

**Species niche and fitness differences explain the  
success and impact of biological invasions:  
Extending Darwin's naturalization hypothesis**

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# Biological invasion: success and impact



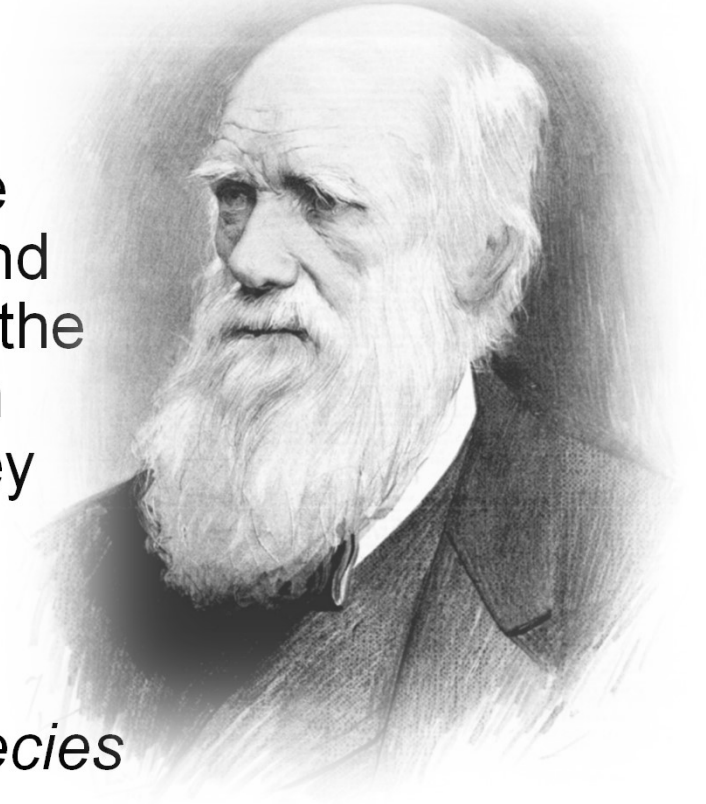
Invasive species in Georgia: kudzu

Photo credit: user: streaminspector/Flickr

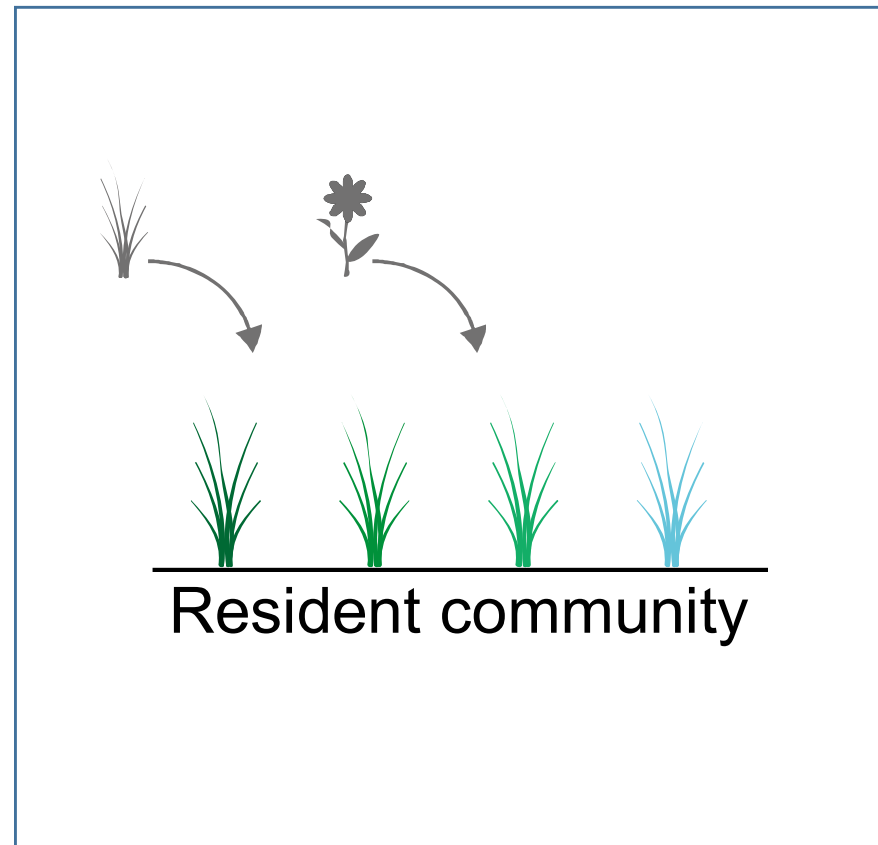
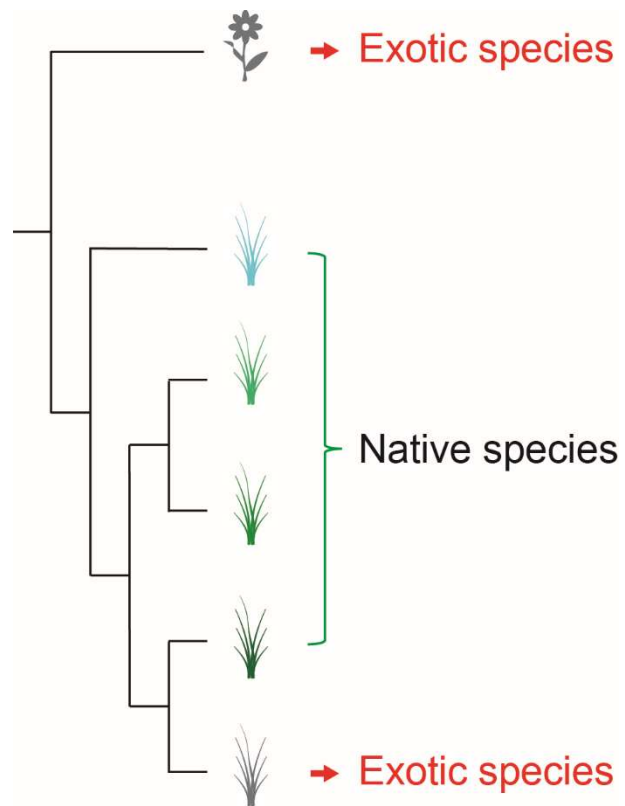
# Darwin's naturalization hypothesis

