Ecological effects and management aspects of an exotic tree species: the case of lodgepole pine in Sweden


Umeå University, SE-901 87 Umeå, Sweden
Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden
Swedish Forestry Research Institute, SE-918 21 Sävar, Sweden
Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden
University of Wyoming, WY 820 71 Laramie, USA
Montana State University, Bozeman, MT 59717-3460 USA
University of Edinburgh, Edinburgh, EH9 3JK UK
New Zealand Forest Research Institute, Fendaltions Christchurch, New Zealand
Beechwood House, Lydney, Glos GL 156SL UK
Lund University, SE-223 62 Lund, Sweden

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Abstract

The North American tree Pinus contorta var. latifolia was experimentally introduced in Sweden already in the 1920s, and has been used in Swedish forestry on a large scale since the 1970s. These plantations now cover 565,000 ha, mainly in the northern area.

In this paper we summarize and discuss existing ecological knowledge of this species introduction. With regard to long-term sustainability we suggest management means to minimize harmful effects of the introduction on ecosystems. These include aspects of self dispersal, pests, ecosystem and landscape structures, and also ecological processes and biodiversity. We also focus on observed and possible interactions in the ecosystems. As Pinus contorta seeds are disseminated and trees regenerated outside initial plantations, this may have future bearings on biodiversity.

We suggest a strategy which takes account of the uncertainty in predicting future ecological effects. The strategy includes areal restrictions and zones without Pinus contorta, but also to set up a monitoring program. Observations of adverse effects from the plantations would then give the possibility to adjust P. contorta management. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Trees have long been transferred from one country to another for economic, aesthetic, scientific and other reasons. Most have excited little more than mild curiosity or the interest of specialists, but those which have been introduced in substantial numbers, or which have spread naturally in their new environments, have generated much public reaction, leaving hardly anyone untouched (Richardson and Rundel, 1998). Public attitudes towards exotic tree species are important aspects of the introduction process. However, from a long term perspective the effects of exotics on native ecosystems are of primary importance. Such effects may be highly complex and interactive, but can nonetheless be structured under a few headings to facilitate and develop our understanding. These may include self dispersal, pests, ecosystem and landscape structures, and also ecological processes and biodiversity. Further, management strategies for ecosystems that include an exotic element must try to understand both the effects of each of these factors and the interactions that occur.

The North American lodgepole pine (Pinus contorta var. latifolia) was introduced to Sweden in the 1920s on an experimental scale, but from the 1970s onwards it has been planted as full-scale plantations, which now cover about 565,000 ha. Although environmental effects have been part of earlier reviews (von Segebaden, 1992; Lindgren, 1993), few thorough assessments of the environmental effects of lodgepole pine introduction have been conducted. As called for by the Rio Convention (1992) as well as the Swedish Forestry Act (1994), the maintenance of biodiversity and wood production should be considered as equally valuable objectives. Clearly the time is right for consolidation of existing knowledge and the promotion of new research on the effects of tree species introductions and their influence on ecosystem sustainability and biodiversity.

This article reports on a workshop held in Ammarnäs, Sweden (9–13 March, 1998) on lodgepole pine ecology and the known effects of lodgepole pine introduction (Andersson et al., 1999). Here the workshop participants summarize the results of the joint discussion with regard to the implications for long term sustainability and suggest management measures that, according to existing knowledge will minimize the deleterious effects of such introductions. This special feature aims to synthesize and analyse what is presently known about the ecological effects of lodgepole pine introduction in Sweden. Therefore, reading of the other articles in this special feature is recommended, as referred to in the text below. We also recognise that there is an increased need to draw materials from the biosphere to sustain increasing human populations, but believe that this must be done by methods which do not impair its educational, psychological and spiritual values.

