

The Rufford Foundation Final Report

Congratulations on the completion of your project that was supported by The Rufford Foundation.

We ask all grant recipients to complete a Final Report Form that helps us to gauge the success of our grant giving. The Final Report must be sent in **word format** and not PDF format or any other format. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work. Please be as honest as you can in answering the questions – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please complete the form in English and be as clear and concise as you can. Please note that the information may be edited for clarity. We will ask for further information if required. If you have any other materials produced by the project, particularly a few relevant photographs, please send these to us separately.

Please submit your final report to jane@rufford.org.

Thank you for your help.

Josh Cole, Grants Director

Grant Recipient Details	
Your name	Jaime Moyano
Project title	What traits favor non-native Pine invasions in Patagonia? Tools for preventing future conservation problems
RSG reference	23089-1
Reporting period	September 2017 – September 2018
Amount of grant	£4940
Your email address	mjaime@agro.uba.ar
Date of this report	24/9/2018



1. Please indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achiev	Partial achiev	Fully achiev	Comments
	/ed	ly /ed	/ed	
Measure seed predation for different Pine species in north Patagonia				Predators consumed seeds of non- native pines selectively, preferring small seeded species. This results show that big seeded pine species represent a threat of invasion in this region, since a large proportion of their seeds survive predation by native rodents. Seed predators were mainly native rodents Oligoryzomys longicaudatus and Eligmodontia morgani.
Evaluate seed dispersal and seed predation at different distances from Pine plantations of the most widely planted Pine species in north Patagonia				I was able to assess seed dispersal and seed predation for two of the most widely planted pine species in north Patagonia: <i>Pinus ponderosa</i> and <i>Pinus</i> <i>contorta</i> . For <i>P. ponderosa</i> seed predation is higher than seed dispersal from 25 m from the pine plantation and at further distances. This result highlights the importance of focusing the monitoring and control of invasion in the first 25 m from the pine plantation edge. For <i>P. contorta</i> seed dispersal is higher than seed predation at all the distance range evaluated (from plantation edge to 200 m), highlighting the importance of monitoring and controlling pine invasion on at least the first 200 m from the pine plantation edge.
Evaluate the establishment rate for different Pine species in north Patagonia				I measured seedling emergence and survival for different pine species during a full growing season. I found that pines with larger seeds have higher emergence and higher survival under different biotic and abiotic conditions. My results show that pine species with large seeds presented a great risk of becoming invasive and should not be planted without monitoring. Further research is needed to assess the



Provide basic information that could		suitability of the pine species that show limited establishment (and, therefore, low invasion risk) for timber production in north Patagonia. Through this project we provided information that helps identify possible species for forestry in the region with
the negative impacts of forestry in north Patagonia		low risk of becoming invasive. Our findings also guide the monitoring and control of established pine plantations in the region in order to prevent invasions from spreading. We are still contacting different stakeholders to discuss possible ways to apply our results to help guide management.
Communicate the results of this project with the local community.		We were invited to a regional radio for an interview on our research project where I spoke of the implications of our results. We also visited a local primary school to organize a workshop with children, where we used games to describe our work and the importance of nature conservation. Furthermore, we participated on a workshop where many primary schools from Bariloche city were gathered and again through games we taught them about our research. We also participated in a workshop on management of invasive species, with multiple stakeholders of the forestry industry in Patagonia, where we had the opportunity to share our research. Finally, we organized our own workshop with all local stakeholders interested in the topic to present the findings of this project and discuss criteria for selecting pine species with low risk of invasions in future plantations in the region.
Communicate the results of this project with the scientific community.		We presented a seminar in the National University of Comahue showing our research project to students, professors and researchers from the University. We also shared some of the findings of this project in an international scientific meeting in Puerto Varas, Chile.



Publish the results of		We have submitted a manuscript to a
this project in a peer-		peer-reviewed international journal
reviewed international		(Oecologia), which is now under
journal and in a local		review. We are also working on another
journal		manuscript to submit to another peer-
		reviewed international journal
		(Biological Invasions) and a third
		manuscript to submit to a local journal
		(Ecologia Austral) to maximize regional
		readership.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled (if relevant).