“As species of the same genus have usually ... some similarity in habits and constitution, and always in structure, the struggle will be more severe between species of the same genus, when they come into contact with each other...”

----Darwin. 1859. *The Origin of Species*

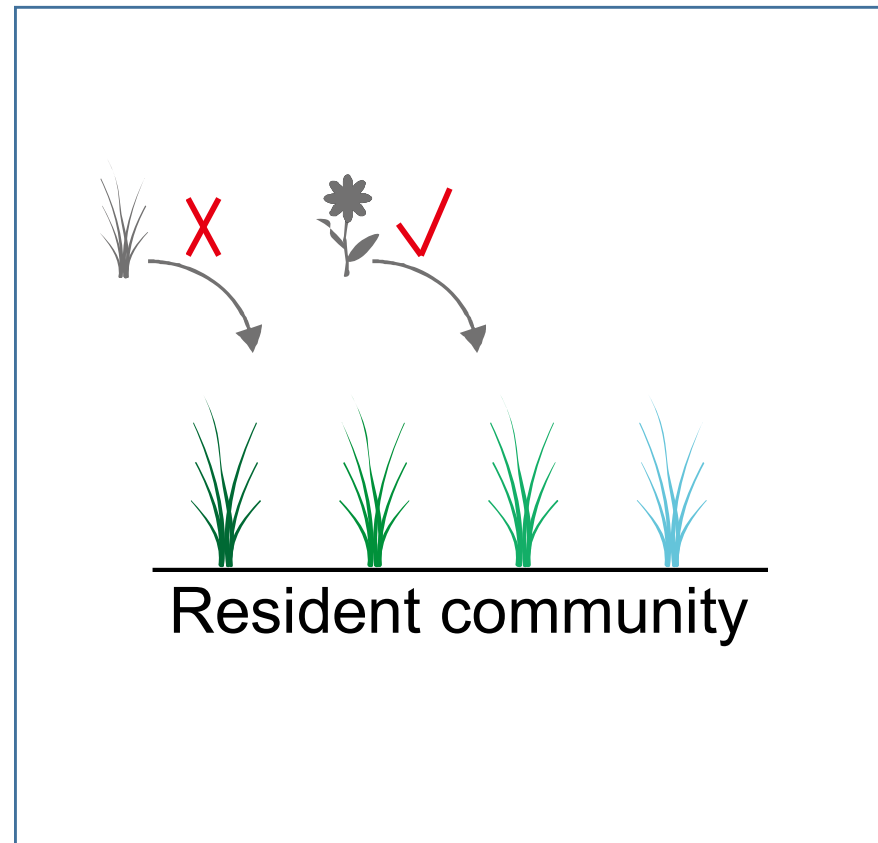
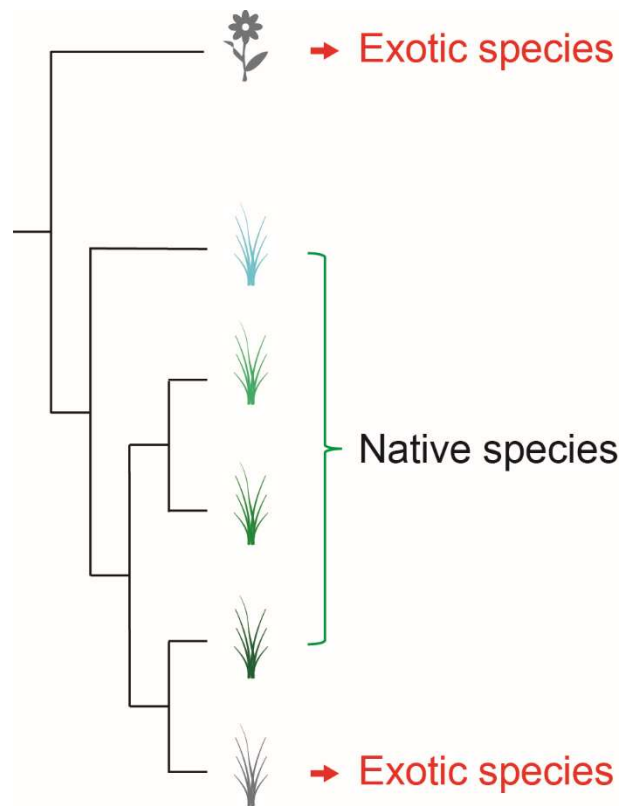