2. Swedish lodgepole pine versus Scots pine silviculture

Exotic tree introductions may cause both large and small scale changes in ecosystem structures and processes that affect biological diversity (here we define biodiversity according to the Rio Convention (1992), i.e. the diversity within species, between species, as well as the diversity of ecosystems; cf. Bernes, 1994, and others). If we consider, for example, stand scale differences between lodgepole pine and Scots pine (P. sylvestris) plantations in Sweden, both are for obvious reasons far different from virgin or even semi-natural native Scots pine stands. The ecology of virgin northern Swedish forest ecosystems have been reviewed by others (e.g. Esseen et al., 1997; Engelmark, 1999) and will only be touched on briefly here. Instead, we emphasise the ecosystem similarities and/or differences between introduced lodgepole pine (henceforth called LP) and domestic Scots pine (SP) plantations.

The Swedish forest landscape has long been a managed landscape (Sjöberg and Lennartsson, 1995; Engelmark, 1999). Man has utilised the land since early Holocene (8000 year BP) (Baudou, 1988), although commercial tree cuttings did not start until the 1600s. Large scale tree harvesting for saw timber began in the 1800s, followed in the next century by the onset of the pulp industry. Today most forested land is covered by highly managed coniferous stands of different ages, creating a mosaic of managed patches. Compared to natural landscapes, deciduous trees are presently under-represented in Sweden. Furthermore, the preserved forests cover only about 3% of the
productive forest land area. This situation creates the
need to conduct commercial forestry in ways that
sustain natural biodiversity.

The large-scale planting of LP that started in the
1970s had as its main objective to meet, at that time,
the predicted future shortage of harvestable soft-
woods. Therefore, at first large areas were planted,
after which the annual planting decreased. Problems
such as pathogens and tree instability also contributed
to the annual decrease in planting. Plantings were
done on till and sandy soils, thereby replacing not
only SP on coarse soils, but also the native Norway
spruce (Picea abies) on the fine-textured soils. How-
ever, according to the latest available yield evalua-
tions, LP produces about 36% more (total volume
growth) than SP, irrespective of site index (Elfving
et al., 2001, this issue). Provided this holds true also in
older stands, and that the wood quality is comparable
to SP, the industry may maintain its interest in LP
silviculture.

3. Self dispersal to new environments

A crucial consideration when introducing exotic
species to new ecosystems is the self dispersal capa-
city of the species in question (cf. Richardson and
Higgins, 1998), primarily because unwanted self dis-
persal may influence our ability to control the species.
A review of the spread of introduced LP in Sweden,
the United Kingdom and particularly in New Zealand
(Ledgard, 1993, 2001, this issue) concluded that there
was little evidence of natural regeneration in Sweden
at that time. However, experience with introduced
conifers in new environments indicates that spread
events could begin at any time, even if little significant
spread had been observed up to that time. Possible
reasons could be synchronisation of all factors needed
for successful spread (e.g. plentiful seed, low predator/
pathogens, good germination and seedling establish-
ment conditions), arrival of suitable symbionts (espe-
cially mycorrhizae) to aid early establishment, and
climatic change to conditions more suited to LP (cf.
Despain, 2001, this issue). Environmental factors
influencing natural regeneration or self dispersal can
be examined under three headings — seed production,
seed dissemination and seedling establishment and
survival.

3.1. Seed production

LP seeds are borne in cones that are either seroti-
nous (remain closed at maturity until they have been
subjected to temperatures in excess of about 50°C) or
non-serotinous (open and release seeds annually).
Young trees up to the age of 20–30 years produce
mainly non-serotinous cones. Tree age, nutrition and
climate are the main factors influencing seeding fre-
quency and amount. Cones are produced beginning as
early as 5–10 years, but large numbers of cones are not
produced until the trees reach about 15–20 years.
Serotinous cones do not open until they have been
subject to the high temperatures which occur during a
fire either on the forest floor or in the tree crowns, or
when the cones are situated within about 30 cm of the
soil surface on warm sunny days (e.g. Lotan, 1975;
Perry and Lotan, 1977). Once the temperature require-
ment for serotinous cones is met, the main factor
influencing cone opening for both serotinous and
nonserotinous cones is cone moisture content. The
cones release seed when the scales dry out and the
cones open.

