

Final report for SNS research projects

Submit the report to sns@slu.se by 24:00 CET, 1st of September, 2022, at the latest.
The report should not exceed 2500 words (including words in the template).

Please adjust the size of the box according to the length of your answer.

1. Project title:	Assessing the role of climate factors in association with spread of invasive <i>Phytophthora</i> species in forests and from urban landscapes.
2. Reporting year:	2016-2019

3. Project coordinator:	Michelle Cleary
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Activity report

4. Provide a project summary, including:
<p>a) The purpose of the project/main problems /hypothesis addressed</p> <p>Over the last decades, the prominence of <i>Phytophthora</i> tree pathogens in northern Europe has increased dramatically because of new introductions occurring through international plant trade, and because of climate change which can potentially favour its spread and development. In order to protect valuable resources in the Nordic region, more knowledge is needed about <i>Phytophthora</i> species affecting forest and urban trees, and factors affecting its behaviour. The project aims to contribute more understanding of the present distribution range and activity of <i>Phytophthora</i> species across the Nordic and Baltic regions in order to formulate optimal mitigation and management strategies to minimize losses to tree species of high economic and ecological importance.</p> <p>b) A short description of the main activities of the project</p> <p>Subproject 1: Mapping the distribution and diversity of <i>Phytophthora</i> species affecting host trees in forest and urban landscapes. The sampling, isolation and DNA analyses of samples collected from various plants/substrates has been a continuous effort alongside other research endeavors in each of the partnered countries, and has contributed greatly to more knowledge on which <i>Phytophthora</i> species occur where and on which hosts – an important benchmark for future predictions of the spread and impact to those hosts. Activities are summarized below for individual countries.</p> <p>In Sweden, knowledge has advanced regarding distribution and diversity of <i>Phytophthora</i> species as a result of surveys in protected and managed forest areas, nurseries, parks and urban landscapes, followed by baiting, isolation and DNA analysis of samples. This work has run in parallel to three other co-funded projects including a Citizen Science platform established for engaging the public to report the location of diseased trees. Several publications are now pending. Two Masters projects focusing on beech in protected and urban areas, respectively, has added to this work. Extensive engagement with the public and other stakeholder groups has been made to increase public awareness of the problem with <i>Phytophthora</i>.</p> <p>In Norway, a series of investigations have occurred: testing soil samples from garden waste deposited by rivers and forest edges; testing peat and soil products imported to Norway – import companies identified through The Norwegian Food Safety Authority; testing commercial bags of soil and peat mixes obtained from several garden centers (e.g. Plantasjen, Bauhaus); and testing soil landfill and soil production sites where many garden owners and landscaping businesses purchase soil in large quantity. Baiting and DNA sequencing of isolates have revealed presence of <i>Phytophthora</i> species, emphasizing the importance of this pathway and further work needed.</p> <p>In Finland, a single <i>P. uniformis</i> (-like) isolate was isolated from an alder seedling purchased for out-planting (this is the first detection of alder <i>Phytophthora</i> in Finland). Successful inoculation tests were performed on both alder and silver birch. Other relevant work is using next generation sequencing to look at how the mycobiome is affected and determine <i>Phytophthora</i> species presence in vole or mechanical damage, under two different experimental setups: i) Vole and mechanical damage affected silver birch and Norway spruce planted in a test field (analysis 10 years after the damage); ii) Vole damaged Norway spruce (6 years old) in the forest (analysis within four years after the damage). Analysis of the results are ongoing and results of each experiment are planned to be published separately. Furthermore, the group has collaboration with the University of Eastern Finland in a project to study</p>

the wood/plant distillates against tree pathogens including *Phytophthora*.

In Lithuania and Estonia, surveys were conducted related to the common project described below, but in addition, Estonian colleagues sampled from *Alnus* sp. *Betula* sp. and *Salix* sp. located along streams and rivers to determine presence of *Phytophthora* spp.

In Denmark, surveys in alder led to a new first report publication. Preparations were made for a *Phytophthora* survey in beech during 2018, using the National Forest Inventory teams; that would be followed up by testing bark samples from trees with symptoms using Diagnostic Kits *in situ*, and then positive samples taken to the lab for baiting and DNA extraction/analyses, and q-PCR to determine *Phytophthora* species present. Surveys and testing trees in forests and urban areas (including birch) are ongoing, though few positive samples have been found. Other work supporting the project includes a Bachelor project which developed maps of potential *P. ramorum* sites in Denmark using climate data for temperature and precipitation, and data on the distribution of *Larix* sp. and registration of *Rhododendron* sp. in nature. A *Phytophthora* info sheet was developed as well as an IPM manual for management of *Phytophthora* in forests. Public awareness spreading continues including presentations to gardeners/landscape practitioners on preventative measures against *Phytophthora* and other quarantine pests.