# Darwin's naturalization hypothesis



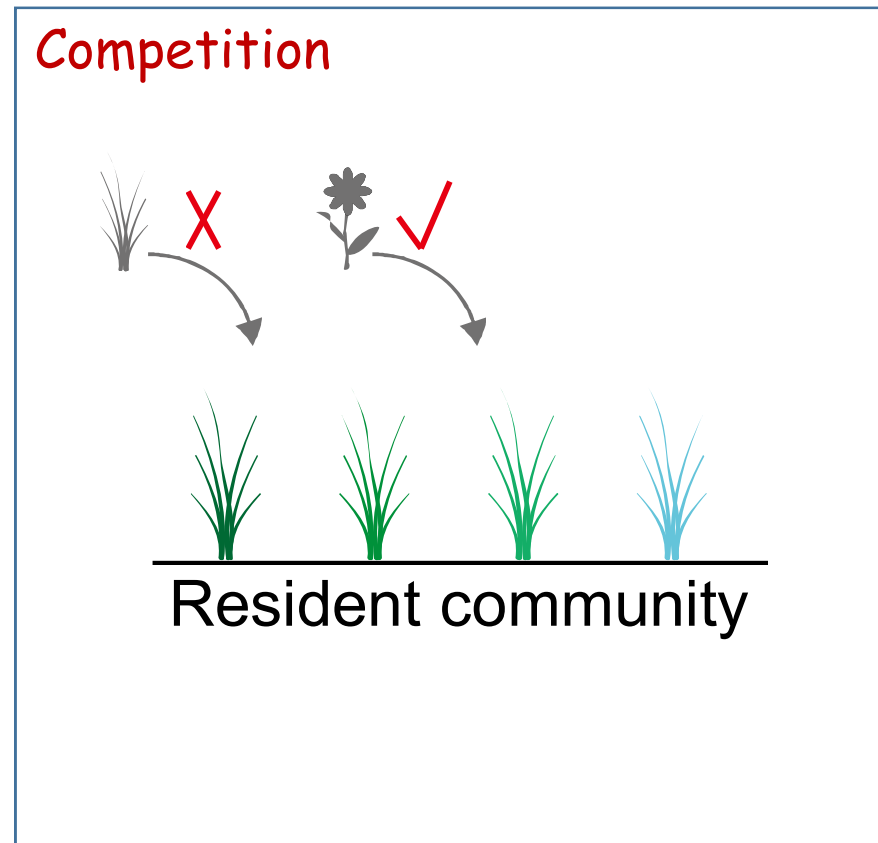
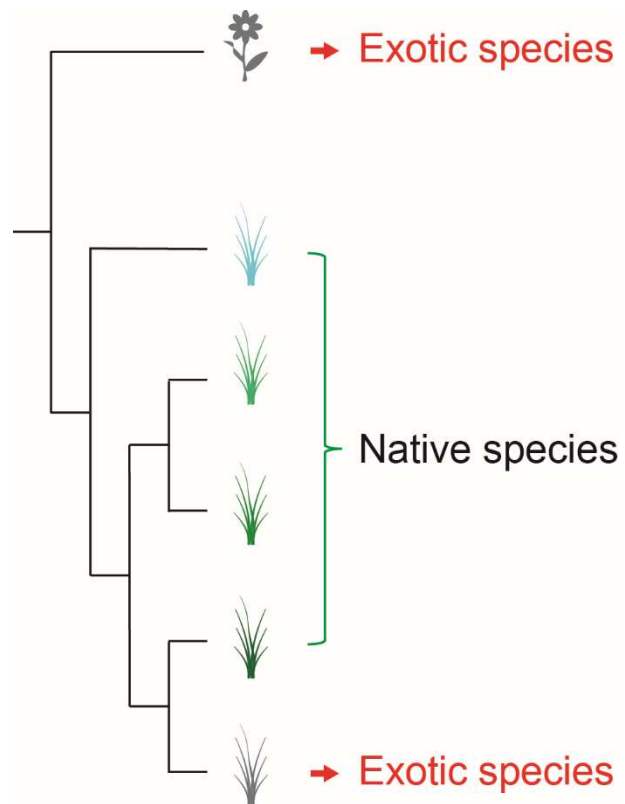
*Li et al. 2015. Ecology Letters*