3.2. Seed dissemination

The main influences on seed dissemination are wind
direction and force. Most seeds fall within 100 m
downwind, but they can be blown considerable dis-
tances from exposed slopes and ridges, sometimes
called ‘take-off’ sites (Ledgard, 1993). Long distance
dispersal can also result from strong updrafts asso-
ciated with thunderstorms or seed blown over snow
surfaces in the winter. Seed caching by birds and small
mammals could disperse seeds further afield, but most
seeds are usually stored close to where they are
produced.

3.3. Seedling establishment and survival

The germination demands of LP are generally well
met in the Swedish environments. Occasionally, seed-
ning losses immediately after germination may be
high, due to drought, frost, and predation (mostly in
year 1) by insects, birds, and mammals.

LP is likely to invade all sites currently occupied by
SP. Seedlings establish best on mineral soil with little
competition. Such sites are common after fire or
timber harvest. In addition, LP is probably more likely to invade wetter (mire, bog) and shadier sites than SP (N. American, New Zealand experience) (also cf. Ohlson and Zackrisson, 1992), and it may be more competitive in soils with lower temperatures.

LP is probably a better competitor than SP, particularly in wetter and shadier sites, although in the latter two sites it could well be slower growing (almost senescent) and unlikely to mature to cone-bearing age. In general, LP is considered more competitive than SP when the two species occur together (Norgren, 1996; Elfving et al., 2001, this issue).

3.4. Suggestions on how to minimise possible adverse effects

- Do not allow LP on hilltops or upwind of spread to susceptible areas where spread is unwanted.
- Aggregate plantations in least sensitive areas.
- Save or plant 2–3 rows of native and/or less spread-prone species (e.g. SP) around external boundaries or along margins of unplanted reserve areas inside plantation. We hypothesize that most fringe spread comes from seed produced by edge trees, which have more green foliage than internal trees and are closer to spread-prone areas.
- Design plantation shape to minimise edges at right angles to prevailing wind during seed release season.
- Wherever possible include sites with boundaries from where spread is almost impossible or acceptable (e.g. grazed areas, actively managed production forests, wide roads).
- Watch for seedlings around all plantations and keep records on where and when natural regeneration occurs.
- Remove all unwanted spread before age of coning.

4. Spread of pathogens and pests to native species and ecosystems

Pests and pathogens following introduction of exotics is another crucial concern and stems from two sources: (i) the possible destabilising effect of the introduced host on the indigenous host–pathogen systems, and (ii) the devastating effects of exotic pests and pathogens that may follow the introduction of their host. Thus, there is the possibility of mass attack of LP plantations by native pest populations, and the spread of these outbreak populations onto native hosts.

In addition, there is the possibility of LP pathogens establishing on plantations of its host in Sweden and spreading to native species from these centres (Ennos, 2000, this issue, Karlman, 2001, this issue).

As the most closely related member of the indigenous flora, SP has been the major host of pathogens attacking LP in Sweden. It appears that there has been rapid transfer of some of the indigenous necrotrophic pathogens from SP to LP. Where maladapted provenances have been planted, where plantings have been made on inappropriate sites, and where trees even of the most northerly provenances have been stressed by exceptional weather conditions, severe outbreaks of Gremmeniella abietina have occurred causing significant damage. High inoculum levels have been developed in these plantations (cf. Karlman, 2001, this issue).

Transfer of biotrophic pathogens (principally rusts) from SP has been thoroughly monitored. Due to their more specialised mode of interaction with their host, greater difficulties with such host transfers are anticipated. Nevertheless, infection of a few LP trees by the pine twisting rust Melampsora pinitorqua has been documented.

In terms of insect pests, transfer of a proportion of the species occurring on SP has been observed. In general, their effect has been minimal due to the fact that LP has been planted principally north of latitude 60°N where conditions are not favourable for insect outbreaks. However, significant damage has been caused by species that are preadapted to various features of LP. An example is the pine flower weevil that benefits from the copious production by LP of large male flowers. In contrast to experience with pathogens, a number of bark and wood beetles have transferred to LP from Picea abies rather than SP, presumably due to the thin bark of the exotic.

