# Increased temperatures shift flower height distributions and seed dispersal patterns in invasive thistles

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Background & Introduction

Study System & Methods

Results

Discussion & Conclusions


Image source: O. Skarpaas


Image source: brc.ac.uk


Image source: web.ewu.edu

# Background & Introduction

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# What is dispersal?

Image source: pbs.org

Image source: Wikipedia

Any movement of organisms that can possibly generate gene flow.

# Why quantify dispersal?

*We can do a better job of…*

Understanding how species distributions shift

Understanding gene flow between populations

Making predictions regarding the spread of invasive species

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*… which entails …*

Predicting how quickly invasive species spread

Understanding which life stages contribute most to dispersal

Understanding which agents most strongly drive dispersal

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Understanding which life stages contribute most to dispersal

Understanding which agents most strongly drive dispersal

*A better understanding of dispersal in invasive species can help us make more informed management decisions that save time and money*

# Climate change may affect dispersal


Climate change has the potential to affect dispersal of organisms, either by directly affecting dispersal vectors or indirectly by affecting dispersal-related factors.

This includes:

- Temperature
- Precipitation
- Wind speeds
- Frequency of extreme events

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Wind-dispersed invasive species!

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Could affect growth; seeds released higher and travel further

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- Precipitation
- Wind speeds Faster wind blows seeds further
- Frequency of extreme events

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Extreme wind events can carry seeds very long distances

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# Research goal


Image source: O. Skarpaas

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Not all species will exhibit the same responses to temperature increases, though.

We need to choose a species to use as a case study…

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# Study system: invasive thistles

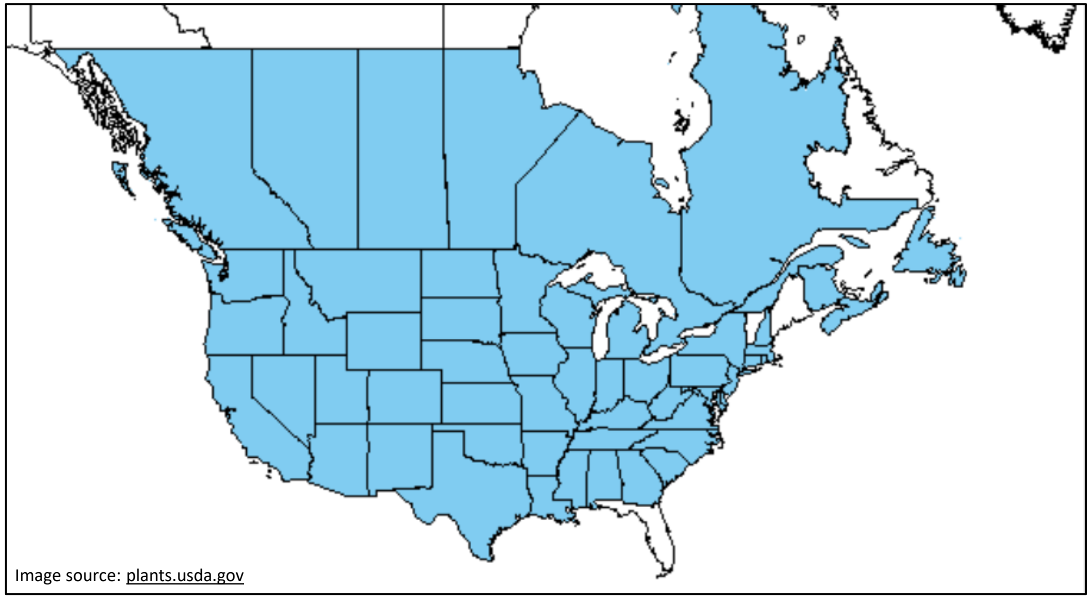
*Carduus nutans*


“musk thistle”, “nodding thistle”

*Carduus acanthoides*


“plumeless thistle”, “spiny plumeless thistle”

## *Carduus nutans*

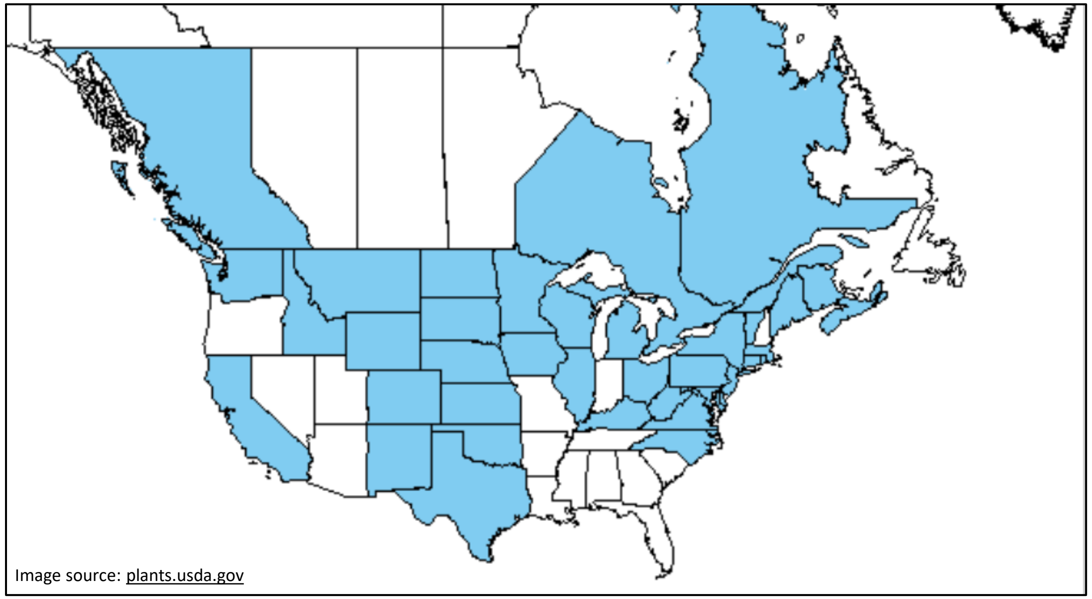



Introduced

- U.S. (All states except AK, FL, HI, ME, VT)
- Canada (All provinces except NT, NU, PE, YT)
- South America (Chile)
- Africa (South Africa)
- Australia and New Zealand

*Native to Europe and Central Asia*

## *Carduus acanthoides*




Introduced

- U.S. (33 states)
- Canada (BC, NB, NS, ON, QC)
- South America (Argentina, Uruguay)
- Africa (South Africa)
- New Zealand

*Native to Europe and Central Asia*

Seeds are the propagules through which these thistles are dispersed.

Image source: T. Drees


Image source: inspection.gc.ca

*Carduus nutans*

*Carduus acanthoides*


Image source: inspection.gc.ca

Wind is the primary dispersal mechanism.

Image source: O. Skarpaas

Image source: T. Drees

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*But how do we model this dispersal?*

Wind dispersal can be simulated using an inverse Gaussian distribution based on a mechanistic fluid dynamics model:

$$p(r) = \sqrt{\frac{\lambda}{2\pi r^3}} \exp\left(-\frac{\lambda(r-\mu)^2}{2r\mu^2}\right)$$

Katul *et al.* 2005, Skarpaas and Shea 2007

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***Dispersal kernel*** giving probability density for a seed travelling distance *r* from release

***Scale parameter*** from:

- Mean wind speed
- Wind measurement height
- Vegetation cover characteristics
- Seed release height

***Mean/location parameter*** from:

- Mean wind speed
- Seed release height
- Seed terminal velocity

Katul *et al.* 2005, Skarpaas and Shea 2007

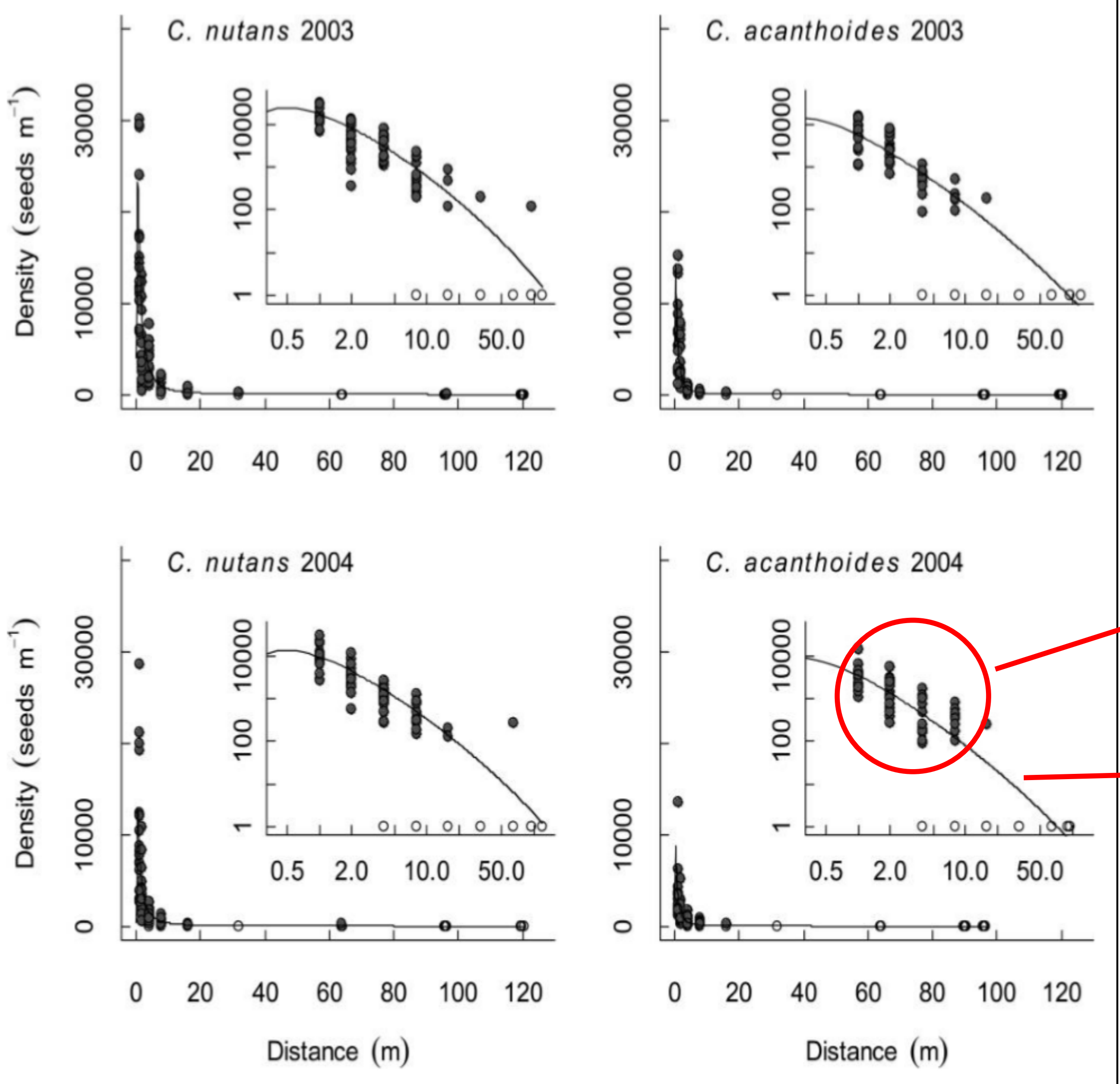

Image source: Skarpaas and Shea (2007)

This wind dispersal model has been tested in several systems, including in *Carduus nutans* and *Carduus acanthoides*, and can quantify dispersal reasonably well.