# Darwin's naturalization hypothesis



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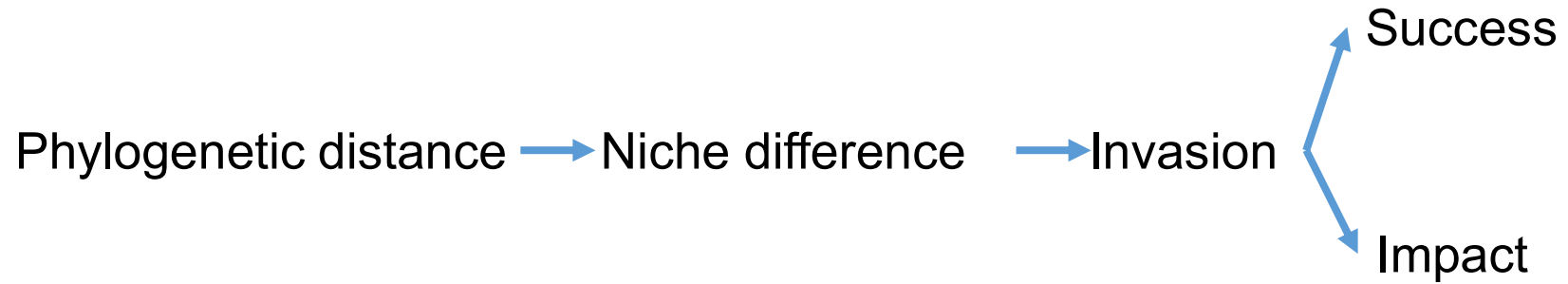
# Literature Mixed

Table 1. The effect of phylogenetic relatedness on the probability of establishment by nonnative species

Study	Taxon	Location	Effect of relatives
Mack et al., 1996 (32)	Plants	United States	-
Rejmanek, 1996 (33)	Plants	California	-
Daehler, 2001 (38)	Plants	Hawaii	+
Duncan and Williams, 2002 (39)	Plants	New Zealand	+
Diez et al., 2008 (40)			
Lambdon and Hulme, 2006 (47)	Plants	Mediterranean islands	0
Ricciardi and Mottiar, 2006 (48)	Fish	Global	0
Diez et al., 2009 (41)	Plants	Australia, New Zealand	+
Jiang et al., 2010 (34)	Bacteria	Experimental	-
Tan et al., 2012 (37)			
Davies et al., 2011 (35)	Plants	California (Serpentine)	-
Tingley et al., 2011 (42)	Amphibians	Global	+
van Wilgen and Richardson, 2011 (36)	Reptiles	California, Florida	-
Violle et al., 2011 (30)	Protists	Experimental	-
Ferreira et al., 2012 (43)	Reptiles	Global	+
Peay et al., 2012 (31)	Nectar yeast	Experimental	-
Maitner et al., 2012 (44)	Birds	Florida, Hawaii, New Zealand	+