In the epidemic populations of G. abietina (and other pathogens) on stressed stands of LP, there is the potential for the evolution of more aggressive pathogen genotypes (Ennos, 2000 this issue). This, together with the high inoculum density even in the absence of increased aggressiveness may increase damage on adjacent stands of SP (Karlman, 2001, this issue). Some increase in damage in SP has been observed,
but there is no experimental evidence for the development of a more aggressive race of the pathogens involved. Investigation of this possibility should be a priority for research.

Planting LP in Sweden enhances the possibility of the introduction of exotic pathogens that have evolved on LP. The chance of this establishment is small, given the remoteness of native LP populations from Sweden. However, if such transfer did occur, the effects are expected to be very large because such exotic pathogens have the potential of causing significant damage on SP with which they have not co-evolved. Testing the potential effects of LP pathogens on SP should be continued in collaborative reciprocal screening trials (cf. Karlman, 2001, this issue).

Because of the northerly siting of LP stands, the possibility of introducing pest insects from LP’s native range is more remote than is the possibility of introducing exotic pathogens. Due to the young age of the more extensive LP plantations, potential disease and pest problems may yet be discovered during the later stages of the LP rotation. As an example, the North American mountain pine beetle (Dendroctonus ponderosae) preferentially attacks larger diameter LP (Cole and Amman, 1980). If late acting pests or pathogens occur, their effects could be very damaging. It must not be assumed that all potential pest and pathogen problems have already been screened.

Although there is no experimental evidence on this topic, there is the potential for pest or pathogen populations to develop either host adapted races on LP, or to evolve a wider host range to include SP and LP. Races with wider host ranges are likely to be less damaging and more stable than a newly evolved host race.

Although climatic warming could potentially lead to a lower level of adaptation of existing planted LP provenances, and an increase in disease and pest susceptibility, the existing variability in climatic variables is considered so large that climate change seems likely to have rather little material influence on pest and pathogen levels. Moreover the same problems will apply to all indigenous host species. Further, if a scenario with major outbreaks would occur, this could, for example, increase the amount of large woody debris, increasing pest population pressure and eventual use of pesticides. In turn, this could have effects on biodiversity as well as soil processes.

4.1. Suggestions on how to minimise possible adverse effects

- Planting practices that encourage heterogeneity of host tree species within and between plantations should be encouraged.
- Where there is a choice, smaller rather than larger areas of LP should be planted to discourage the evolution of host adapted races. (However, cf. below on biodiversity).
- If it is possible to encourage broadleaved trees within plantations, this will reduce pathogen transfer rates, disease problems, and will help to prevent insect pest outbreaks.
- In LP tree breeding, seed collected from populations that have been subjected to screening by pathogens, either accidentally or deliberately, should be used to develop a local pathogen adapted ‘land race’ for planting, in preference to direct importation of seed from the natural range.

5. Ecosystem processes, structure and biodiversity

5.1. Long term productivity — energy and material dynamics

LP and SP differ in their allocation of energy to growth as well as in chemical composition of tissues. These factors modify litter production and decomposition, and may thereby in the long run change the soil storage of carbon and nutrients. LP has a lower litter production but a slower decomposition than SP. These two factors balance each other so that local site conditions, time, and silviculture together determine which of the two species gives rise to the largest soil carbon and nutrient storages. Therefore, change of species per se seems less important for soil conditions than stand management practices (cf. Ágren and Knecht, 2001, this issue).

5.2. Stand scale aspects

In general terms, timber harvesting and plantation establishment at the stand level probably result in a decline in biodiversity in most situations, primarily because wood is removed. This reduces the kinds of substrate/habitat that had existed in the forest for
millenia. Also, the micro-environment is changed dramatically, and in ways that are different from all other non-human disturbances. In the process of fostering the establishment and growth of new trees, various site treatments are used that disrupt the environment in ways that affect some species adversely. The species (other than those that are planted) that may benefit from the new environments created by plantation establishment typically are those that are already common in landscapes where plantation forestry is practised.