Sub-project 2: Characterizing *Phytophthora* populations across a soil-climate gradient in the Nordic-Baltic region.

A common research project was decided and initiated in 2016-2017, in accordance with the overall themed network project. In this project we use a DNA metabarcoding approach to determine *Phytophthora* communities across a soil-climate gradient in the Scandinavian-Baltic region, targeting two broadleaved host genera common to these regions, namely birch (*Betula* spp.) and alder (*Alnus* spp.), and in different site locations (forest and urban parks/amenity plantings). During 2017, a concerted effort was made by project participants to collect soil samples from forests and parks where birch and alder may be affected by *Phytophthora*. All samples were sent to SLU for DNA extraction and preparation for DNA sequencing. Samples were sequenced using the 3rd generation sequencing technologies - PacBio RSII Single Molecule, Real-time (SMRT®) DNA Sequencing System at SciLifeLab in Uppsala. A second meeting of the network was held in Tallin Estonia, in April 2018 to discuss the project results thus far and how to proceed further with the bioinformatics analysis of community sequence data, which is being led by the Estonia team. A research paper entitled "Oomycete diversity associated with *Betula* sp. and *Alnus* sp. across a soil-climate gradient in northern Europe" is now in the works and will be finalized and submitted during 2020.

c) Achieved targets and to what extent the research plan was fulfilled

The project has had two meetings which was in accordance with original plans/budget. The first kick-off meeting occurred in April 2016, in Malmö, Sweden. During that meeting country participants agreed to the continued work in individual countries (subproject 1) and the development of a new common research project (subproject 2 described above) which aligned well to the overall project theme to which most if not all partners would participate. In the second (and final) meeting of the network which occurred in April 2018 in Tallin, in the interim of that common sub-project 2, we reviewed the previous year's efforts and discussed the joint paper. It was agreed that the remaining activities within the network would continue and be finalized with publication of the common project, co-authored by all participants.

Besides the common project, immense efforts have gone into subproject 1 (described above), with dedicated efforts from network participants (up to 16 persons across the project period including senior scientists, students) advancing the knowledgebase of *Phytophthora* in their respective countries, and disseminating and communicating research results and general awareness to the public and stakeholders. To that end, a remarkable number of publishable and practical outputs have cumulated within the project period (See Sections 5 & 6).

Deviations from the project: At the 2nd network meeting in Tallin it was also discussed to conduct an assessment of the future risk for *Phytophthora* species in the Nordic-Baltic region in light of climate change and the larger overview of *Phytophthora* species distributions and diversity across the region. That work would rely heavily on baseline scenarios and knowledge of *Phytophthora* species distributions and host-tree associations, among other factors affecting tree vitality and spread. Incorporating the results of the two subprojects detailed above, and previous work generated from older network projects such as the "*Phytophthora-diseases of deciduous forest trees in Nordic and North-European regions*", and "*Preventative and restorative measures to reduce damage on forests – Phytophthora diseases in focus*", now provides a basis by which this work could move forward, mobilizing efforts amongst the network consortium for a larger meta-analyses. As sub-project 2 is based on data collected across a climate gradient in Northern Europe, aspects of future risk in terms of the *Phytophthora* populations present will be discussed the manuscript that is now in preparation.

5. Published outputs achieved as a consequence of the project (peer-reviewed articles, other publications)

Manuscripts in prep:

Drenkhan, R., Riit, T., Marčiulyrienė, D., Talgø, V., Poimala, A., Witzell, J., Uimari, A., Burokiene, D., Oliva Palau, J., Thomsen, I.M., Cleary, M. Oomycete diversity associated with *Betula* sp. and *Alnus* sp. across a soil-climate gradient in northern Europe. [aim to finish/submit in 2020]

Publications (peer-reviewed):

Cleary, M., Blomquist, M., Ghasemkhani, M., & Witzell, J. 2016. First report of *Phytophthora gonapodyides* causing stem canker on European beech (*Fagus sylvatica*) in southern Sweden. *Plant Disease*. 100:2174

Cleary, M., Blomquist, M., Vetukuri R.R., Böhlenius, H., & Witzell, J. 2017. Susceptibility of common tree species in Sweden to *Phytophthora cambivora*, *P. plurivora* and *P. cactorum*. *Pathology* 47: n/a, e12329. doi:10.1111/efp.12329.