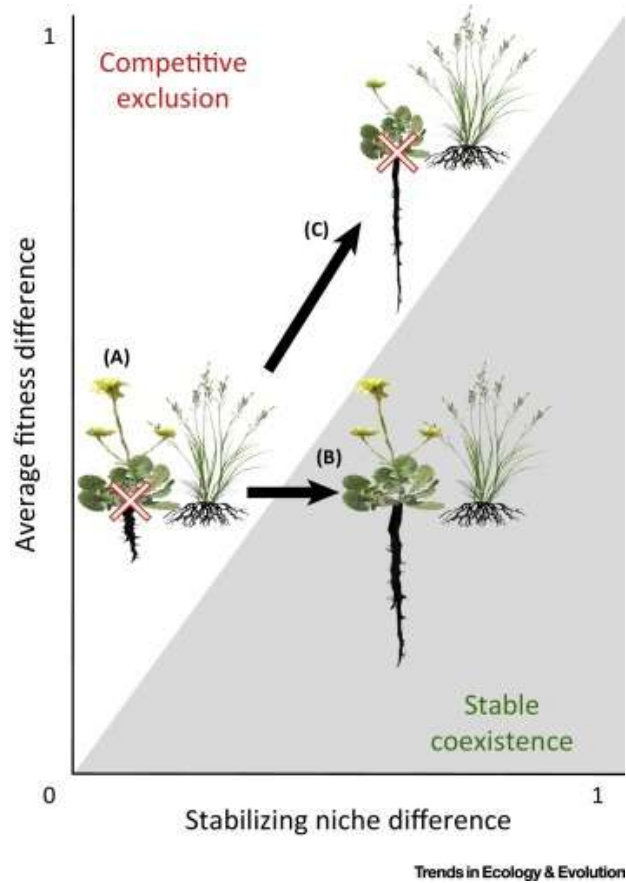
Jones *et al.* 2011, *PNAS*

# Darwin's naturalization hypothesis

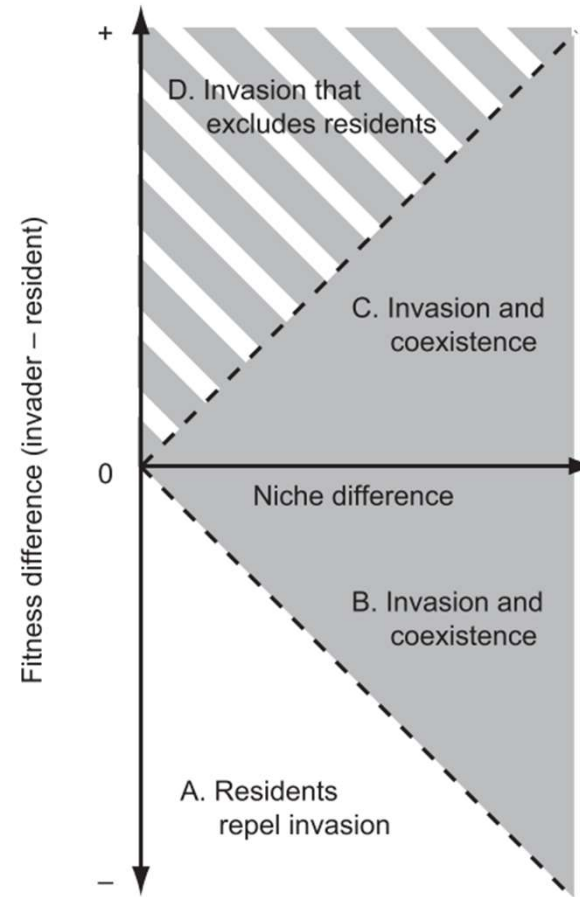




# Modern coexistence theory

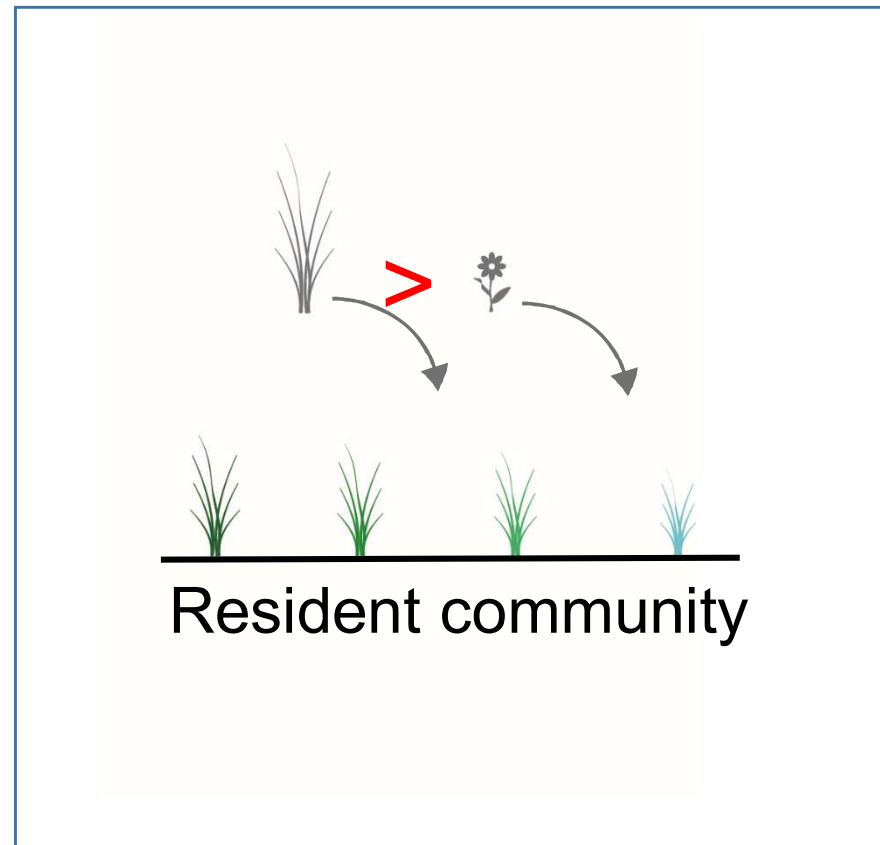
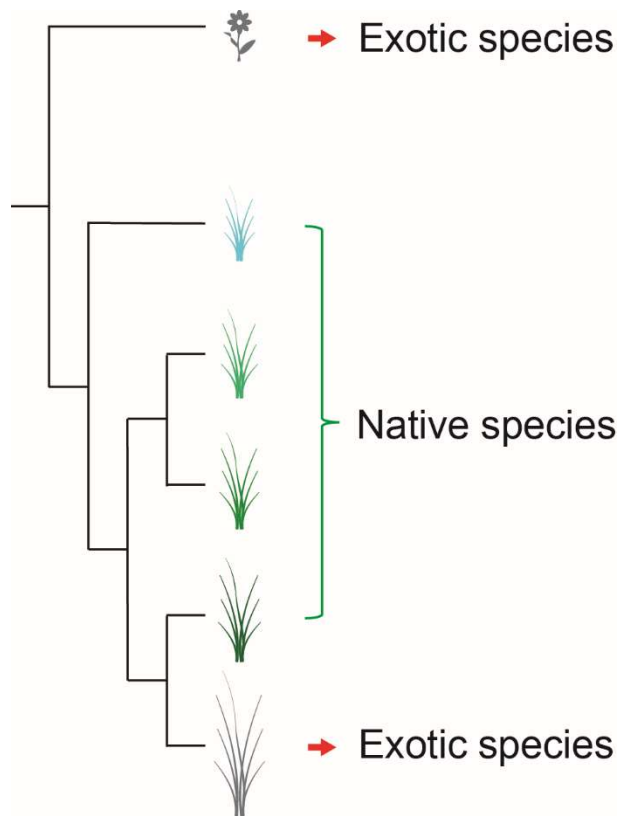