Both LP and SP plantations are relatively poor habitats for both plant and animal species in Sweden. LP stands are shadier than native SP stands when tree densities are comparable. This is mainly due to the higher leaf area index in LP stands, and partly due to the fact that needle age classes remain longer than in SP canopies. This shade influences the occurrence of plants, invertebrates, and vertebrates as well as soil processes. These effects may differ significantly, depending on the degree to which other tree species are mixed with the LP. For example, if hardwoods are allowed to grow, a higher proportion of hardwood dependent species may occur. A higher proportion of hardwoods would also increase the amount of light in the stands, thereby allowing more shade-intolerant plants to persist.

5.3. Plants

The generally more shady below-canopy environment, and chemically different litter (A˚gren and Knecht, 2001, this issue), seem to be the main differences influencing plant species diversity (Andersson et al., 1999; Engelmark and Nilsson, unpublished). However, diversity studies (e.g. Lundmark et al., 1982; Kardell and Eriksson, 1989) do not suggest generally significant differences between vascular plant species diversity. Instead, LP dominance in early stand stages seems to favour understory species also common in SP stands, while understory species generally common in spruce stands tend to be favoured in later LP stand stages when the canopy is more closed. Those studies are largely preliminary, but do nonetheless indicate that lichen and herb diversity may be higher in SP than LP stands. The role of the canopy, the shade it causes, and how this affects the understory species composition have been discussed by Collins et al. (1985) and Stone and Wolfe (1996), indicating that a more open canopy (and thereby less shade) leads both to more biomass and higher species diversity in the understory.

5.4. Invertebrates

With regard to insects, 80 species have been observed to reproduce on LP in the Nordic countries. Most are herbivorous species living on needles, buds, flowers and cones. The majority have SP as the main host. Feeding guilds which are poorly represented on LP are sucking insects, e.g. aphids and gall-making insects. Also, some other species are missing on LP (e.g. the bark bug Aradus cinnamomeus), probably due to different morphological properties such as bark structure. This also seems true for the pine bark beetles (Tomicus spp.). On the other hand, there are some saproxylic insects, mainly bark beetle (Scolytidae) species, that normally live on spruce but which are found in dead or dying LP (Lindelöw and Björkman, 2001, this issue).

For a few insect species there seems to be a lack of co-evolution to LP, e.g. gall midges, pine cone weevil, and pine flower weevil for which LP appears to be a superoptimal host, and on the other hand, Pityogenes chalcographus, which normally reproduces on spruce, seems to be suboptimal on LP in the larval stage. In addition, provenance differences can be found.

We could expect to find more insect species on LP as time progresses. Larger areas of older stands and their accompanying dead trees would bring more saproxylic insects. This could be mitigated partially by minimising disturbance to the understory vegetation and soil surface, leaving a more diversified stand structure (e.g., leave more snags, green trees, and coarse woody debris), lowering the stem density to counteract the higher shading of LP, and encouraging a reasonable retention of hardwoods. If more diversified stand-level management occurs, then there may be less risk to biodiversity in any type of plantation.

5.5. Vertebrates

Several vertebrate species utilise pine species, but in different ways. For example, such different herbivores as voles, moose and the woodland grouse
capercaillie all utilise both LP and SP as food. The voles mainly use the bark of seedlings and saplings, the moose the twigs and shoots of young trees up to about 3 m of height (and to some extent bark from LP, even from older ones), and the capercaillie primarily the needles of old trees. For that kind of utilisation a combination of qualitative and quantitative factors makes the difference between the pine species. Qualitative factors include chemical composition of the bark, branches and needles, as well as concentration of indigestible fibres, while the amount of available twig biomass is an important quantitative factor (e.g. Hansson and Gref, 1987; Niemelä and Danell, 1988; Sjöberg and Danell, 2001, this issue).

