

The following text is a transcript to help increase the accessibility of our presentation. Text for all narration is in the order it appears in the presentation, and is grouped by slide.

TITLE SLIDE

Slide 1. Hello everyone. My name is Trevor Drees and today, I will be presenting to you some of my recent research on how increased temperatures shift flower height distributions and seed dispersal patterns in two invasive thistles.

BACKGROUND AND INFORMATION

Slide 1. First, I will start by offering some background on dispersal and climate change, as well as what the goal of our study is.

Slide 2. What is dispersal? Simply put, it is any movement of organisms that can possibly generate gene flow.

Slide 3. Why should we quantify dispersal? There are several good reasons to do so, most of which are related to explaining the movement of genes, individuals, populations, species, and communities.

If we seek to quantify the spread of a given species, particularly an invasive, we're often interested in estimating a spread rate, understanding the life stages that contribute the most to said spread, and understanding the agents that most strongly drive dispersal.

All in all, we care about quantifying dispersal because a better understanding of dispersal in invasive species can help us make more informed management decisions that save time and money.

Slide 4. Quantifying dispersal is already challenging enough, and is further complicated by the fact that climate change can alter patterns of dispersal by affecting dispersal-related factors such as temperature, precipitation, wind speeds, and frequency of extreme events.

For example, consider a wind-dispersed plant like the one shown in the picture here.

Increases in temperature and precipitation can enhance plant growth, leading to taller flower heights. This increase in seed release height means that seeds will be suspended in the air for longer and can be blown further by wind.

Increases in wind speed also means that seeds can be blown further by wind.

Increases in the frequency of extreme events can also affect seed dispersal; storms with strong winds can cause seeds to travel extremely long distances, which may become more common if extreme storms become more frequent.

Given that climate change can cause shifts in several different climatic aspects, our research narrows this down and examines changes in dispersal arising specifically from increases in temperature.

Slide 5. The goal of the research described in this presentation is to use empirical data and mechanistic models to predict how climate change will alter dispersal patterns in invasive plant species. In doing so, we focus on changes in temperature and its effects on seed release height, a key determinant of dispersal distance.

However, because not all species will exhibit the same responses to temperature increases, we need to be specific about which species we're working with, and use it as a case study to inform possible dispersal changes in similar species.

STUDY SYSTEM AND METHODS

Slide 1. So now, let's take a look at the study system we are using, as well as the methods used to quantify dispersal and how temperature increases affect it.

Slide 2. The two species we will use for our study system are *Carduus nutans* and *Carduus acanthoides*. Both of these are invasive thistles often found in highly disturbed areas such as roadsides and pastures.

Slide 3. While these two invasive species are of Eurasian origin, they can be found in many places outside their native range, and have been reported in a large number of U.S. states and Canadian provinces.

Slide 4. Both thistle species are dispersed by seed, with seeds displaying a smooth elongated achene and a small elaiosome at the end. The elaiosome is particularly attractive to ants and plays a role in ant-mediated seed dispersal.

Slide 5. Wind is the primary dispersal vector for these thistle seeds. They are often blown out of the flower head after a gust of wind, as can be seen in the photo here. The seeds are small and are carried in the wind due to their lightweight pappus, the small feathery structure on top of the seed. This pappus allows seeds to stay suspended in the air for significantly longer, increasing the time that they are exposed to wind and thus the distance they travel.

So, we know that wind is the primary dispersal vector, but how can we model it?

Slide 6. We can actually simulate wind dispersal using an inverse Gaussian distribution based on a fluid dynamics model, and obtain the probability of a seed travelling a given distance.

This $p(r)$ is a dispersal kernel, or probability distribution, for a seed travelling some distance r from release.

The dispersal kernel here is dependent upon a variety of parameters including wind speed, seed terminal velocity, and seed release height.

Slide 7. This model of wind dispersal has actually been tested in several systems for various wind-dispersed plant species, including *Carduus nutans* and *acanthoides*. Previous work with these two thistle species compares this model against empirical data from seed traps and demonstrates that this model can accurately model dispersal in this system.

Slide 8. So, we have our dispersal model now. But how do we incorporate climate change into this model?

To do so, we use a field experiment to examine the effects of warming on flower head height, a key determinant of dispersal distance.

In this experiment, for each species, we randomly assigned half of the plants translucent open-top fibreglass chambers, which increase the ambient temperature by approximately 0.6 degrees Celsius without affecting other environmental conditions.

Slide 9. Previous studies have actually shown, at least in *Carduus nutans*, that warming increases plant height and shifts dispersal kernels to the right, leading to longer dispersal distances being more common. However...

We don't know if the same thing happens for *Carduus acanthoides*, as previous studies have not examined that. Also, previous studies have only considered seed release as a single point source at the maximum flower height; what about all of the other release heights?

Slide 10. If we use the maximum height like previous studies did, we're only considering a single point of seed release on a given plant.

But in reality, seeds are released from other flowers on the same plant too. So the question here is how does the dispersal kernel change when we account for those other seed release heights?

To address this, we integrate across the distribution of flower heights, $p(H)$, to account for dispersal from flower heads across the entire plant.

Slide 11. So, considering how warming affects seed release height, which in turn affects dispersal distances, as well as how our estimates of dispersal distances can change if we use the distribution of flower heights rather than just the tallest one, we seek to address three questions with this research. First, how does increased temperature affect the distribution of flower heights, and thus seed release heights? Second, how does increased temperature affect dispersal distances over the distribution of flower heights? And third, are there differences in dispersal when using the distribution of seed release heights rather than the maximum height?