Densities of seeds collected using seed traps

Predicted seed density based on mechanistic dispersal model



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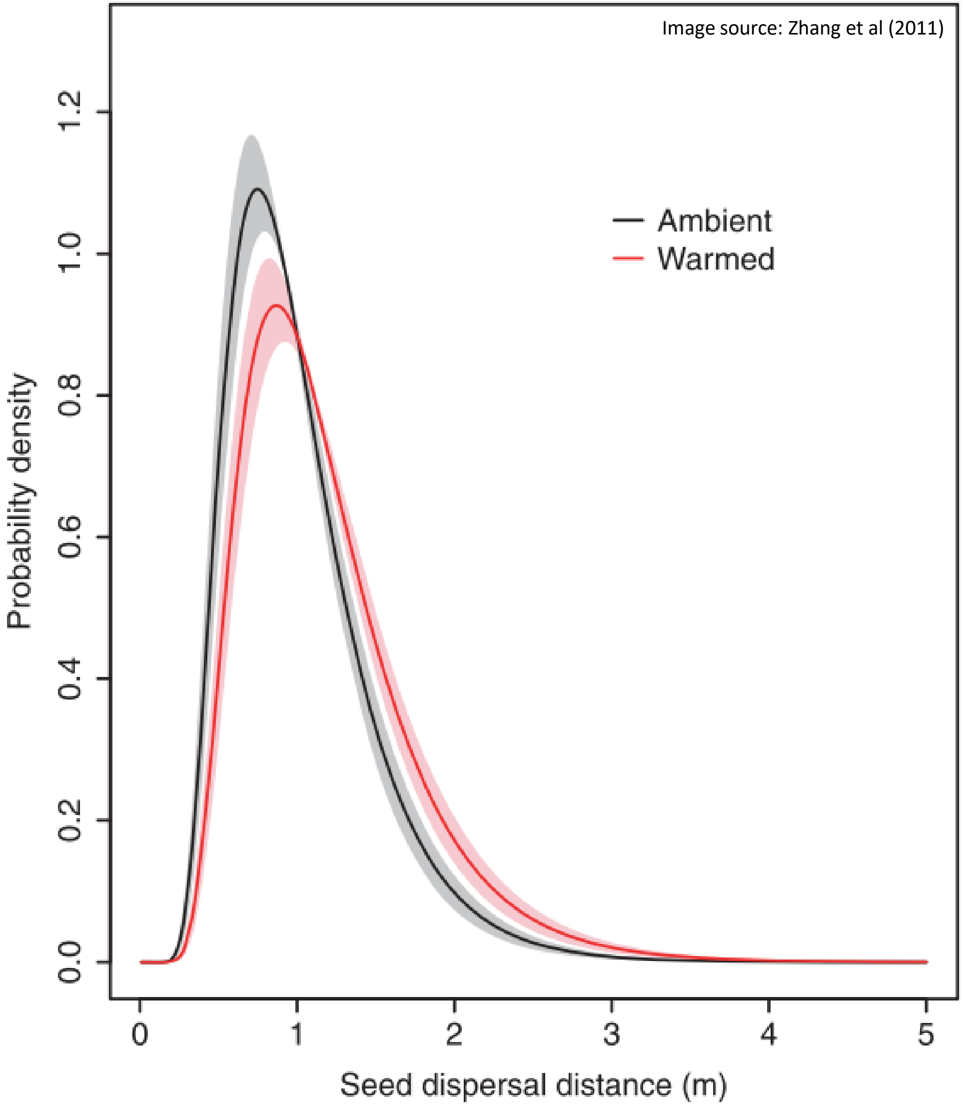
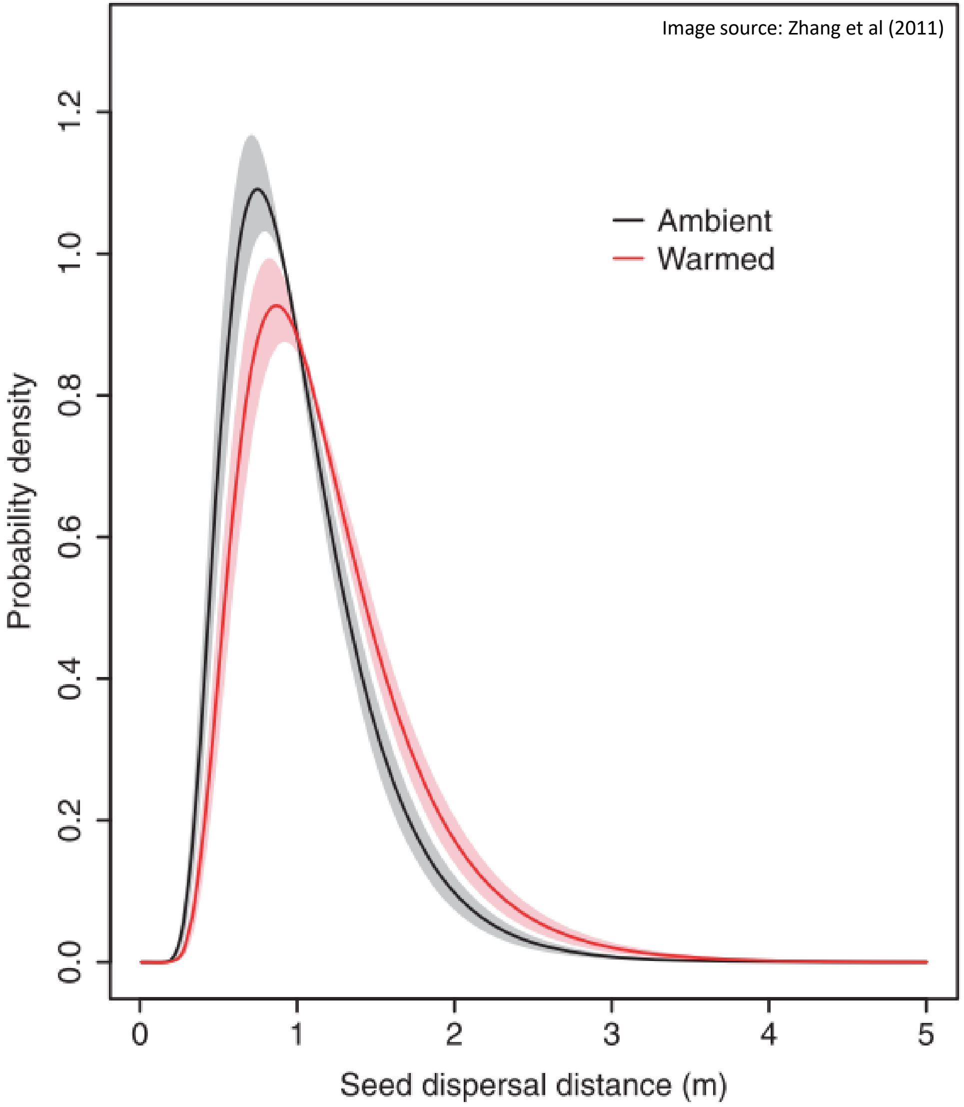
For treatment blocks of *C. nutans* and *C. acanthoides*, half the individuals were grown in a fibreglass open-top chamber. These chambers simulate a 0.58 °C average increase in ambient temperature, and do not affect soil moisture or snow depth (Zhang *et al.* 2011). Chambers were places around the thistles in the autumn and remained for the duration of the experiment.




Previous studies have shown that, at least in *C. nutans*, that warming increases plant height and shifts dispersal kernels to the right. However…




Previous studies have shown that, at least in *C. nutans*, that warming increases plant height and shifts dispersal kernels to the right. However…

This is not as clear for *C. acanthoides.*

Also, previous studies have only considered seed release as a single point source at the maximum flower height; what about other release heights?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$$k(r) = \int p(r)p(H)\, dH$$

# Research questions

1. How does increased temperature affect the distribution of flower head heights (and thus seed release heights)?

2. How does increased temperature affect projected dispersal distances over the distribution of flower head heights?

3. Are there differences in projected dispersal when using the distribution of seed release heights rather than the maximum height?