On the other hand, some vertebrates use the pine stands primarily for cover, e.g. for protection from predators, or as breeding, resting, or foraging areas. That is the case for most vertebrates, such as the Passerines. For them the concentration of food (e.g. invertebrates), the shade on the forest floor, the morphology of the trees, and other factors make the differences in utilisation of the two pine species (e.g. Danell and Sjöberg, 1993). Thus, the effect of the introduction of the LP on different vertebrate species will differ among ecological groups, depending on successional stage, distance between trees in a plantation, plantation size and configuration, homo- geneity of the plantation, and provenance.

### 5.6. The landscape perspective

It is useful to think about timber harvesting in a landscape context. If our goal is to mimic nature, then the ideal could be to create harvest units that have the same size distribution, spatial location, and other attributes of natural disturbances as in the pre-industrial forest (cf. Bergeron et al., 1998). Thus, the goal would be an increase in the use of variable harvest unit patch sizes, perhaps approaching the declining inverse distribution of sizes that has been found for natural disturbances throughout the world. Moreover, high-contrast edges, such as those between a clearcut and adjoining forest, would be avoided. It is possible to buffer the edge by leaving a zone of higher green tree retention around the edge of the harvest unit. Clearly, harvest units should be placed so as to minimise their direct effects on the stand structure, which must be determined separately for each landscape where plantations exist or are planned for the future.

All components of biodiversity have developed in a constantly fluctuating, non-equilibrium landscape in which a variety of habitats are distributed (Knight et al., 2001, this issue). Therefore, it is compelling to use a variety of silvicultural systems in a landscape rather than just clear-felling and plantation establishment (exotic or native). Conceivably, the best way to preserve biodiversity may be less timber harvesting for a longer period in some areas than was previously planned (longer rotations). Also, the indigenous biodiversity probably cannot be maintained without the restoration of more land to hardwoods. Clearly, the current heavily managed landscape is beyond the range of natural variability with regard to hardwood forest representation.

Does it matter to biodiversity preservation if exotic tree plantations are used instead of native tree plantations? On one hand, the higher productivity that seems possible may enable the restoration of more land to hardwoods or interior forests. Considering the heavily managed nature of many Nordic landscapes, this may be a significant advantage if society and industry are willing to curtail the potential for short-term additional profits. On the other hand, exotic species can have undesirable effects in the long term, especially if they spread to lands where a native analogue is absent. Careful planning and further analysis is therefore necessary for specific landscapes. Suggestions on how to minimise possible adverse effects on biodiversity and landscapes are discussed in more detail in the next chapter.

### 6. Acceptance of uncertainty

Past experience of introducing tree species from other countries shows that there may be many different consequences for the environment, the introduced tree itself and native ecosystems. Examples can readily be collected from, for example, (i) failure of the introduced tree to grow successfully, (ii) damaging changes to native vegetation, flora and fauna, and (iii) competition between the introduced trees and native trees. A worst-case scenario will inevitably show that an introduction is unwise. However, when past introductions and their consequences are assessed, the only general
conclusion must be that the consequences of an introduction cannot be predicted. Until the introduction has actually taken place, we do not know what will happen. If an experiment is performed to test the consequences before introduction, that in itself counts as an introduction. If the test is on a small scale, the consequences of a small-scale introduction may differ from those of a large-scale introduction. Furthermore, any test is likely to be short-term, but some of the consequences may develop only over many decades or longer, depending on climate change effects (cf. Peterken, 2001, this issue, Sykes, 2001, this issue) and other variables.

Against that background it is prudent to devise a strategy which takes account of uncertainty. This would enable the introduction to proceed whilst the effects of the introduction are examined. The only worthwhile experiment is to go ahead with the introduction in such a way that, if any damaging consequences are identified, we can at least moderate the damage.