RESULTS

Slide 1. Now, we take a look at the results from the warming experiment and dispersal simulations.

Slide 2. First, how does increased temperature affect the distribution of flower heights, and thus seed release heights?

Slide 3. Our results indicate that warming increases mean flower head height in *Carduus nutans* and *acanthoides*. In *Carduus nutans*, warming increased mean flower head height by 14.2%; in *Carduus acanthoides*, warming increased mean flower head height by 33.1%. Similar percent increases were also observed in maximum flower head height for each species, respectively.

As can be seen in the figure here, the distribution of flower head heights are significantly different when examining warmed and unwarmed individuals within each species, with warming causing the distribution to shift to the right.

Slide 4. It is clear that warming shifts the distribution of flower head heights across the entire plant to the right. How does this shift affect dispersal, though?

Slide 5. We observe that in addition to the distribution of flower head heights, dispersal kernels also shift when comparing warmed individuals to unwarmed individuals. For both *Carduus nutans* and *acanthoides*, differences between the warmed and unwarmed dispersal kernels are statistically significant; they are indeed two distinct distributions. For the warmed dispersal kernel in each species, the peaks of the kernel decrease while the rest of the kernel shifts to the right; shorter dispersal distances become less common, while longer dispersal distances become more common.

Note that while differences between the kernel tails are small in absolute terms, they are actually much larger in relative terms.

Slide 6. And we can see that here. The figure on the left shows that the chance of a seed from a warmed plant exceeding a given distance relative to the chance of a seed from an unwarmed plant exceeding that same distance increases as the distance in question increases. For example, seeds from warmed *Carduus acanthoides* are 1.71 times as likely to travel 10 metres or more and 2.41 times as likely to travel 50 metres or more than seeds from unwarmed *Carduus acanthoides*.

Note that the bootstrap intervals in our figures grow larger for longer dispersal events. Part of this is because we incorporate variability in wind speed and seed terminal velocity into our analyses, so we're bound to see more variability in long-distance dispersal in the first place. Also, long-distance dispersal events are rare and difficult to capture, both in simulations and in nature.

Slide 7. So, we see that warming not only shifts the distribution of flower head heights, but also dispersal kernels. But does it really make a difference if we use the distribution of flower head heights instead of just using the maximum head height like previous studies did?

Slide 8. For each combination of species and warming treatment, differences between kernels constructed using the flower head height distribution and maximum flower head height are statistically significant; they are indeed two distinct distributions.

However, the shifts do not appear to be drastic, at least upon a brief visual inspection, but these shifts are similar to what we saw earlier: the peaks of the kernel decrease while the rest of the kernel shifts to the right. Again, note that while differences between the kernel tails are small in absolute terms, they are actually larger in relative terms.

Slide 9. And we can again see that here. The figure on the left shows that the chance of a seed from the maximum flower head height exceeding a given distance relative to the chance of a seed from the flower head height distribution exceeding that same distance increases as the distance in question increases. For example, seeds from unwarmed *Carduus acanthoides* are 1.34 times as likely to travel 10 metres or more and 1.59 times as likely to travel 50 metres or more when using maximum flower head height rather than the flower head height distribution.

The bootstrap intervals in our figures increase in size for longer dispersal events. In this case, the intervals become so large that for longer dispersal distances, it becomes difficult to say whether or not there is a significant difference between using maximum flower head height rather than the flower head height distribution.

DISCUSSION

Slide 1. So, what can we take away from our experiment and analyses?

Slide 2. Our study is the first to examine the distributions of seed release heights over the entire plant for *Carduus nutans* and *Carduus acanthoides*, and how warming affects those distributions.

We demonstrate that warming increases the mean flower head heights for *Carduus nutans* and *acanthoides*, and shifts the distributions to the right.

Slide 3. We also demonstrate that warming changes the shape of the dispersal kernel.

Our results show that even when using the entire flower head height distribution instead of the maximum flower head height, warming shifts the dispersal kernel to the right and makes the tail larger; dispersal at shorter distances becomes less common, while dispersal at longer distances becomes more common. We see a similar effect when using the maximum flower head height rather than the distribution of flower head heights.

Slide 4. And we demonstrate that even though the tails of the dispersal kernels may not look that different, even minor differences in these tails can affect dispersal distances. Seeds from warmed parent plants are more likely to exceed a given dispersal distance than those from their unwarmed counterparts.

However, the uncertainty surrounding longer distance dispersal events is quite high, as these events are rare and difficult to detect. When looking at dispersal using the maximum flower head height rather than the distribution of flower head heights, this uncertainty is so great at longer distances that it becomes difficult to discern a significant difference.

Slide 5. It's these long-distance dispersal events at the tails of the distribution that are highly influential in how a population moves across the landscape; models of population spread are often sensitive to these rare events. Sometimes, all it takes is one seed to start a new colony several hundred metres away from the main population.

Thus, warming-induced increases in the frequency or magnitude of long-distance dispersal events could very well increase spread rates.

Slide 6. And these results have implications for weed management. As warming leads to greater dispersal distances, the spread of weeds will be more challenging to contain. Knowing how invasive plants respond to warming can help us continue effective management in future climates, and be better equipped to handle effects of warming-induced phenological changes in invasives that we manage.

REFERENCES

Slide 1. Listed here is the literature referenced in this presentation.

END OF SHOW

And that concludes the presentation. Thanks for watching!