Turcotte & Levine. 2016. *Trends in Ecology & Evolution*

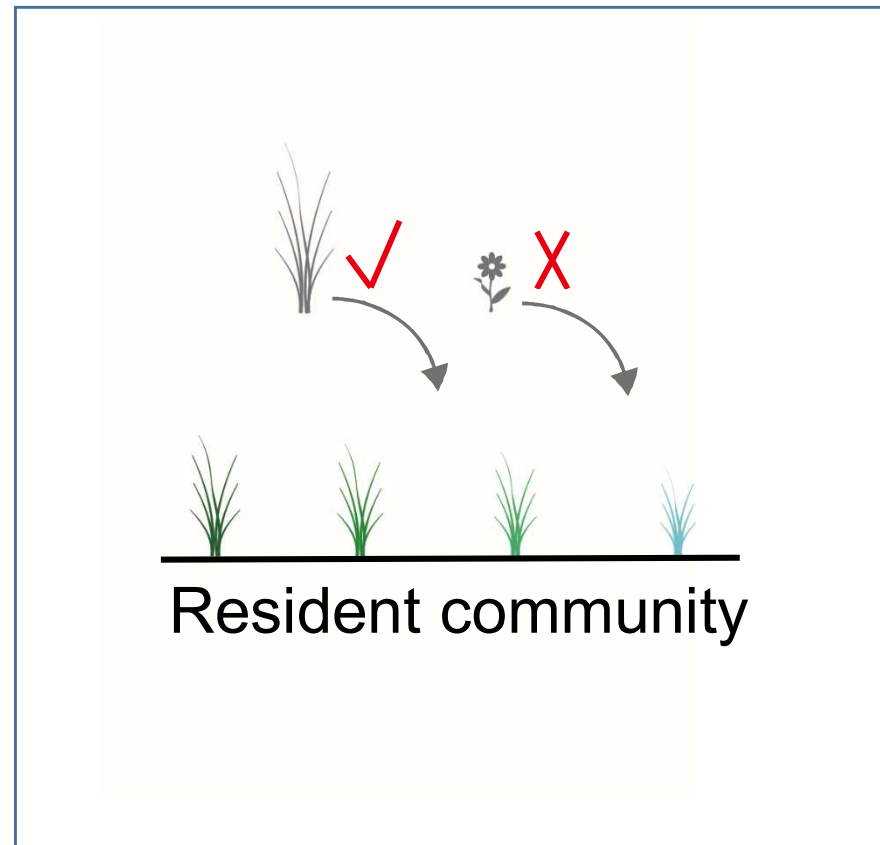
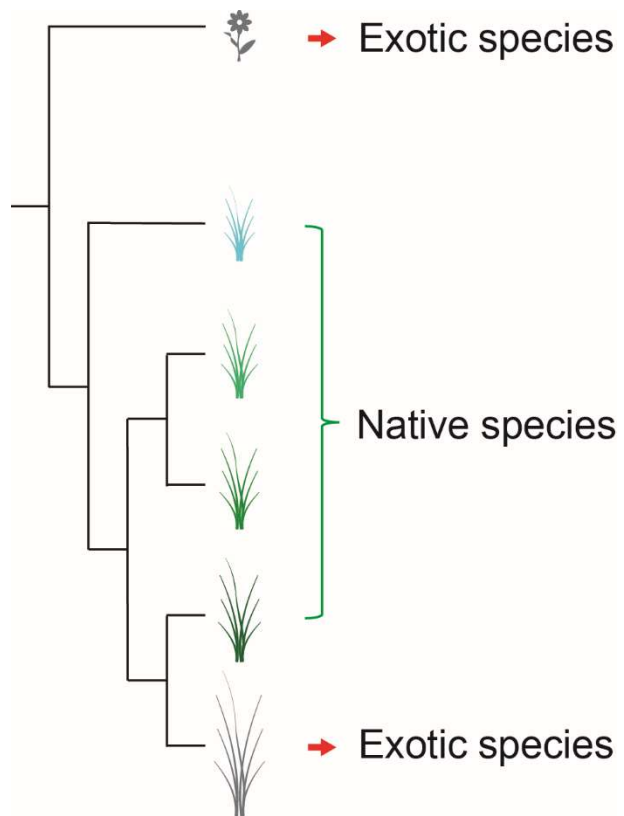


