploides	(Kunth) Raven		Primrose willow	non-indigenous	NZ		10, 15
Luziola peruviana	Juss. ex J.F. Gmel.		Peruvian watergrass	non-indigenous	US		25
Lysichiton americanus	Hultén & StJohn	Skunkkalla	American Skunk-cabbage	invasive	DE, SE	nAm	7, 15, 24, 29
Lysimachia vulgaris	L.	Strandlysing	Yellow Loosestrife	non-indigenous	US, naturalized in SE		25
Lythrum salicaria	L.	Fackelblomster	Purple loosestrife	invasive	CA, US, naturalized in SE		19, 25
Marsilea hirsuta	R. Br		Rough waterclover	non-indigenous	US		25
Marsilea macropoda	Engelm. ex A. Braun		Bigfoot waterclover	non-indigenous	US		25
Marsilea minuta	L.		Dwarf waterclover	non-indigenous	US		25
Marsilea mutica	Mett.		Nardoo	non-indigenous	NZ, US		10, 25
Marsilea quadrifolia	L.		European waterclover	non-indigenous	US		25
Marsilea vestita	Hook. & Grev		Hairy pepperwort, Hairy waterclover, Water clover	non-indigenous	US		25
Mimulus guttatus	DC.	Gyckelblomma	Monkeyflower	non-indigenous	SE		27
Mimulus luteus	(Burm. f.) K. Presl ex Kunth	Kal Gyckelblomma	Blood-drop-emlets	non-indigenous	SE		27
Monochoria vaginalis			Heartshape false pickerelweed,	non-indigenous	US		25
Murdannia keisak	(Hassk.) Hand.-Maz.		Aneilima, Asian spiderwort, Wartremoving herb	non-indigenous	US		25
Myriophyllum aquaticum	(Vell.) Verdc	Tusenblad	Parrot's feather	invasive	IE, UK, US, NZ , AU	sAm	4, 5, 10, 11, 18, 20, 25

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Myriophyllum heterophyllum	Michx.		Broadleaf water-milfoil, Changeleaf parrotfeather, Two-leaf water-milfoil	non-indigenous	US		25
Myriophyllum spicatum	L.	Axslinga	Eurasian watermilfoil	invasive	CA, US	SE	5, 19, 25
Najas graminea	Delile		Ricefield waternymph	non-indigenous	US		25
Najas minor	All.		Brittle waternymph	non-indigenous	US		25
Nelumbo nucifera	Gaertn.		Sacred lotus	non-indigenous	US		25
Nomaphila stricta	(Vahl) Nees		Giant hygrophila	non-indigenous	US		25
Nuphar lutea	(L.) Sibth. & Sm.	Gul näckros	Yellow water lily	non-indigenous	NZ	SE	10
Nymphaea alba	L.	Vit näckros	Water lily	non-indigenous	NZ	SE	10
Nymphaea ampla	(Salisb.) DC.		Dotleaf waterlily	non-indigenous	US		25
Nymphaea capensis	Thunb.		Cape Blue waterlily	non-indigenous	US		25
Nymphaea capensis zanzibariensis	(Caspary) Conard		Cape Blue waterlily	non-indigenous	US		25
Nymphaea lotus	L.		White Egyptian lotus	non-indigenous	US		25
Nymphaea mexicana	Zucc.		Mexican water lily	non-indigenous	NZ, US		10, 25
Nymphaea odorata	Ait.		American waterlily, American white waterlily, White waterlily	non-indigenous	US		25
Nymphaea X daubeniana	W.T. Baxter ex Daubeny		Waterlily	non-indigenous	US		25
Nymphaea X marliacea			Carnea	non-indigenous	US		25
Nymphoides cristata	(Roxb.) Kuntze		Crested floating heart	non-indigenous	US		25
Nymphoides indica	(L.) Kuntze		Water snowflake	non-indigenous	US		25
Nymphoides peltata	(S. G. Gmel.) Kuntze	Sjögull	Yellow floating heart, Fringed water lily	invasive	NZ, IE, SE, NO, US, CA	Asia, Eur	5,19, 20, 25, 26, 27
Oenanthe aquatica	(L.) Poir.	Vattenstäkra	Horsebane	non-indigenous	NZ	SE	10
Orontium aquaticum	L.	Guldklubba	Golden club	non-indigenous	SE		7, 27, 29
Oryza sativa	L.		Rice	non-indigenous	US		25
Ottelia alismoides	(L.) Pers		Duck lettuce	non-indigenous	US		25
Ottelia ovalifolia	(R.Br.) Rich.		Swamp lily	non-indigenous	NZ		10
Panicum repens	L.		Couch panicum, Creeping panic, Panic rampant, Torpedograss, Wainaku grass	non-indigenous	US		25
Paspalum distichum	L.		Mercer grass, Knotgrass, Knotroot paspalum	non-indigenous	NZ		10
Phalaris arundinacea	L.	Rörflen	Reed canary grass	invasive	CA	SE	19
Phragmites australis	(Cav.) Trin. ex Steud	Vass	Phragmites, Common reed	invasive	NZ	SE	10
Pistia stratiotes	L.	Musselblomma, Vattensallad	Tropical duckweed, Water lettuce, Water cabbage	invasive	NZ , US	sAm	5, 10, 22, 25
Potamogeton crispus	L.	Krusnate	Curly pondweed	invasive	CA, NZ, US	SE	5, 10, 19, 25
Potamogeton perfoliatus	L.	Ålnate	Clasped pondweed, Perfoliate Pondweed	non-indigenous	NZ	SE	10
Ranunculus trichophyllus	Chaix		Water buttercup	non-indigenous	NZ	SE	10