Redondo, M.Á., Thomsen I.M., & Oliva, J. 2017. First report of *Phytophthora uniformis* and *P. plurivora* causing stem cankers on *Alnus glutinosa* in Denmark. *Plant Disease*. 101(3), 512.

Grenville-Briggs, L-J., Kushwaha, S.K., Cleary, M.R., Witzell, J., Chawade, A., Savenkov, E., Whisson, S.C., & Vetukuri, R.R. 2017. Draft Genome of the Oomycete pathogen *Phytophthora cactorum* Strain LV007 isolated from European Beech (*Fagus sylvatica*). *Genom Data* 12, 155–156.

Redondo, M.A., Boberg, J., Stenlid, J. & Oliva, J. 2017. Functional traits associated with the establishment of introduced *Phytophthora* spp. In northern forests. *Journal of Applied Ecology*. 55, 1538-552

Redondo, M.A., Boberg, J., Stenlid, J. & Oliva, J. 2017. Contrasting distribution patterns between aquatic and terrestrial *Phytophthora* species along a climatic gradient are linked to functional traits. *The ISME Journal*. 12, 2967–2980

Poimala, A., Werres, S., Pennanen, T., & Hantula, J. 2018. First Report of Alder *Phytophthora* Closely Related to *P. uniformis* on *Alnus glutinosa* seedling in Finland. *Plant Disease* 102(2), 454.

National Reports/Publications:

Burokiene, D. 2017. Annual Report 2016: Activities and Prospects. Institute of Botany at the Nature Research Centre, Lithuania.

Witzell, J., Cleary, M. 2017. Hantering av *Phytophthora* i sydsvenska lövskogar. SLU, Institutionen för sydsvensk skogsvetenskap. Alnarp 2017. 56 pp.

Talgø, V., Pettersson, M., & Brurberg, M. B. 2019. *Phytophthora*: Delrapport for 2018 i OKprogrammet «Nematoder og *Phytophthora* spp. i jord på importerte planter». NIBIO RAPPORT 5(62)

Talgø, V., Brurberg, M. B., & Pettersson, M. 2019. Kartlegging av *Phytophthora* i bøkeskogen i Larvik i 2018. NIBIO RAPPORT 5(63)

Talgø, V., Perminow, J. I. S., Pettersson, M., & Brurberg, M. B. 2019. Sjukdomar på tre i Oslo. NIBIO RAPPORT 5(78)

Talgø, V., Pettersson, M., Perminow, J.I.S., Magnusson, C., Blystad, D.R. & Brurberg, M.B. 2019. Norsk natur trues av fremmede plantesjukdommer. *Naturen* 6(143) 287-296

Thomsen, I.M.; Talgø, V. 2019. IPM forebyggelse af *Phytophthora* i skove. Videntjenesten for Skov og Natur, IGN. 11 pp.

6. Other practical outputs of the project (websites, policy recommendations, conferences, scientific meetings, large-scale project applications, research training etc.)

Conference Presentations:

Cleary, M., Witzell, J. "Citizen Science helps to combat invasive *Phytophthora* diseases in southern Sweden" in the session 'Early detection and monitoring of invasive forest pests and pathogens with citizen science'. IUFRO 125th Anniversary Congress, All Division 7 – Forest Health meeting. Freiburg, Germany, 19-22 September, 2017.

Redondo, M.A. Boberg, J. Stenlid, J. Oliva, J. "Traits associated with the establishment of *Phytophthora* in Scandinavia". IUFRO Working Party So7-02-09 *Phytophthora* in Forests and Natural Ecosystems, Hanoi-Sapa Vietnam, 18 - 25 March 2017

Redondo, M.A., Boberg, J. Stenlid, J. Oliva, J. "Monitoring *Phytophthora* species in river systems in Sweden by high throughput sequencing", IUFRO Working Party So7-02-09 *Phytophthora* in Forests and Natural Ecosystems,

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Hanoi-Sapa Vietnam, 18 - 25 March 2017

Blomquist, M., Witzell, J., Cleary, M. "Phytophthora affecting protected beech forests across Southern Sweden". IUFRO Working Party So7-02-09 Phytophthora in Forests and Natural Ecosystems, Hanoi-Sapa Vietnam, 18 - 25 March 2017

Cleary, M., Witzell, J. "Eyes on the Trees – Forest health monitoring a 'human' level". In the session: 'Forest health defenders: empowering citizens to protect forests through research contributions'. XXV IUFRO World Congress 2019. Curitiba, Brazil; 29 September – 5 October 2019.