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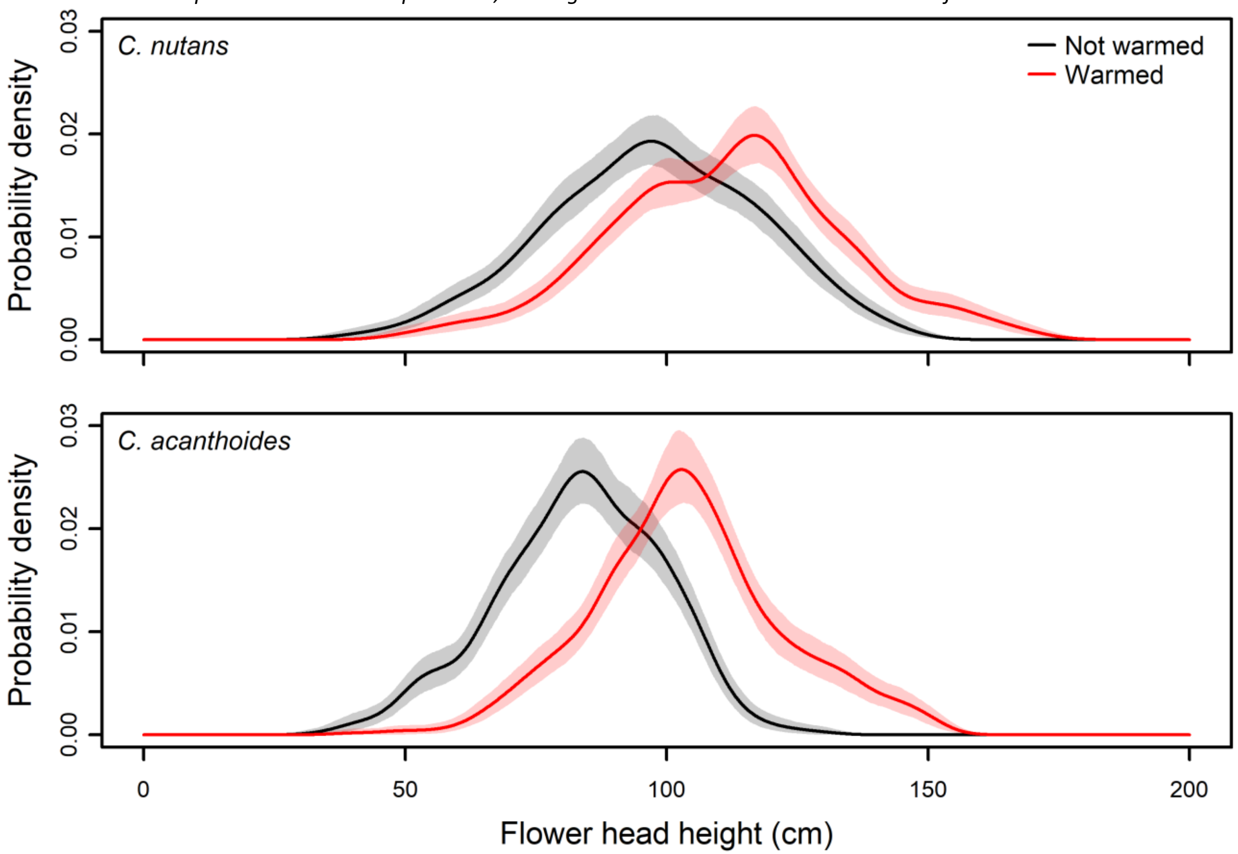
***For each species, warming results in a rightward shift in flower head height distribution…***

**Bands represent 95% bootstrap interval; Kolmogorov-Smirnov test used to determine if distributions are distinct*




Warming increased mean *C. nutans* flower head height by 13.5 ± 3.7 cm, or 14.2% (GLM, $n = 1402$, $p < 0.001$).

Warming increased mean *C. acanthoides* flower head height by 26.0 ± 3.5 cm, or 33.1% (GLM, $n = 1519$, $p < 0.001$).

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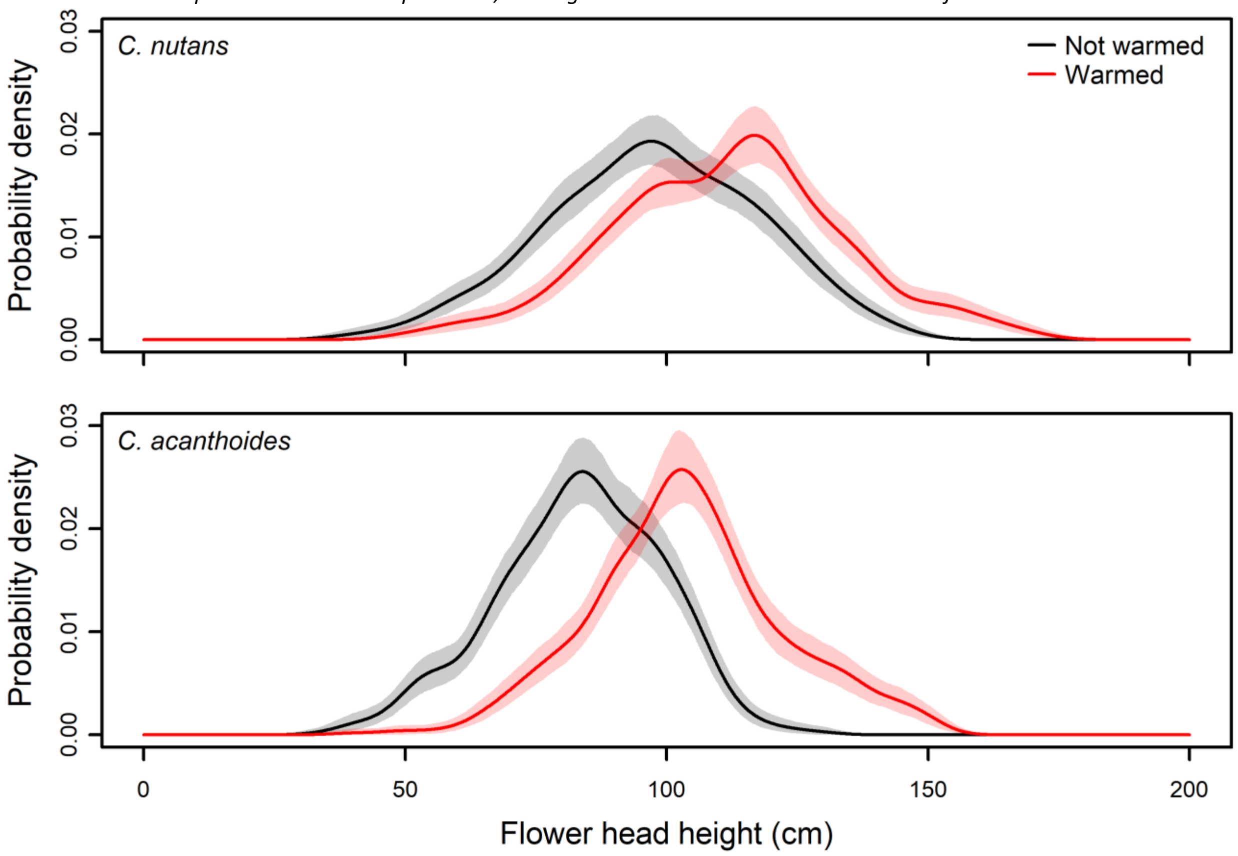


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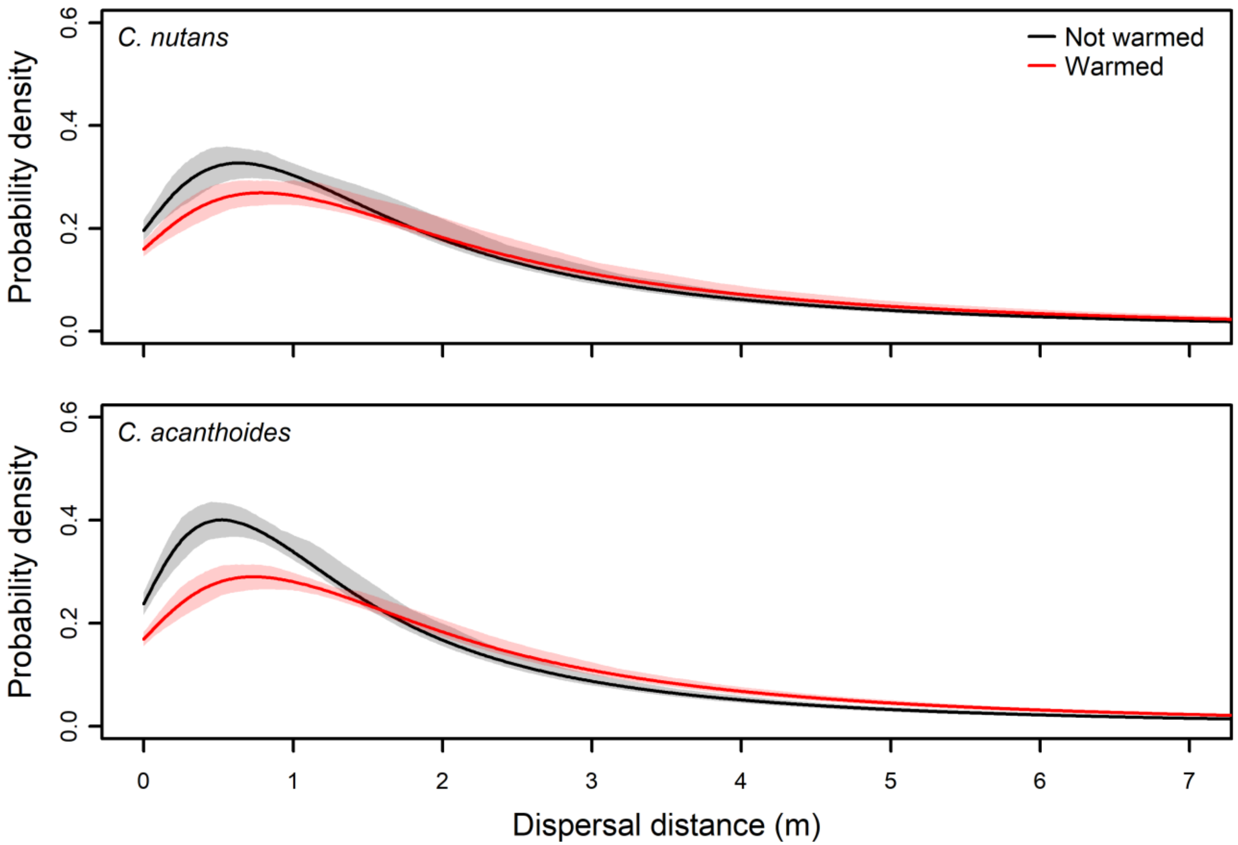