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Ricciocarpus natans	Corda	Vattenstjärna	Purple-fringed riccia	non-indigenous	SE		9
Rorippa amphibia	(L.) Bess.		Marsh cress, Great yellowcress	minor-invasive	CA, US		19, 25
Rorippa microphylla	(Boenn. ex Reichenb.) Hyl. ex A.& D. Löve		Watercress	non-indigenous	NZ		10
Rorippa nasturtium-aquaticum	(L.) Hayek		Watercress	non-indigenous	NZ, US	SE (Skåne, Halland)	10, 25
Rotala indica	(Willd.) Koehne		Indian toothcup	non-indigenous	US		25
Rotala rotundifolia	(Wallich ex Roxb.) Koehne		Roundleaf toothcup	non-indigenous	US		25
Sagittaria graminea	Michx.		Grassy arrowhead	non-indigenous	US		25
Sagittaria guayanensis	Kunth		Guyanese Arrowhead	non-indigenous	US		25
Sagittaria montevidensis	Cham. & Schlecht.		Arrowhead	non-indigenous	NZ, US		10, 25
Sagittaria platyphylla	(Engelm.) J.G. Sm.		Sagittaria	non-indigenous	NZ		10
Sagittaria rigida	Pursh		Sessilefruit arrowhead	non-indigenous	US		25
Sagittaria sp.	L.		Arrowhead	non-indigenous	NZ		10
Sagittaria subulata	(L.) Buch.		Awl-leaf arrowhead	non-indigenous	NZ		10
Salvinia minima	Baker		Water fern, Water spangles	non-indigenous	US		25
Salvinia molesta	D. S. Mitchell		African payal , African pyle, Aquarium watermoss, Salvinia, Giant salvinia, Water fern, Water spangles, Kariba weed	invasive	NZ, US, UK, IN, Afr, A-P	soBR, nAR	5, 10, 18, 22, 25
Sarracenia purpurea	L.	Flugtrumpet	Pitcherplant	non-indigenous	SE		27
Schoenoplectus californicus	(C.A. Mey.) Palla		Californian bulrush	non-indigenous	NZ		10
Solanum tampicense	Dunal		Wetland nightshade	non-indigenous	US	MX, BZ	25
Spartina alterniflora	Loisel.		Atlantic cordgrass, Saltmarsh cordgrass, Smooth cordgrass	non-indigenous	US		25
Spartina anglica	C.E. Hubbard	Engelskt marskgräs	Common cord grass,Rice grass, Townsends grass	invasive	DE, US, IE, UK, sAm, sAm, ZA, AU, NZ, CN		5, 24, 25
Spartina densiflora	Brongn.		Denseflower cordgrass	non-indigenous	US		25
Spartina patens	(Ait.) Muhl.		Marshhay cordgrass, Salt meadow cordgrass	non-indigenous	US		25
Spartina spp.	Schreb.		Cordgrass	non-indigenous	IE		20
Spirodela punctata	(G.F.W. Mey.) C.H. Thompson		Purple-backed duckweed	non-indigenous	NZ		10
Spirodela punctata	(G.F.W. Mey.) C.H. Thompson		Dotted duckmeat, Dotted duckweed	non-indigenous	US		25
Trapa natans	L.	Sjönöt	Water Chestnut	invasive	US, UK	extinct in SE	5, 18, 25
Urochloa mutica	(Forsk.) T.Q. Nguyen		Para grass	non-indigenous	US		25
Utricularia inflata	Walt.		Swollen bladderwort	non-indigenous	US		25
Vallisneria americana	Michx.		American eelgrass, Eel-grass, Watercelery	non-indigenous	US, NZ		10, 25
Vallisneria gigantea	Graebn.		Eelgrass	non-indigenous	NZ		10

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Veronica beccabunga	L.	Bäckveronika	Brooklime	non-indigenous	US	sSE	25
Zizania aquatica	L.		Annual wildrice, Canadian wild rice	invasive	LV, US	sAm	21, 25
Zizania latifolia	Griseb.		Manchurian wild rice	invasive	LV, NZ, UK	Asia	5, 10, 21
Zostera japonica	Aschers. & Graebn.		Dwarf eelgrass	non-indigenous	US		25

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