One component of such a strategy would be to limit the total area which is stocked with LP. This would take the form of a threshold at which there would be a further review of the evidence relating to the effects of the introduction. That review might agree to maintain that limit, or increase it, according to the evidence. Alternatively, it might recommend a reduction in the area planted. The threshold would be expressed as an absolute total area, and/or a proportion of the total forest area. The factors on which the threshold(s) might be determined include

- the maximum area/proportion which could be completely written-off as a commercial asset without jeopardising the company;
- the area/proportion at which LP ceases to be islands in a matrix of native forest, and becomes the matrix, thereby reshaping the ecosystem structure;
- the area/proportion at which the public makes significant protests about the deterioration of their use of the forest for recreation or, say, berry-picking or hunting.

A second component would be to ensure that LP-free landscapes survive. This would not only ensure that the effects of LP can be measured on a landscape-scale, but would help ensure the survival of landscapes which are free of any damaging consequences that may develop.

This idea can be extended to ensuring that landscapes are available in future with different patterns of LP, ranging from landscapes where LP is concentrated into few, but large patches, to landscapes where it is dispersed through many but small patches. In the long-term, this variety (with respect to LP) of landscapes would be designed for future large-scale research. The scale of these landscapes would probably be at 10–100 km², i.e. whole catchments or larger. They would be large enough to

- encompass the ranges of the largest fauna (or a viable population thereof);
- contain a full range of LP age-classes, eventually.

This large-scale pattern would have to be based on the existing distribution of LP. It could be developed by controlling the pattern of future LP planting (see below).

A third component would be the retention of old stands of LP. These would enable us to understand the development of this novel ecosystem, and to discover how the native fauna and flora make use of LP throughout its potential rotation. One of the possible concerns about the introduction of LP is the fate of species which depend on old-growth forest. By studying old LP stands, we would discover whether old-growth species could make use of these LP stands, and thus whether any future concern for these species could be met by extending LP rotations or expanding retentions. There are at present about 25 LP stands of 40–60 years, ranging in size from 0.5 to 9.0 ha and reasonably well-distributed over northern Sweden. These would be the nucleus of the set of old-growth reserves. The aim would be to monitor the succession so that the main components (such as soil, ground vegetation, faunal groups) can be described at each stage.

In practice it would be necessary to identify other stands which would be added to the existing old stands to ensure a better overall distribution. The minimum set of stands would enable north-south and east-west gradients to be identified. Ideally, these would be paired with SP stands treated in the same way. Ideally too, we would select sites which have been studied in their early stages, for soil changes, bird fauna, and other variables. The size of a reserve would be in the
order of 10–100 ha, i.e. enough to include some interior conditions. The target would be perhaps nine reserves totalling about 1800 ha maximum (100 ha of both LP and SP).

The ideal set of old-growth reserves would incorporate existing old stands, but these would not be enough. The chosen stands would be expanded by allowing adjacent younger stands to become old. Of course, it would be possible simply to hope that stands would survive by chance. The advantage of planning their survival would be (i) an optimal design for scientific analysis, (ii) the opportunity to monitor stand development, and (iii) reasonable security that a minimum number of stands would survive to become old.

Another requirement is for an early warning system which would identify problems before they become widespread. The basic idea would be to set up a system for routine observations and a plan which would be activated if a problem arose. An early warning system would include monitoring of certain groups of native flora and fauna. The most obvious groups would probably be birds and Lepidoptera, which are well-known by a large number of naturalists, and may be sensitive to changes in the environment. A system which included non-professional observers would maximise the level of surveillance and generate wider support for the monitoring program. The basic need would be for a standard method of recording and a central coordinator for collecting and analysing the observations. The coordinator could also be identified as a contact point for any individual who notices a possible problem attributable to LP.

There would also be a plan of action in the event of a particular problem. It is difficult to suggest what form this would take, but mechanisms might include a published annual audit or review. The actions which would follow might be identified in advance, as an indication of good faith. An example of an adverse scenario for which a plan might be made in advance would be rapid spread by natural LP regeneration into adjacent clear-fell areas.

Recording the rate or intensity of operations which may have damaging effects is also important. For example, frequency of drainage operations; intensity of scarification; amount of pesticide applications. If these change, or exceed an agreed level or standard, there would be grounds for concern.