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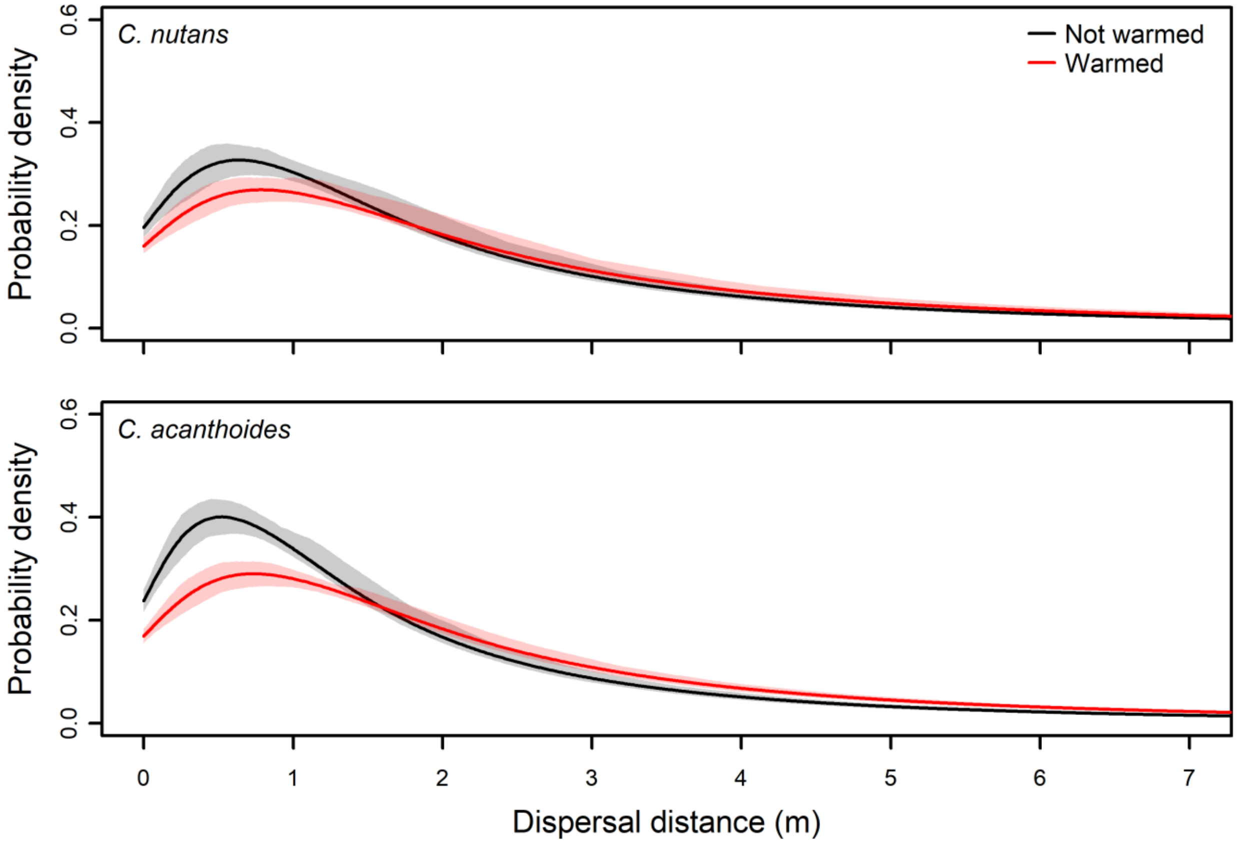


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Differences between the kernel tails may appear small, but are actually very important and can have significant impacts…

## *For each species, height changes from warming increase the relative probability of dispersed seeds exceeding a given distance…*

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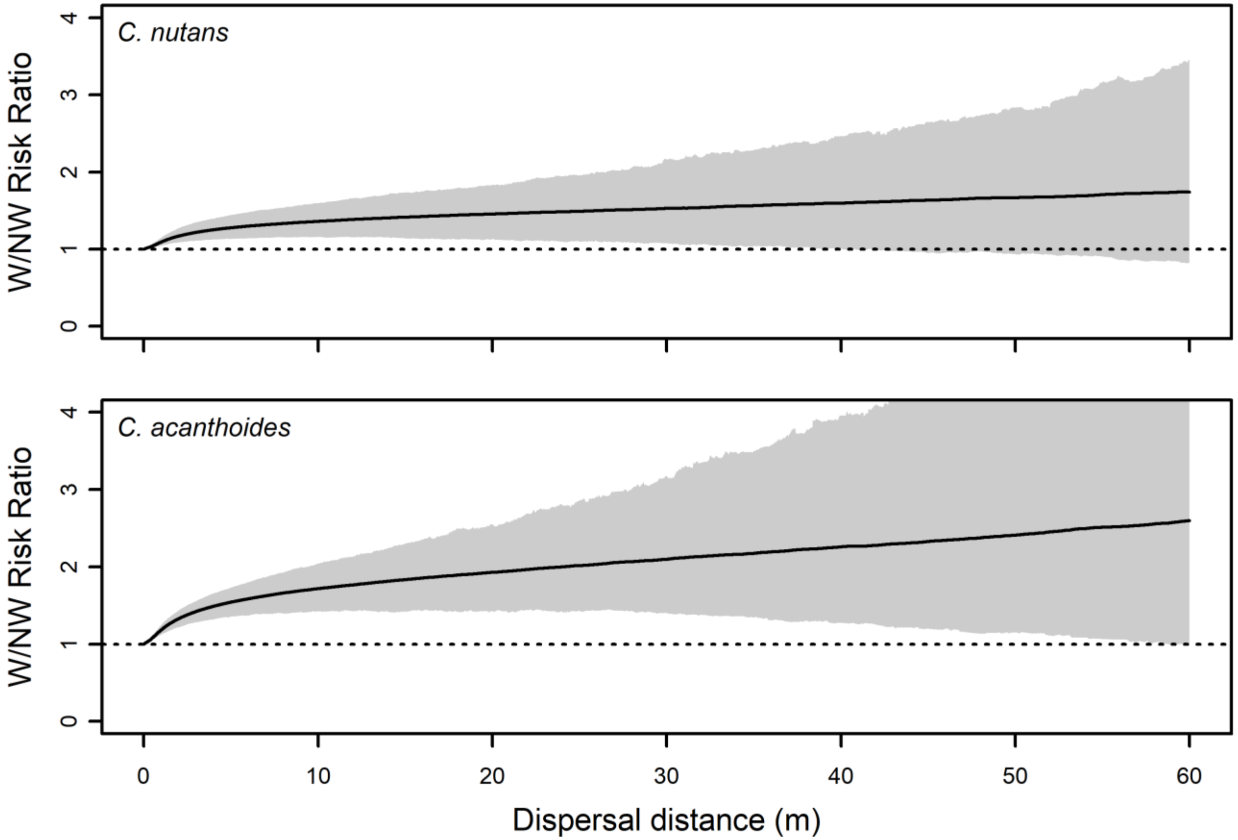


For both *C. nutans* and *C. acanthoides*, the relative chance of a propagule exceeding a given distance when originating from a warmed plant rather than an unwarmed one increases notably with increasing dispersal distance.

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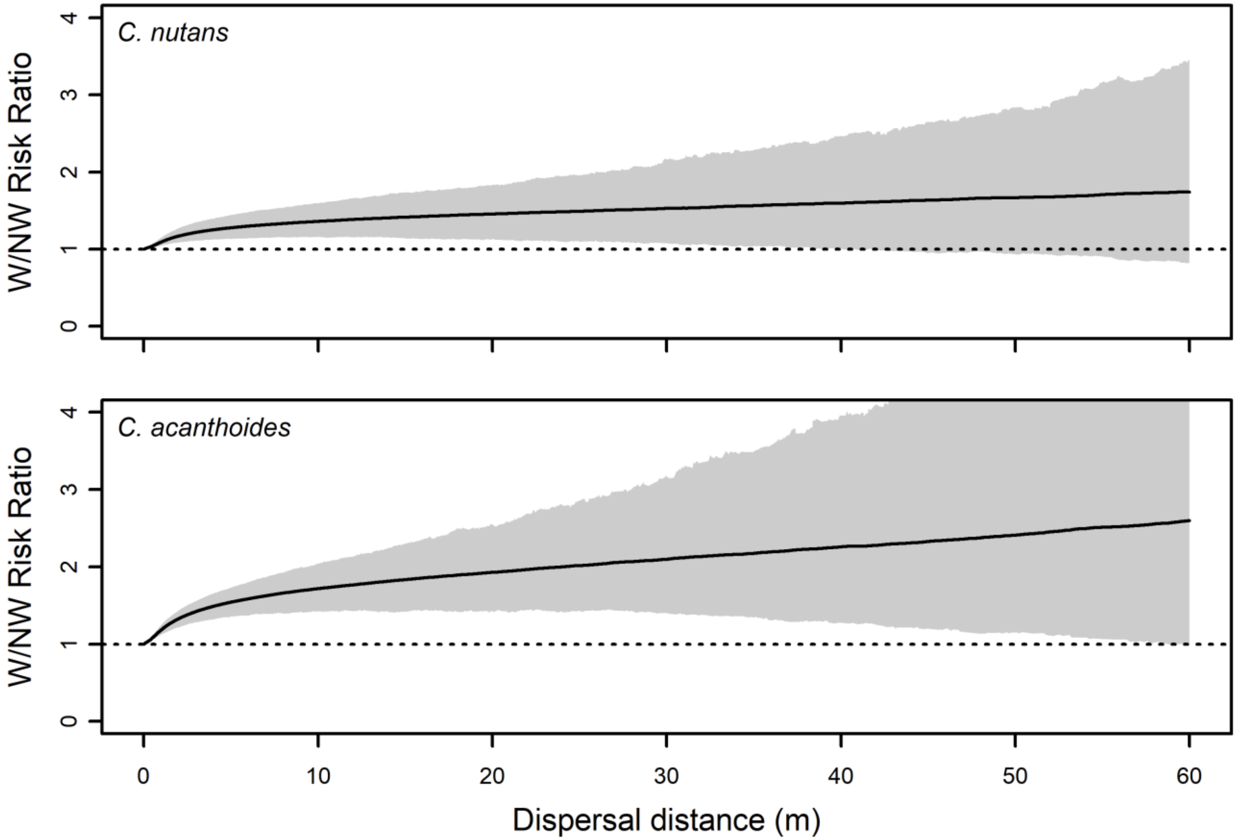


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Uncertainty in this risk ratio becomes high at longer dispersal distances.