I carried out a preliminary study before setting up the pine establishment experiments and found out that seed predation by native rodents was very high in the steppe ecosystem. This would affect our establishment experiments results because seed consumption would reduce seedling emergence. I took this opportunity to conduct two new experiments to evaluate pine seed predation as a barrier to pine establishment. In one experiment we compared seed predation levels between the different pine species of the establishment experiment to evaluate which species would be favored (by lower levels of seed predation). By offering seeds of different pine species and assessing the preference of native rodents we were able to determine which pine species represent a lower threat of invasion (since most of their seeds would be consumed by native seed predators). On the second experiment we evaluated seed dispersal and seed predation at different distances from pine plantations of the most widely planted species in the region: Pinus ponderosa and Pinus contorta. By evaluating the distance to which pine seeds survive predation I was able to determine the distance range with higher risk of invasion. The results from these two studies are critical to best inform pine plantation managers on where to focus control actions to stop invasions. The cost associated with these two experiments was very low because the seeds and materials needed were minimal and each experiment lasted only one month.

During 2017 and 2018 there was a big devaluation of the currency in Argentina. As a result, the cost of fuel, equipment, materials and hand labour increased significantly. Consequently, the Rufford funds deposited in our local currency were not enough to cover the original budget of the project. I also had to include rodent enclosures as an additional cost to prevent seed predation in the establishment experiment. This situation led us to decide to reduce the number of Pine species evaluated, from 18 to 14, in order to reduce the size of the establishment experiment and the associated cost (seeds, materials, etc.). Also to reduce costs I decided not to buy the photosynthetically active radiation sensor and, instead, borrowed one from a colleague.



3. Briefly describe the three most important outcomes of your project.

- 1. I found that native rodents play a key role reducing the number of pine seeds available for establishment. This ecosystem service highlights the importance of the conservation of these native small mammals. Special effort should be put to preserve these native rodent populations. I also found that pine species with larger seeds are less consumed by seed predators (Figures 1, 2 and 3). As a consequence, when using these species for forestry we should monitor plantations closely and control regeneration.
- 2. In addition, I found that pine species with larger seeds have higher rates of establishment in the Patagonian steppe (Figures 4, 5, 6 and 7). The basic knowledge obtained in our project can be applied to build criteria for selecting species for forestry in north Patagonia with a low risk of invasion. These results can guide us when evaluating new pine species for forestry in this region. Now that we know that big seeded species are more successful in the establishment phase of the invasion process we should take care not to use them for large scale plantation without close monitoring. Previous studies based on global databases have found that pine species with smaller seeds tend to be more invasive. A possible explanation is that small seeded species may be more successful by producing more seeds or dispersing them over longer distances. Further research is needed to evaluate seed production and dispersal of multiple non-native Pines in our study region. It is key to have information on the complete life cycle of pine populations in their invasive range to build models of population growth with which we can identify invasive species.
- 3. I found that for *Pinus ponderosa* seed predation overcomes seed dispersal at distances of 25 m and further from the pine plantation edge. This result indicates that *P. ponderosa* invasion is more likely in the first 25 m from the pine plantation. On the other hand, for *Pinus contorta* I found that seed dispersal is higher than seed predation from the pine plantation edge to a distance of 200 m. This result indicates that *P. contorta* invasion may occur far from the plantation edge. These findings may be applied to guide monitoring and control of old plantations. For *Pinus ponderosa* the pattern of seed survival to predators indicates that monitoring and control efforts should focus on the areas near the Pine plantation, reducing monitoring and control of invasion should be done covering a wider distance range.

4. Briefly describe the involvement of local communities and how they have benefitted from the project (if relevant).

We tried to maximise the involvement of the local community in our project and we had many successful experiences in this regard. The local radio of Bariloche city is engaged in informing the local community about the work of researchers and how common citizens can help conserve nature with their everyday actions. Hence, in every programme some recommendations are made. When I was interviewed I



used the opportunity to give some basic guidelines on how to avoid the negative consequences of invasive species. For example, I spoke of the benefits of using native plants species for ornamental purposes, or, when impossible, the use of noninvasive exotic plant species.

Local elementary schools put a lot of effort on teaching their students the value of nature and how to preserve it. During two workshops with elementary schools, we showed the children (through games and interactive material) real research projects oriented to preserve native species and ecosystems. Their teachers were very grateful because this experience was very valuable for the children and also for the teachers, who learned new things that they could include in their future classes. They explained us how children would go home and tell their parents about what they had learned, passing on our message to avoid planting invasive species.

The workshop that we coordinated with local forestry stakeholders was the perfect opportunity to engage with local foresters (Figures 8, 9 and 10). They were particularly interested in the study of new pine species for timber production and learned that research is needed to evaluate forestry species locally. We hope that our future lines of investigation will help local foresters to improve their activity, both in terms of reduced environmental impact and quality timber production. Local authorities of protected areas were also really interested in our results because they consider that this is very important to create guidelines such as invasive species lists and management plans to prevent and control invasions. At the end of the workshop we surveyed the perception of the different stakeholders on the impacts of forestry on native ecosystems. All were conscious on how pine invasions affect native species and were willing to cooperate in a unified effort to prevent and control future invasions.