Cleary, M. "Invasive Phytophthora pathogens in southern Sweden: distribution and diversity in urban forests and nurseries". IUFRO 7.03.04 Diseases and Insects in Forest Nurseries Working Party Meeting. Kuşadası, Turkey 21st - 26th of October, 2018

Witzell, J., and Cleary, M. "Phytophthora damage in deciduous forests of southern Sweden – from genes to landscape". XXV IUFRO World Congress 2019. Curitiba, Brazil; 29 September - 5 October 2019. [poster]

Cleary, M., Witzell, J. "Citizen Science helps to combat invasive Phytophthora diseases in southern Sweden" in the session 'Early detection and monitoring of invasive forest pests and pathogens with citizen science'. IUFRO 125th Anniversary Congress, All Division 7 – Forest Health meeting. Freiburg, Germany, 19-22 September, 2017.

Popular Science Articles:

Blomquist, M., Cleary, M., Witzell J. 2016. Phytophthora på frammarsch i sydsvenska lövskogar. Ekbladet. 31: p. 19-24

"Phytophthora - ett snabbt växande hot mot svensk skog"

http://www.mynewsdesk.com/se/sveriges_lantbruksuniversitet__slu/pressreleases/phytophthora-ett-snabbt-vaexande-hot-mot-svensk-skog-1938186

Student Theses

Blomquist, M. 2016. Invasive Phytophthora spp. affecting important broadleaved trees species in southern Sweden. Masters thesis. Southern Swedish Forest Research Centre, SLU Alnarp.

Van Tour, A., 2016. Invasive Phytophthora spp. affecting beech (*Fagus sylvatica*) in Söderåsen National Park. Masters thesis. Southern Swedish Forest Research Centre, SLU Alnarp.

Andersen, C.G. 2018. Risk Assessment of Spread and Establishment of *Phytophthora ramorum* in Danish Forests and Woodlands. Bachelor thesis, Institut for Geovidenskab og Naturforvaltning, Københavns Universitet. [In Danish with English Abstract and figure legends]

Other extension work:

A series of presentations, invited talks, and seminars have been given by the network members in various forums for stakeholders, associations, practitioners, inspections, excursion, educational seminars, other network meetings and in relation to Citizen Science initiatives. A list can be provided upon request.

7. How and within which areas was the project beneficial for the Nordic countries?

The project has helped fill knowledge gaps about occurrence of *Phytophthora* species in the Nordic-Baltic region including host-associations, and importantly – has allowed for the sharing of new knowledge amongst the participating researchers, including young stage researchers. The group has learned from each other in terms of their experiences in field sampling, baiting and isolation for species identification, and DNA metabarcoding for uncovering hidden *Phytophthora* diversity in environmental samples, as well as identifying new questions and knowledge gaps needing to be filled. The network's wide-ranging expertise with *Phytophthora* in nurseries, forests and urban environments and positive cooperation will facilitate further collaboration and research initiatives that work towards common solutions that help address this growing problem in Nordic countries.

8. Provide a short popular science piece of the project (maximum 500 words) for publication by SNS in various channels

Damage to trees in forests and urban environments caused by fungal-like, *Phytophthora* pathogens is on the rise in many parts of the world, including the Nordic countries. *Phytophthora*, which seriously damages the fine roots of trees, is effectively introduced to new environments through imported plant material (e.g. trees or other woody shrub or herbaceous plants in traded nursery stock) where its propagules can then escape into the surrounding

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environment via soil and water. Since trees have not coevolved together with these non-native pathogens, virtually all important forest and urban trees are susceptible. Climate change seemingly worsens this problem because it affects the way the pathogen interacts with the trees and the ability of trees to resist novel infections. One main hindrance to our ability to manage this problem is the difficulty of detecting infection in nurseries, the increased and unregulated transport of those plant goods/substrates, as well as nature tourism which contributes to the intensified spread of *Phytophthora* species. *Phytophthora* has a well-adapted life cycle, capable of spreading rapidly and efficiently, but also can survive longer periods under adverse conditions. Once *Phytophthora* has established itself in the soil, the possibilities of eradicating it are very limited.