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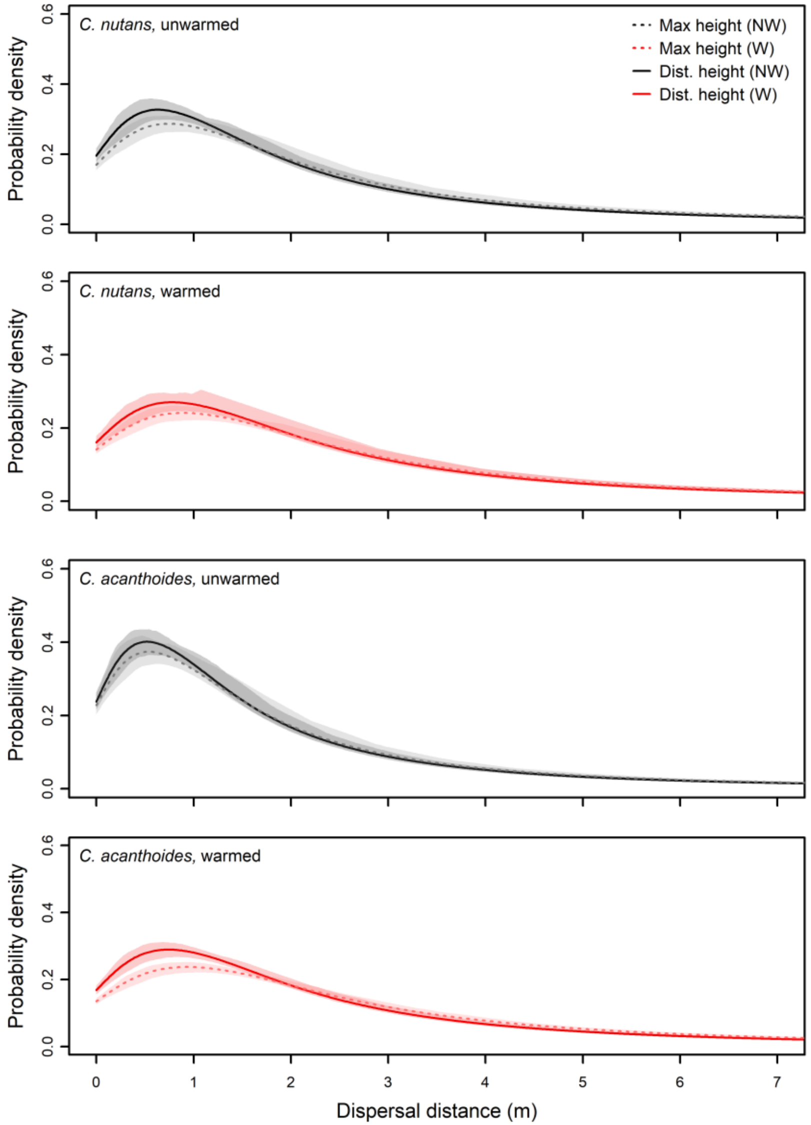


***Using the flower head height distribution instead of maximum flower head height results in a different dispersal kernel…***

For each combination of species and warming treatment, dispersal kernels using the height distribution of flower heads were different than those using only the maximum flower head height (K-S test, $p < 0.001$).

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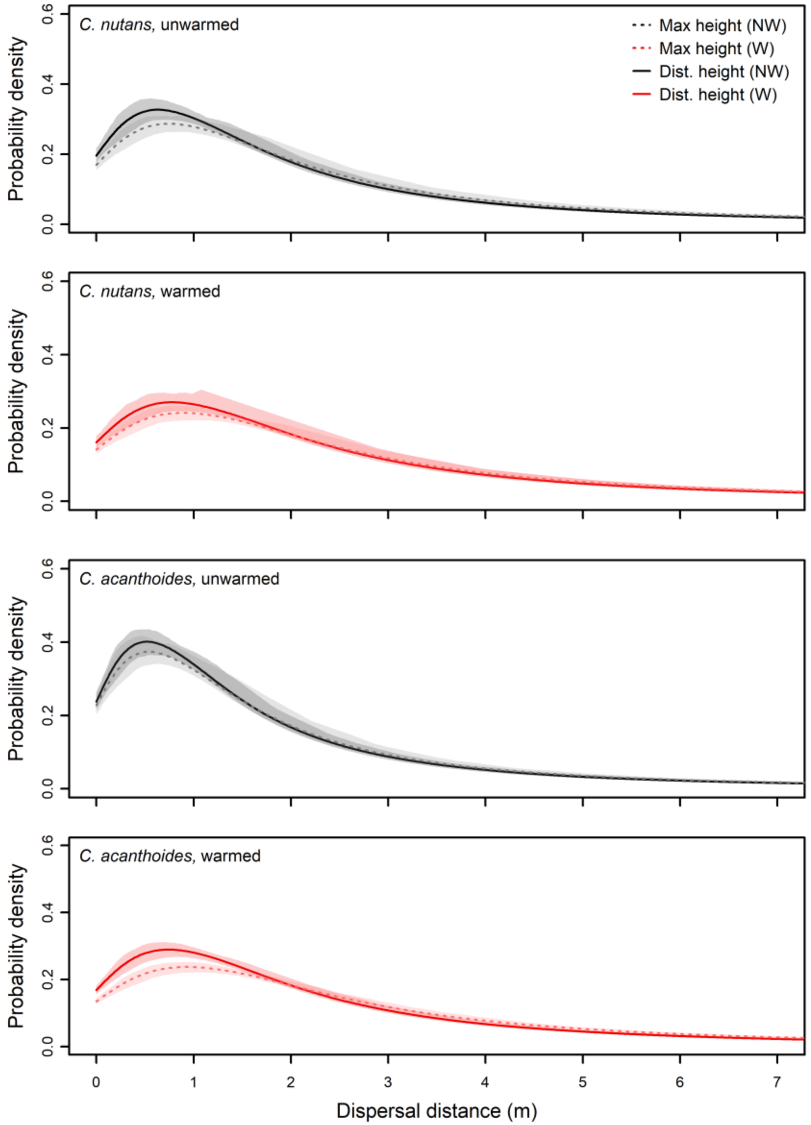


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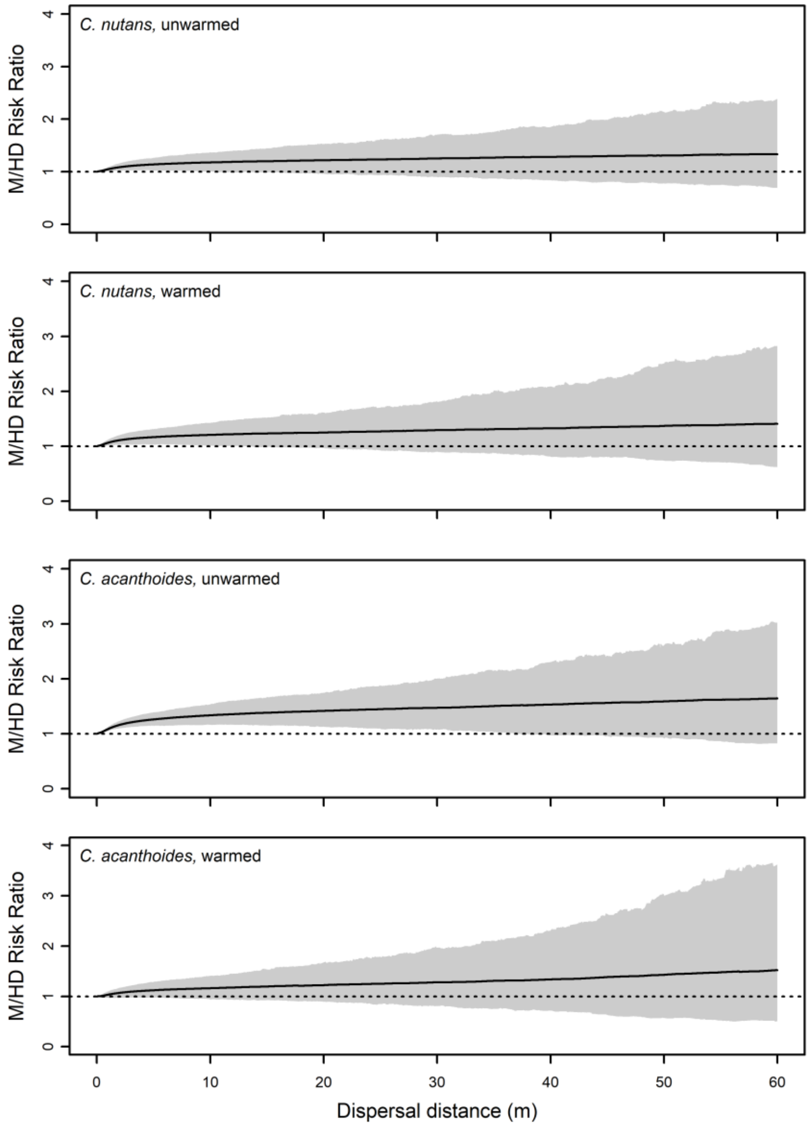


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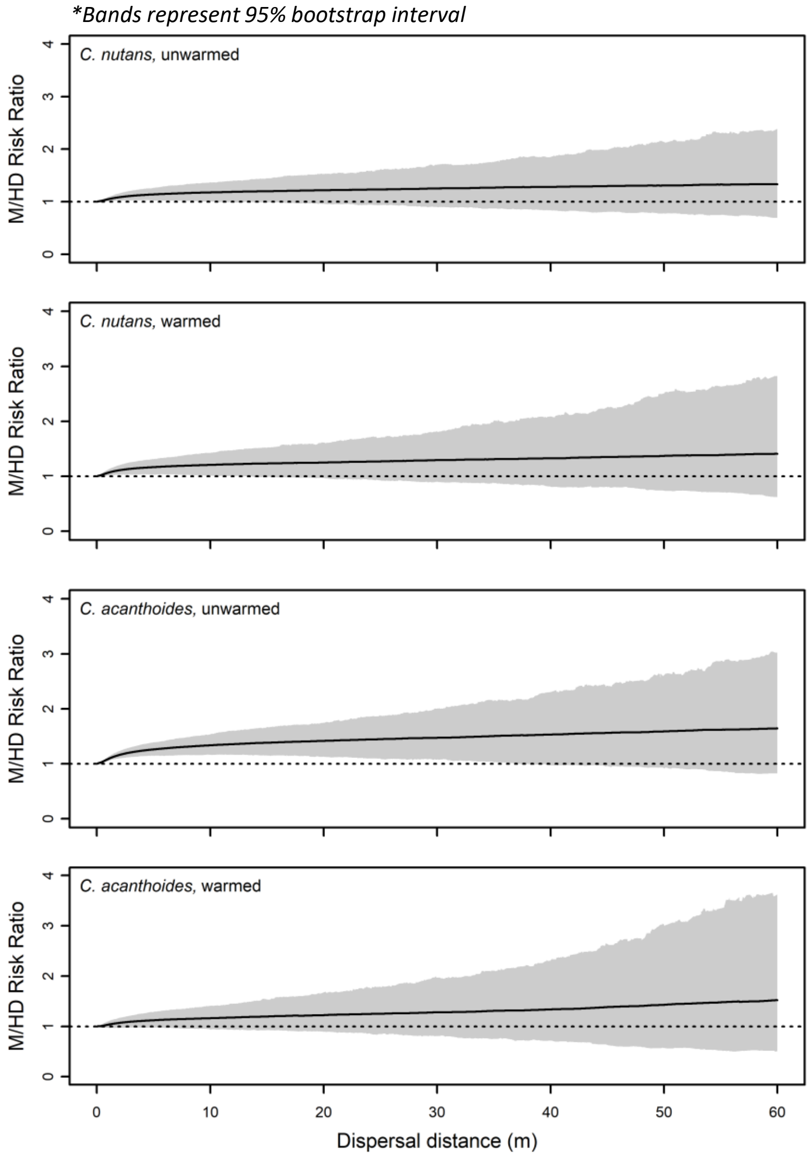