5. Are there any plans to continue this work?

We have plans to continue this work on predicting pine invasions in Patagonia. To assess the risk of invasion for pine species that have not been planted on large scale in the region I can use simulation models that will help us estimate the probability of invasion on the long term (100 years). The objective of this second phase of our research is to build population growth models for multiple pine species that help us predict which ones will become invasive. With the data on seed predation and seedling establishment I can assess which pines are more successful during the early stages of invasion. The next step will be to collect information on the rest of the life cycle of pine populations in the region. The processes on which we are missing information are juvenile survival and seed production and dispersal of adult trees.

For juvenile survival I can continue our establishment experiment for another year.

For adult seed production and dispersal I can use an old long term experiment in which stands of 30 pine species were planted 100 years ago to evaluate forestry qualities. This experiment gives me the opportunity to assess parameters of the later stages in the life cycle of pine populations. With this information I will be able to



model the population growth rate of different pine species and assess the threat of invasion for each one of them.

Once we have assessed the risk of invasion in this region for the 30 pine species the next step will be to evaluate the wood production and timber quality of the species with low threat of invasion. The long term experiment mentioned was originally meant for the evaluation of multiple forestry species when this activity was only starting in the region. However, for different reasons forestry was developed using only very few pine species for which seeds were available at the time. Some data has been collected from this long term experiment but it has been hardly used to guide species selection for forestry in the region. We plan to measure stand height and diameter at breast height for all 30 species in the experiment to estimate annual wood productivity. We also plan to measure wood density for all species to estimate wood quality. In addition, we will survey disease and pest's incidence and severity on each stand to estimate susceptibility for each species. Finally we will match information on forestry suitability of the different pine species with their invasion threat in the region and will identify species that are both suitable for forestry and pose a low invasion threat. We believe that if we achieve our objectives both regional forestry and nature conservation will benefit from our research.

6. How do you plan to share the results of your work with others?

In November 2017 I presented some results of the seed predation experiments on a Congress in Puerto Varas, Chile (<u>http://www.biologiachile.cl/wp-content/uploads/2017/04/Afiche-Congreso-2017.pdf</u>). Many of the pine invasion problems we have in Argentinean Patagonia are the same in Chilean Patagonia, so many researchers and students were interested in our project and made many helpful comments and suggestions. In May 2018 I was invited to a regional radio for an interview on our research project. This was particularly useful because I was able to describe my work and make some recommendations for the locals regarding invasive plants and especially non-native pines.

Also in May 2018 I presented a seminar in the National University of Comahue showing my research project to assess which pine species are less likely to become invasive. The public of this meeting was mainly students, professors and researchers from the University. Again I received very valuable feedback on my research. I also visited a local primary school to organize a workshop with children, where I used games to describe our work and the importance of nature conservation. Furthermore, we participated on another workshop where many primary schools from Bariloche city were gathered. On this event our research group, together with many others, interacted with children of different ages to show them what we are working on and why it is important to fight invasive species and take care of native species and ecosystems.

Moreover, I participated in a workshop on management of invasive species, with multiple stakeholders: pine plantation owners, forestry extensionists, park rangers, national park technicians, researchers, students and government authorities. On this workshop we discussed the most important problems regarding regional invasive



species. Preventing non-native pine invasions was one of the priorities for many of the participants. This was a very good opportunity to share our research with the decision makers in the forestry industry and discuss ways of preventing pine invasions. Finally, I also coordinated our own workshop with local stakeholders that came from six different cities of north Patagonia (please see this blog from one of the participants: <u>http://patagoniaandinaforestal.blogspot.com/2018/08/taller-sobre-problematicas-</u>

<u>y.html?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+bl</u> <u>ogspot%2FmJfqL+%28Patagonia+Andina+Forestal%29</u>). The objective of this workshop was to share the findings of this project and discuss possible was of applying this knowledge to prevent and control pine invasions. We got very positive feedback on our work and discussed future research needs. In addition, I submitted a manuscript to a peer-reviewed international journal (Oecologia) with some of the results of this project. The manuscript is now under revision. Finally, I am working on another manuscript to send to a different international journal (Biological Invasions) and a third manuscript to submit to a local journal (Austral Ecology).

7. Timescale: Over what period was The Rufford Foundation grant used? How does this compare to the anticipated or actual length of the project?

The RSG was used from beginning of September 2017 to the end of August 2018, according to what we planned. The Rufford funding covered all the expenses for fieldwork during the complete duration of the project. As such the RSG was key to carry out our objectives.