MacDougall *et al.* 2009. *Journal of Ecology*

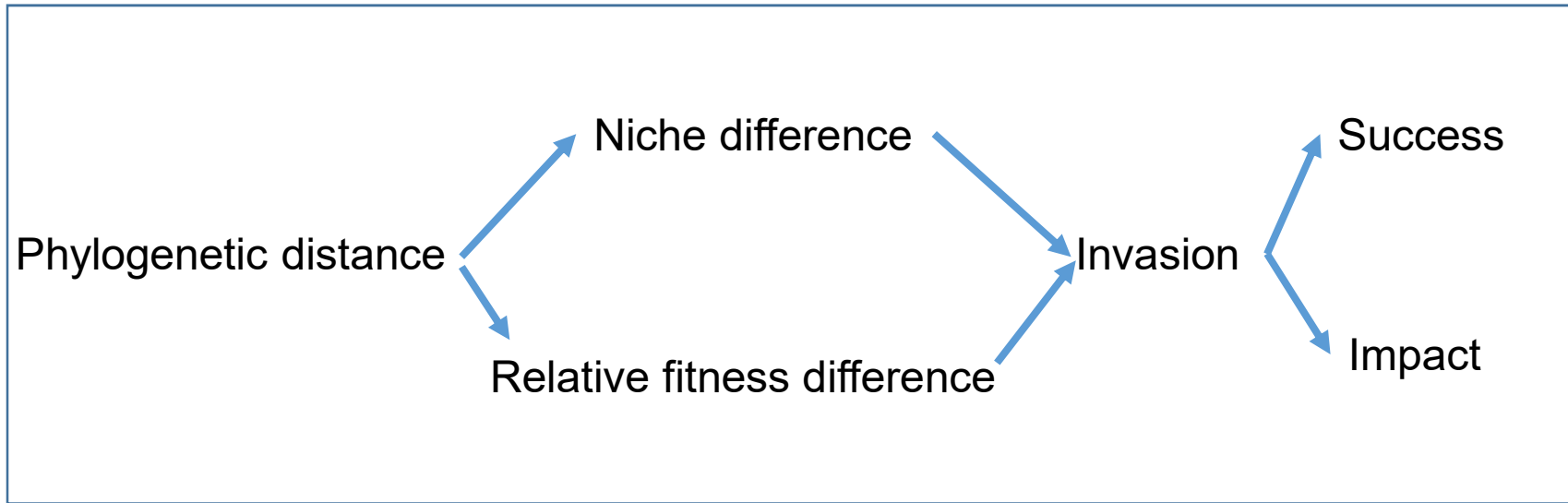
# Darwin's naturalization hypothesis



# Darwin's naturalization hypothesis



# Our framework



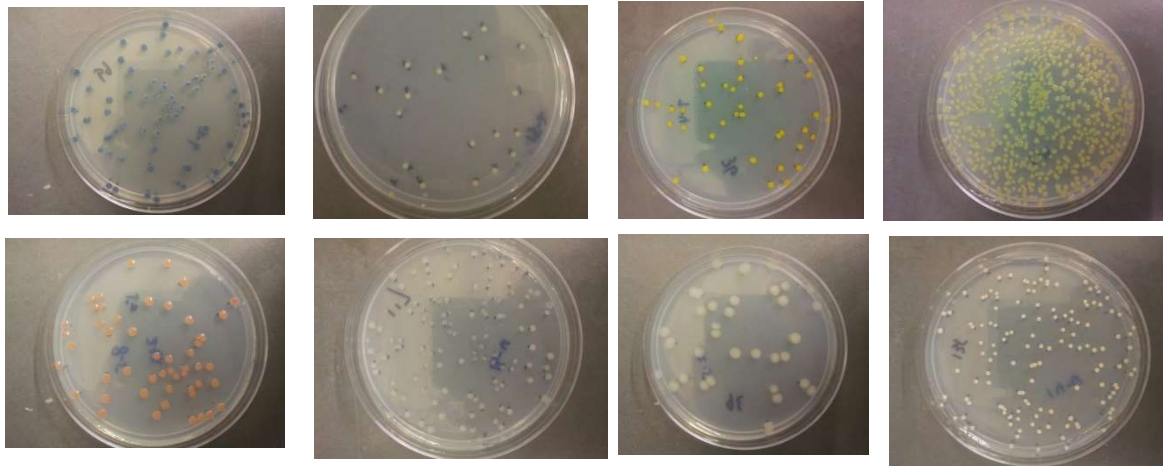
# Scientific questions

1. Could phylogenetic distance capture the niche and relative fitness differences between invaders and natives?
2. How invader-native niche and relative fitness differences regulate invasion success and impact?
3. When Darwin's naturalization hypothesis is valid?