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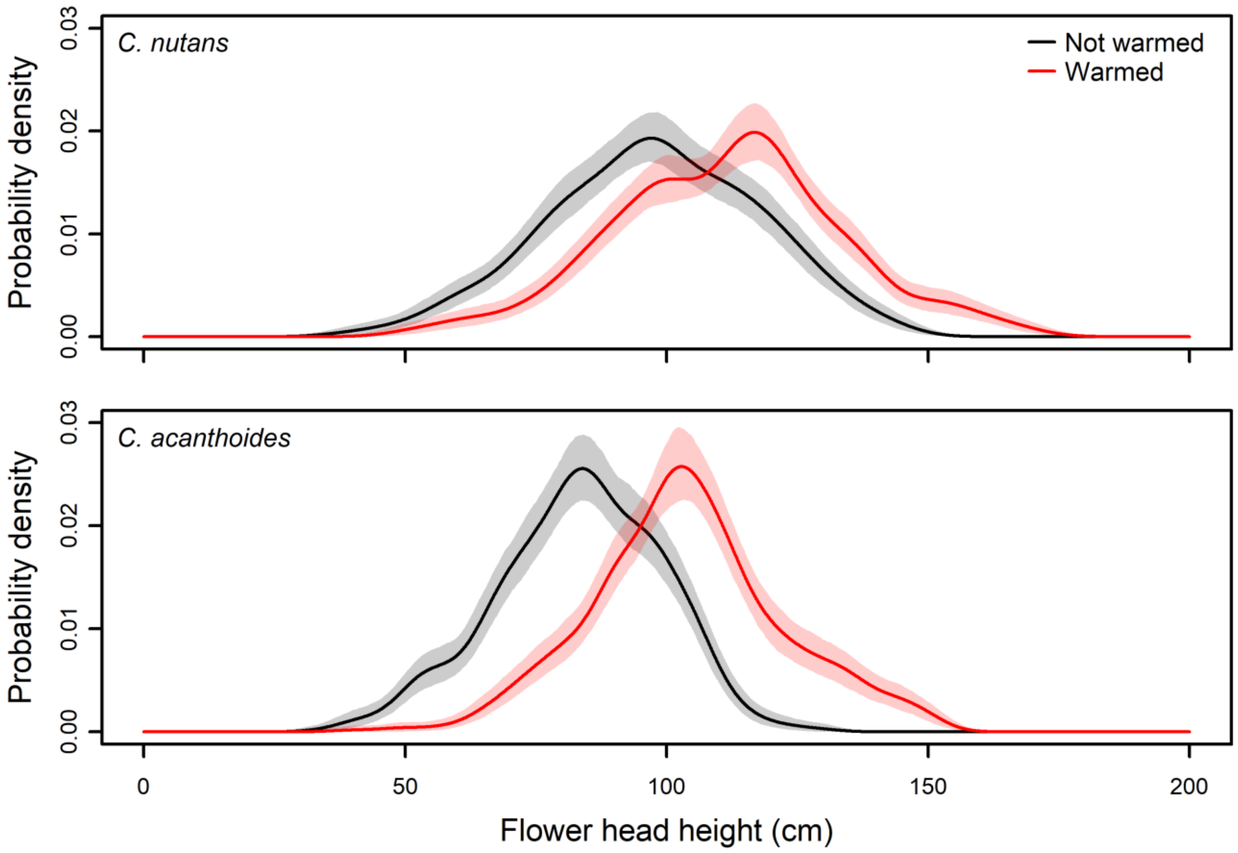
# How warming affects height…

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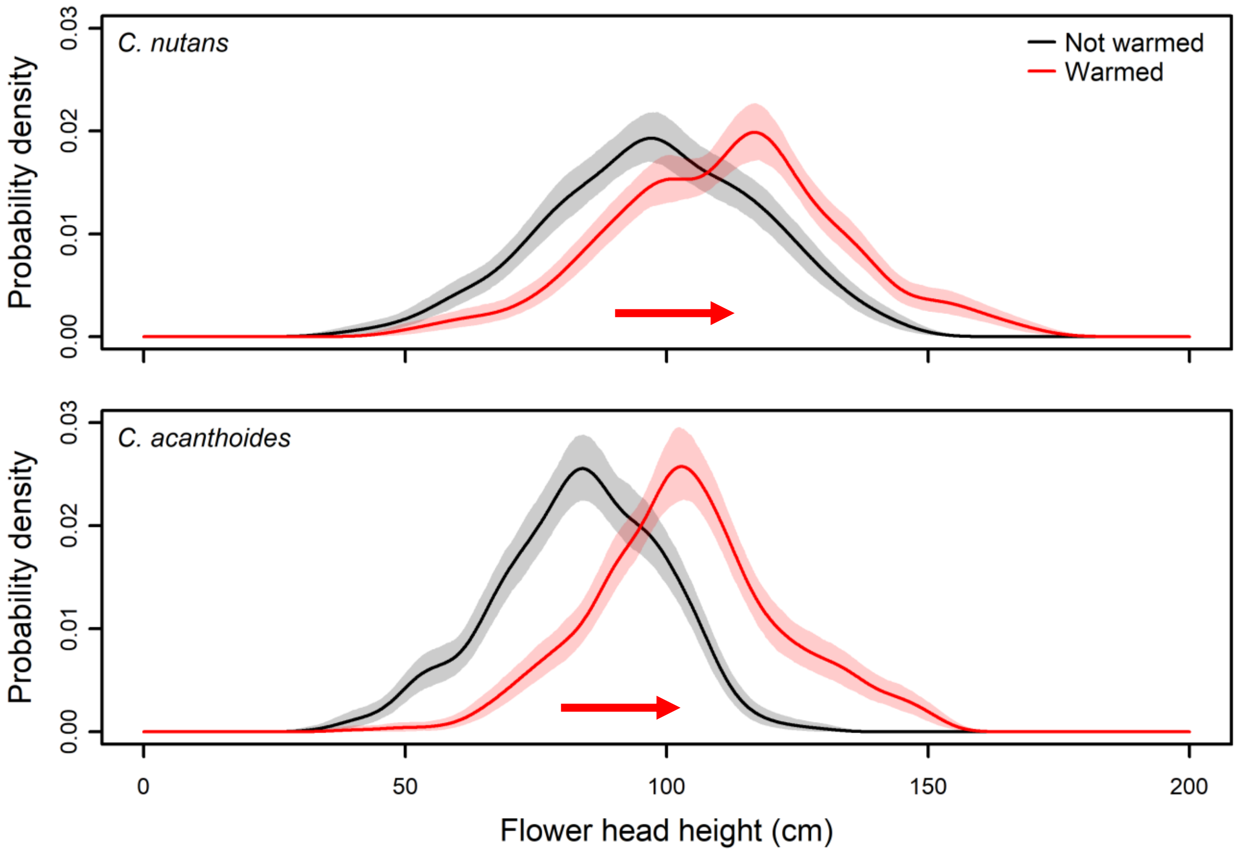
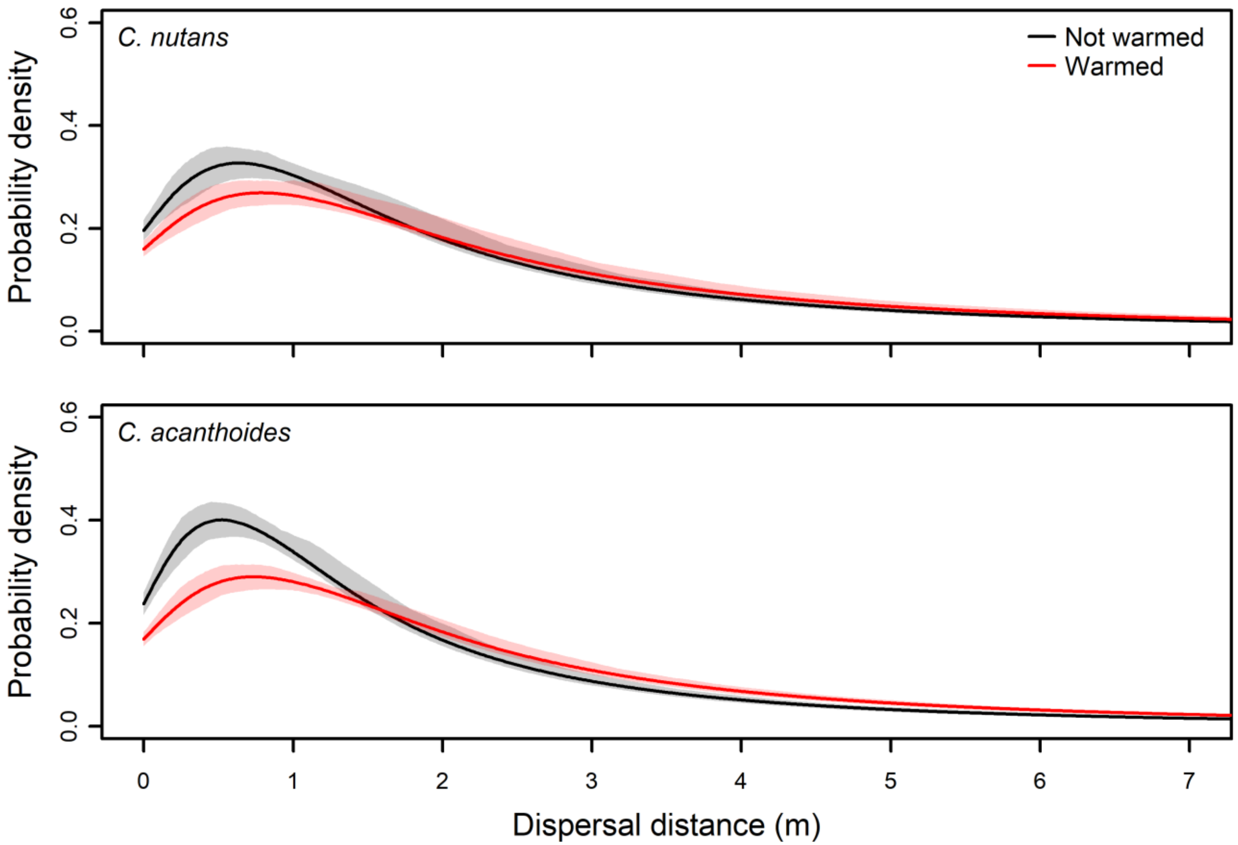