8. Budget: Please provide a breakdown of budgeted versus actual expenditure and
the reasons for any differences. All figures should be in £ sterling, indicating the local
exchange rate used.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Photosintetically Active Radiaton (PAR) sensor	143	0	-143	After Argentinean currency devaluation and increase of costs we decided to prioritize fieldwork and did not buy this piece of equipment. Instead we borrowed one from a colleague
Field assistant (£43 per day for 40 days)	1733	1935	202	The fieldwork associated with the two seed predation experiments meant that we had to hire a field assistant for more days than initially planned.
Fuel (Field truck)	183	225	42	The fieldwork for the two seed predation experiments resulted in



				more trips with the field truck and an increase in the fuel consumed
Field truck maintenance	0	170	170	The field truck had a mechanical issue during the summer and we had to fix it to carry on with the fieldwork.
Field supplies: flagging, plastic trays, paper envelopes, water containers, etc.	81	78	-3	
Tools and materials: PVC tubes, wire, shade cloth, zip tags, coloured wire, etc.	1852	1480	-372	Reducing the number of Pine species in the establishment experiment reduced the cost of materials, specially PVC (which is the most important cost in this item)
Rodent enclosures	0	200	200	To prevent rodents from consuming the seeds in the establishment experiment we had to build enclosures using a metallic mesh.
Pine species seeds	948	850	-98	Reducing the number of Pine species in the establishment experiment reduced the cost in Pine seeds.
Total	4940	4938	-2	Rate of Exchange: 1£ ~ 48.68\$ Pesos Argentinos

9. Looking ahead, what do you feel are the important next steps?

The first step would be to use what I learned about the most widely planted pine species in Patagonia and build regulations that help stop pine invasions. One such regulation would make foresters responsible for the monitoring and control of the invasions that are originated on their plantations. A systematic check on the area of influence of each plantation every two years would help identify invasions earlier, when control is more effective and with lower costs. In this regard, the area of influence of *Pinus ponderosa* would be only 25 m from the plantation edge, while for *Pinus contorta* would be at least 200 m from the plantation. After detecting spontaneous regeneration the forester should be responsible for cutting out the seedlings when they are most vulnerable. However, it will be very difficult that foresters cover the cost of monitoring and control of pine invasion because forestry is not such a profitable activity in Patagonia nowadays. The government, which already subsidises pine plantation costs, should also subsidise the control of pine invasions.

Another important step would be to collect information of important processes after seedling establishment: juvenile survival, adult seed production and dispersal for multiple pine species. With this information, together with what we have already learned about seed predation and seedling establishment we could model population growth for each species. This would give us a clear idea of the invasion



threat of each species. Then would come the evaluation of growth rate and wood quality of non-invasive pines to assess their suitability for forestry. With all this information the government should build incentives to promote the use of non-invasive pines that grow well in the region and have good wood quality. This would not only favour the conservation of native ecosystems in Patagonia but would also benefit forestry in the region.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did The Rufford Foundation receive any publicity during the course of your work?

I used The Rufford Foundation logo when I presented results of the seed predation experiments in the Congress of Puerto Varas (Chile). I also used the logo on the seminar I presented in the National University of Comahue. Finally, I used the logo in the workshop we organized with forestry local stakeholders from north Patagonia and on this opportunity I thanked Rufford for all their support. Moreover, I acknowledged the funding from the Rufford Foundation in the manuscript that I have submitted to the peer-reviewed international journal and will do the same in the two manuscripts that we are working on.

11. Please provide a full list of all the members of your team and briefly what was their role in the project.

The team of this project is integrated by Jaime Moyano (JM), Martin Nuñez (MN) and Mariano Rodriguez-Cabal (MRC). JM is the leader of the team. JM, MN and MRC conceived the ideas in this project and JM designed the experiments to test them, with the help of MN and MRC. JM carried out the field work, and collected the data with the help of a field assistant. JM led the writing of all three manuscripts with the results of the project. MN and MRC revised the manuscripts and made comments to improve them. JM was responsible for sharing the results in the local community and the scientific community, with help from MN and MRC.

12. Any other comments?

We would like to thank the Rufford Foundation for the grant received. The RSG was key for the realization of this project. Without the support from the Rufford Foundation we would not have been able to achieve our objectives. We want to highlight that the workshop that we organized with local stakeholders in the forestry industry was a success and would not have been possible without the support from Rufford. We believe that the Rufford Foundation plays a very important role funding research in developing countries, where research is most needed and economic resources are usually scarce. I hope to apply again for a RSG in the near future.











Figures 3 & 4





Figures 5 & 6





Figures 7 & 8





Figures 9 & 10