Experience in other parts of Europe and the world clearly shows that *Phytophthora* pathogens pose a potentially serious threat to forest production as well as nature conservation; and this fact is becoming more prominently recognized in northern Europe. In order to proactively deal with this growing threat to the Nordic region, a consortium of researchers representing Nordic and Baltic countries have cooperated in the SNS-funded project "Assessing the role of climate factors in association with spread of invasive *Phytophthora* species in forests and from urban landscapes" that aims to gather better scientific evidence on the distribution and diversity of *Phytophthora* species affecting forests and landscape trees across these regions. The project is firmly anchored with the involvement of key experts working with *Phytophthora* in nurseries, forests, and urban environments and having close cooperation with the stakeholders (gardeners, landscape planners, forest owners, managers, and nature conservationists). The project's expected short-term impact is to provide a scientific basis for updating management and action plans to deal with this threat. In a longer time perspective, this may contribute to limiting the spread and intensity of *Phytophthora* damage in the Nordic region.

Participation

9. Number of participants

Country	Young researchers / PhD students	Senior researchers	Stakeholders	Others (specify)	Gender			Total
					Women	Men	Other	
Denmark		1		1 (Bachelor student)	1	1		2
Finland		2			2			2
Iceland								
Norway		1			1			1
Sweden	2	1	2	2 (Masters students)	3	4		7
Lithuania	1	1			2			2
Estonia	1	1				2		2
...								
Total	4	7	2	3	9	7		16

10. List the participating institutes/sectors

Swedish University of Agricultural Sciences (SWEDEN); Norwegian Institute of Bioeconomy Research (Nibio) (NORWAY); University of Copenhagen (DENMARK); Estonian University of Life Sciences (ESTONIA); Lithuanian Research Centre for Agriculture and Forestry (LITHUANIA); Institute of Botany – The Nature Research Centre (LITHUANIA), County Administration Board of Skåne (SWEDEN).

Economic report

11. Received grant from SNS in total (SEK):

Total grant awarded was 939 000 SEK. A surplus of 46 475,17 SEK from the previous SNS project coordinated by Johanna Witzell was applied to this project with permission (reference to first annual report, March 2017 where it is documented), thus bringing the total amount of funding from SNS to 985 475,17 SEK.

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12. Transfer of SNS funds to project partners

Country	Partner organization	Sum (SEK)
Denmark	University of Copenhagen	99000
Finland	LUKE	225000
Sweden	SLU (Uppsala)	25000
Norway	NIBIO	225000
Iceland		0
Other countries (specify)		0
Total SUM		574 000

13. Costs

	SNS funding	External funds*	Total*
Travel and hotel	49825		
Meeting costs	11834		
Consumables	41089		
Salary	141300		
Communication			
Consult	167427		
Total SUM (SEK)	411475	1923000	2863000

* If possible, provide details otherwise summarize the total sum for external funds and total.

14. Economic result (deficit or surplus):

There is no deficit or surplus funding.

Optional: Comments to the economic reporting:

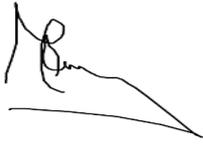
The costs for meetings was underestimated in the original application and some money was reallocated to cover travel and facilities costs. Consumables included materials (Pocket Diagnostic kits; DNA extraction kits) supplied to Baltic partners participating in the common project (sub-project 2), as well as costs for sample preparation for DNA sequencing at SLU. Consultancy costs include the PacBio sequencing of samples and bioinformatics. External funds supporting the project are stated here in accordance to the co-financing level determined in 2015 (at the time of application), but in the end the level of co-financing was even higher due to several newly funded projects during 2016-17, even if considering only that to main applicant (incl. a 3-yr grant from Swedish Research Council).

15. Submit a policy brief as a separate document. Provide pictures (size at least 500x500 pixels and resolution at least 72 pixels) as separate files (.jpg). Include caption to each picture, including the name of photographer.

I hereby declare that the above statements are true to the best of my knowledge

Signature of the project coordinator

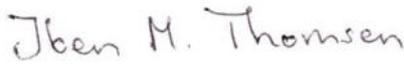
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	--- SLU Southern Swedish Forest Research Centre--	March 10, 2020
Signature	Institution	Date
---Michelle Cleary---		
Printed name		

Signature of the department head at the department of the project coordinator

	SLU Southern Swedish Forest Research Centre	10/03-2020
Signature	Institution	Date
Giulia Attocchi		
Printed name		

Second applicant's signature, place and date

	---University of Copenhagen-----	---10/03-2020-----
Signature	Institution	Date
---Iben M. Thomsen-----		
Printed name		

Third applicant's signature, place and date

	Natural Resources Institute Finland	March 3 rd 2020
Signature	Institution	Date
Anne Uimari		
Printed name		