This is the first study to examine the distributions of seed release heights over the entire plant for *C. nutans* and *C. acanthoides,* and how warming affects those distributions.

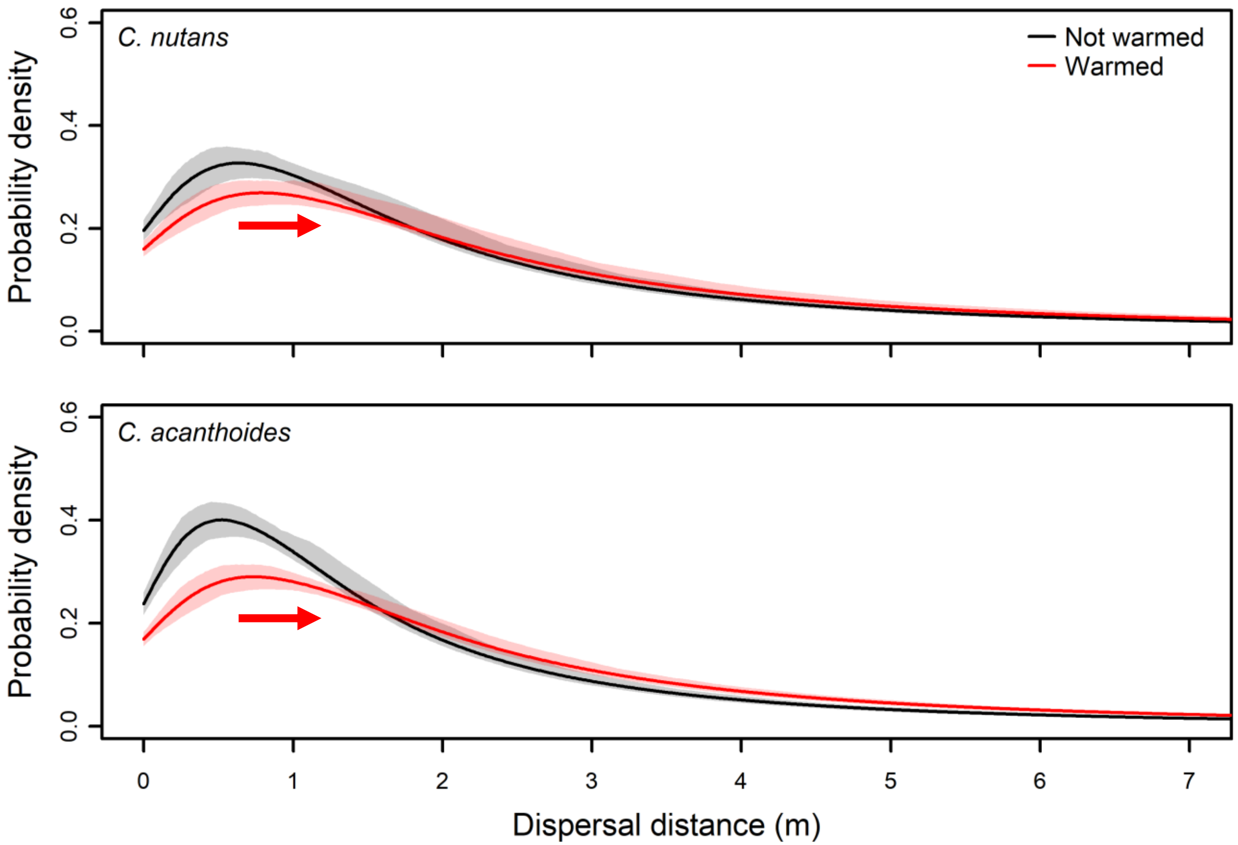
Our results show that warming shifts both distributions to the right, increasing seed release heights (and mean seed release height).

# … and overall dispersal




As was seen in previous studies, warming changes the dispersal kernel.

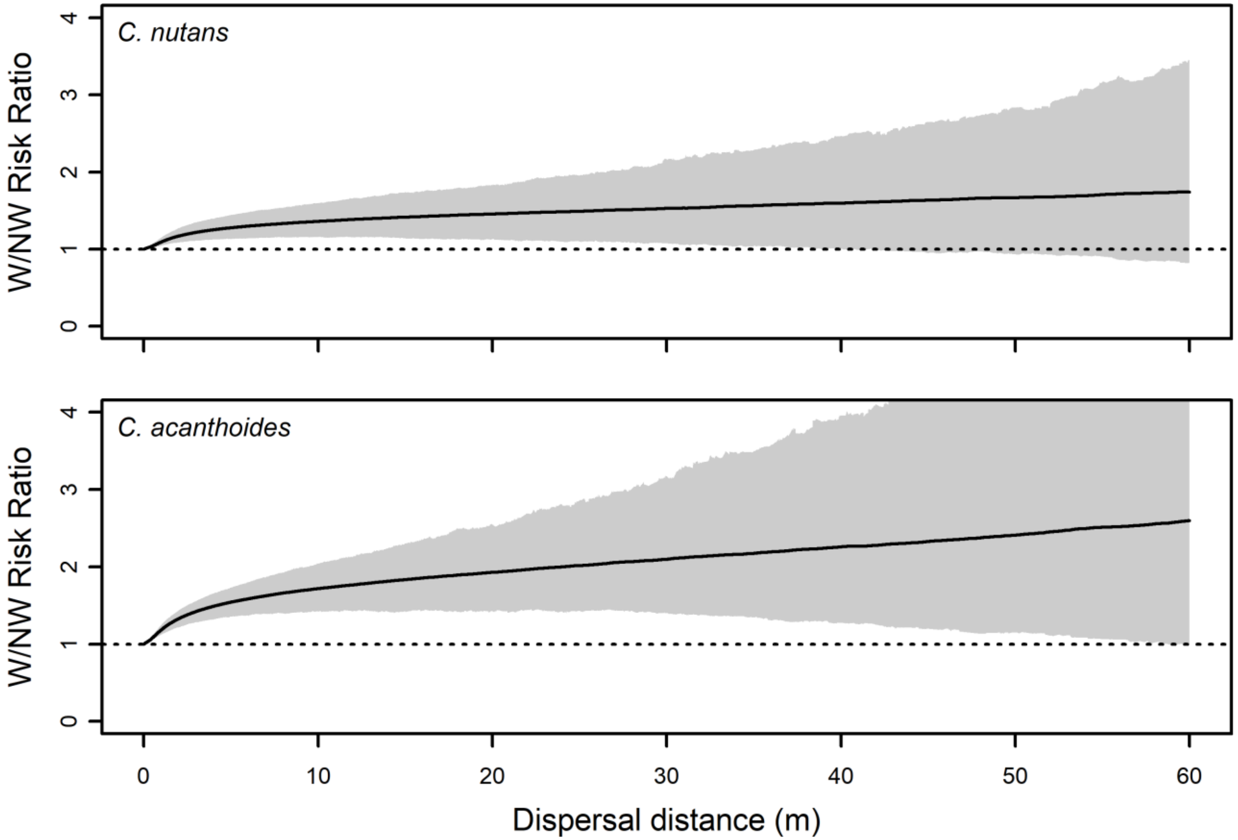
# … and overall dispersal




As was seen in previous studies, warming changes the dispersal kernel.