7. Public, ethic and aesthetic aspects

Throughout this paper we have considered technical and quantifiable effects of LP introduction. When these are considered in relation to economic issues, a cost-benefit analysis can be made of whatever courses of action are under consideration. However, it is important to recognize that issues relating to LP introduction cannot be resolved by purely technical considerations. Emotional and ethical factors must also be taken into account, and these may lead to objections to further spread of LP on principle. Modern societies increasingly interfere with and control natural processes, thereby generating environments which are dominated by human ideas and constructions. The prime example of this is the city. This dominance has generated a concern for environmental issues.

Against that background, increasing the area of LP forestry represents an increasingly obtrusive reduction in the capacity of rural districts to function as natural counterpoints to urban populations. True, any form of intensive plantation-based forestry has this effect, but plantation forestry with an introduced tree species intensifies the artificiality. There is thus a case for restraint. We already interfere so much with natural processes and states that we must do what we can to minimise any further interference. Control of the human environment may seem complete, but we cannot be sure that it will always be complete. Flood control provides a fine example: despite immense and impressive engineering of river channels and floodplains, which prevent almost all floods, it has recently still been possible for the Mississippi and the rivers of central and northern Europe to flood in a devastating way. As a result, there is a new interest in moving away from engineering solutions towards working with the natural character of the rivers, i.e. to live with floods, not try to prevent them altogether. LP pine forestry represents a similar engineering solution, in this case for faster timber production. It may proceed without constraint for many years without generating problems, but we can never be sure of control. We need, therefore, to restrain LP forestry by either restricting its extent or devising more natural methods of forest management.

Another consideration is the role of landscape in defining nationality. A nation is its people and their
history, and it is manifested in their culture and their environment. The landscape of Sweden has been generated by Swedes and expresses national characteristics, culture and history. It is different from the landscape of other countries, partly because of inherent (natural) characteristics and partly because of the way in which it has been moulded. The introduction of LP forestry introduces an alien element. Admittedly, it will increasingly be accepted as part of the culture, but it is unlikely to maintain the distinctiveness of the Swedish landscape. LP pine plantations look like LP pine plantations in other countries, or indeed like pine plantations of any species all over the globe. They represent an aspect of a world-wide homogenisation of environments. Applying this to the case of LP forestry, the case for restraint in the use of LP is reinforced, and the case for admitting natural elements is reinforced.

A third consideration is scientific. Any society would be wise to understand how its environment evolved and functions. This includes, for example, large-scale considerations of species movements and genetic adaptations to local environments. It is conceivable that extensive LP forestry might eventually take up so much ground and be treated so intensively that certain types of environmental research become impossible, or at least more difficult. Such concerns add to the case for restraint and implies that any site within areas of LP forestry that might be valuable for research should be preserved, e.g. mires where pollen sequences might be informative.

8. Concluding suggestions

Based on the Rio Convention (1992) as well as the Swedish Forestry Act (1994), LP should not be grown in ways that cause threats and irreversible damages to biodiversity, for e.g. loss of genes, species or ecosystem sustainability. Together with recreational, cultural, and aesthetic values, this calls for general areal limitations as well as prevention from LP in areas with natural and valuable biodiversity. Since LP has a significant self dispersal potential, active measures are needed to exclude LP from areas where it is not wanted. Operational measures to achieve this and to minimise possible adverse effects from actual LP plantations are mentioned in the papers that follow, but the following suggestions are noteworthy:

- concentrate LP in more controllable areas in order to restrict growth and thereby prevent unwanted spread of LP and related pests;
- define LP free zones and areas with regard to site quality, altitude, and latitude in order to maintain natural biodiversity;
- define maximum area for LP on national and landscape scale, respectively;
- set up a monitoring program;
- be in state of alert with LP silviculture so that effective measures can be taken if necessary in the future;
- support research that will reduce the level of uncertainty;
- consider further LP silviculture on a (inter)national level since ecological effects do not recognise administrative, political or other physical borders.

References