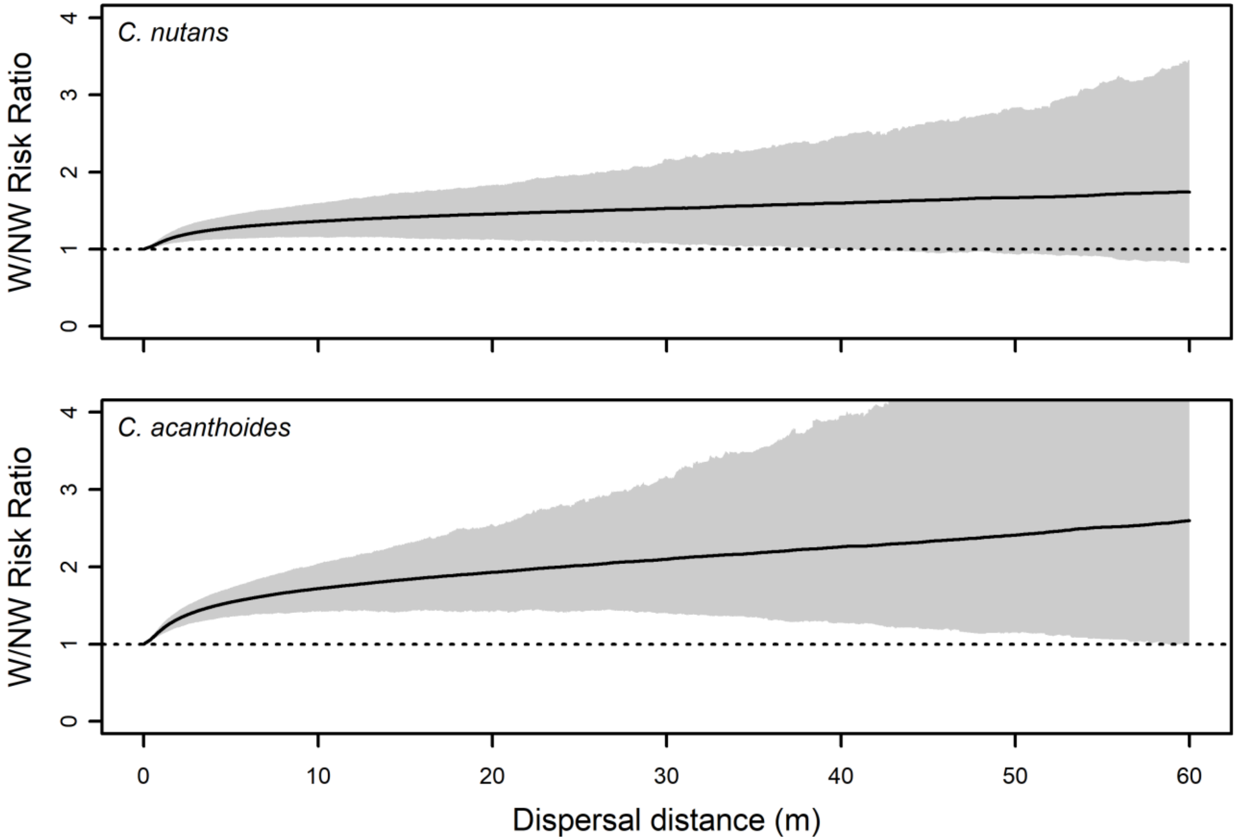
Here, our results show that even when using the entire height distribution instead of the maximum height, warming shifts the dispersal kernel to the right and makes the tail larger… dispersal at shorter distances becomes less common, while dispersal at longer distances becomes more common.

# … and long-distance dispersal




Warming increases the probability of long-distance dispersal events. This increase becomes more pronounced when looking at longer distance dispersal thresholds…

# … and long-distance dispersal



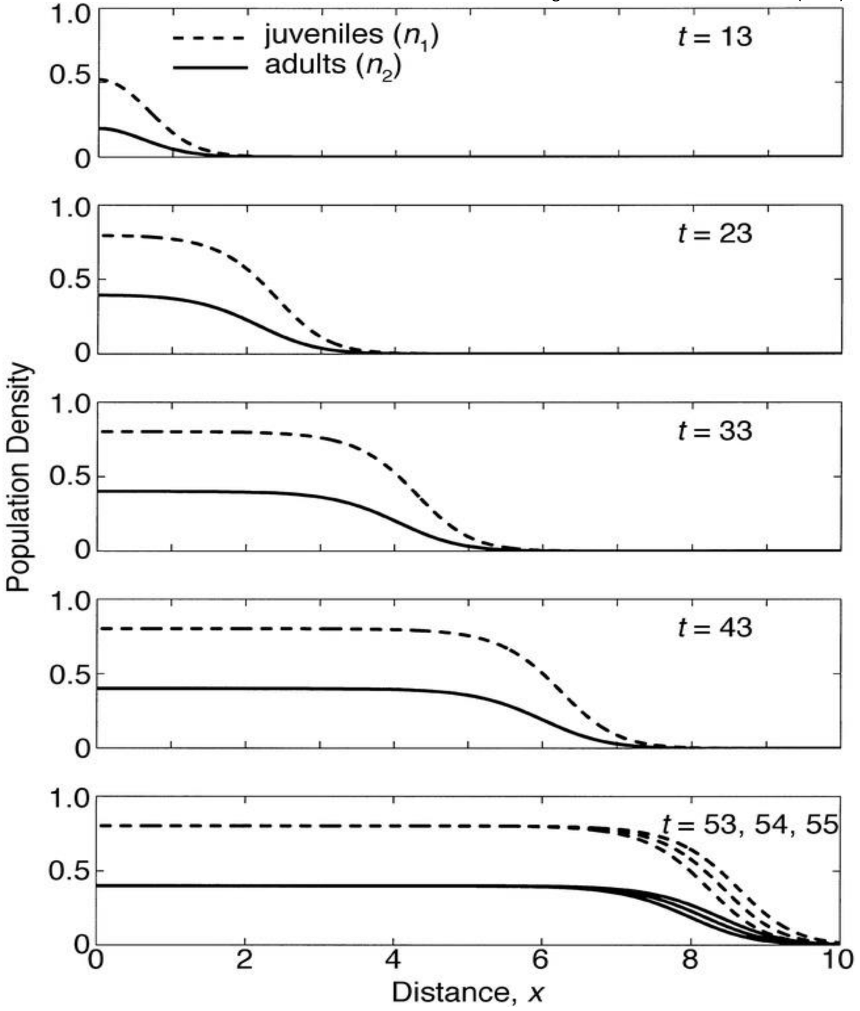

Warming increases the probability of long-distance dispersal events. This increase becomes more pronounced when looking at longer distance dispersal thresholds…

… but so does the uncertainty surrounding these events.

# … and population spread

These events at the tail end are highly influential in how a population moves across the landscape; models of population spread are often sensitive to these rare events.

Image source: Neubert and Caswell (2000)



# … and population spread

These events at the tail end are highly influential in how a population moves across the landscape; models of population spread are often sensitive to these rare events.

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

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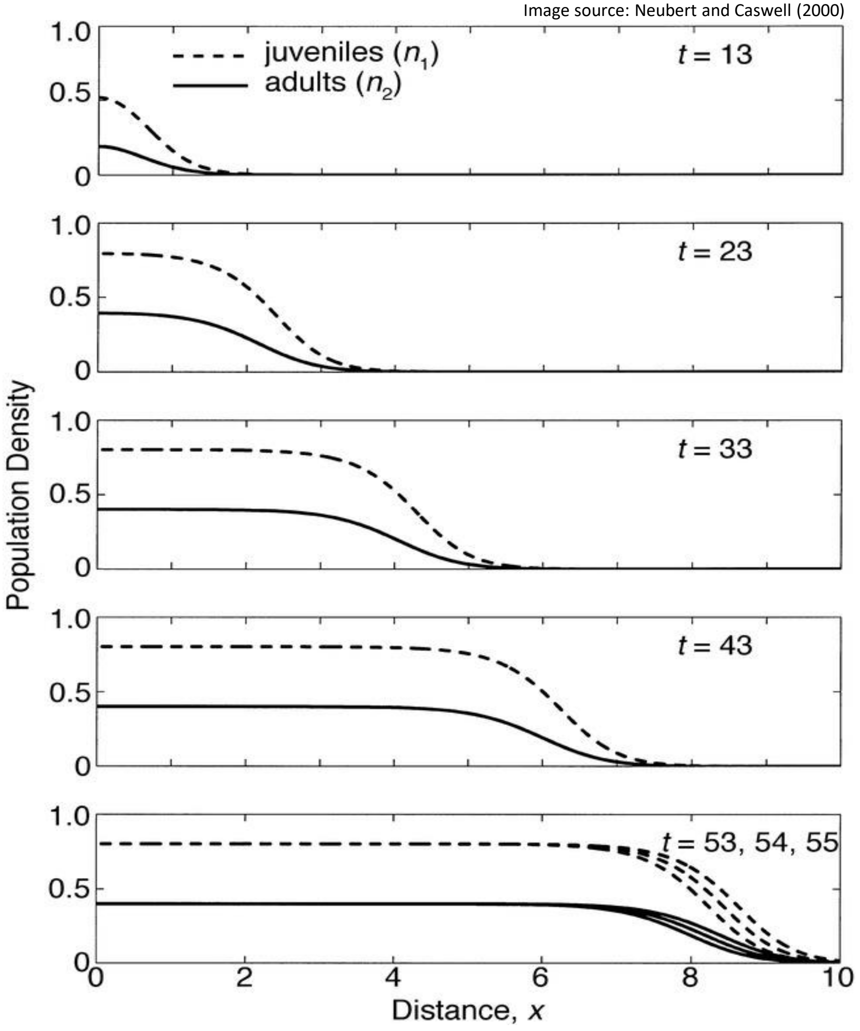

# Weed management implications


Image source: Pixabay

These results have implications for weed management… as warming leads to greater dispersal, the spread of these weeds will be more challenging to control.

Knowing how invasive plants respond to warming can help us continue effective management in future climates.

# References


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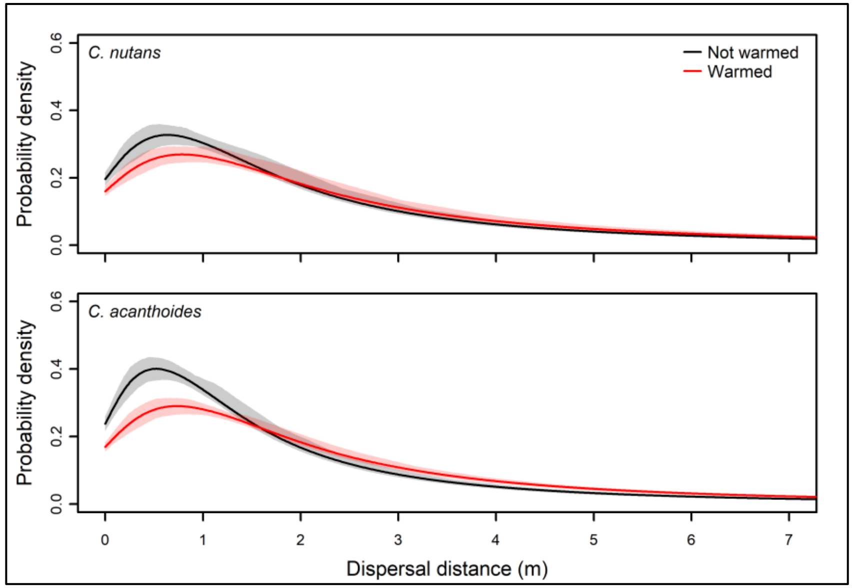
# Questions?

- Ask them in the live Q&A
- Email them to me at thd5066@psu.edu


*Many thanks to the Penn State ecology program for their support, as well to the Shea Lab for providing resources, guidance, and feedback!*