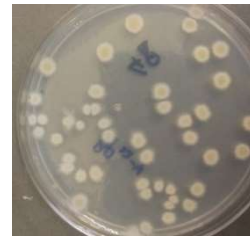
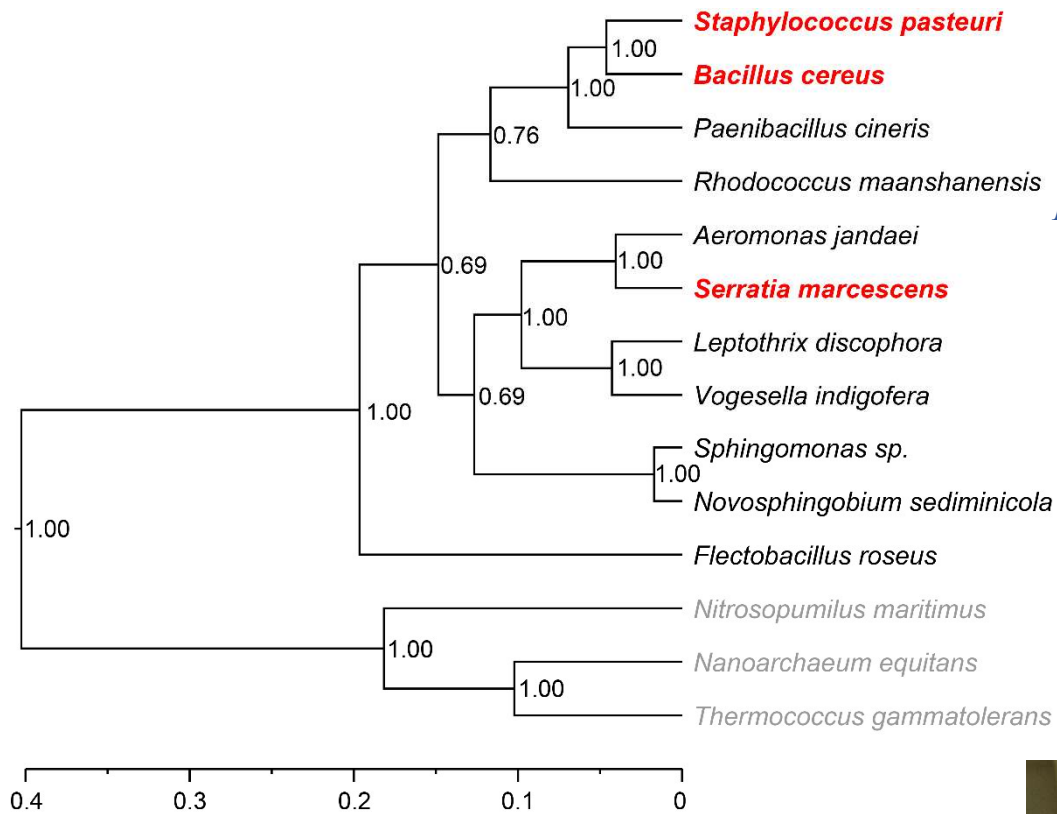
# Native species



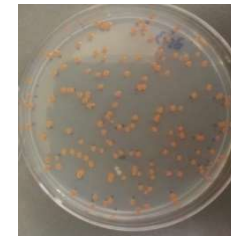
Lake Clara Meer in Piedmont Park of Atlanta



# Species pool



*Bacillus cereus* (BC)

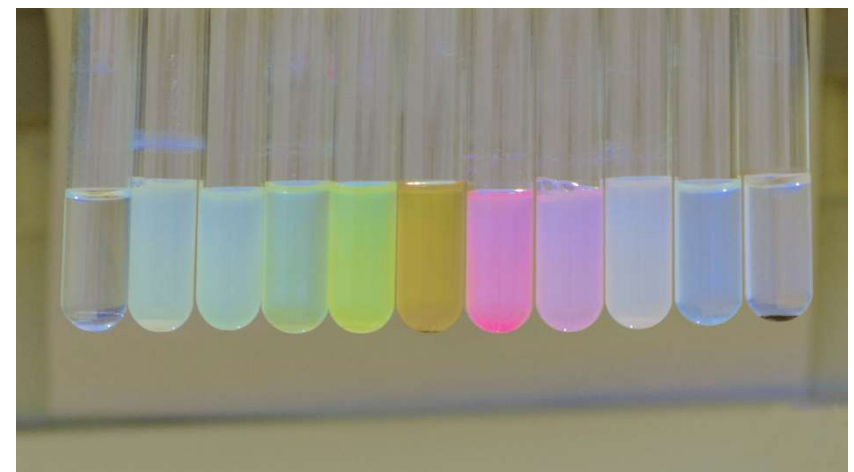


*Staphylococcus pasteuri* (SP)

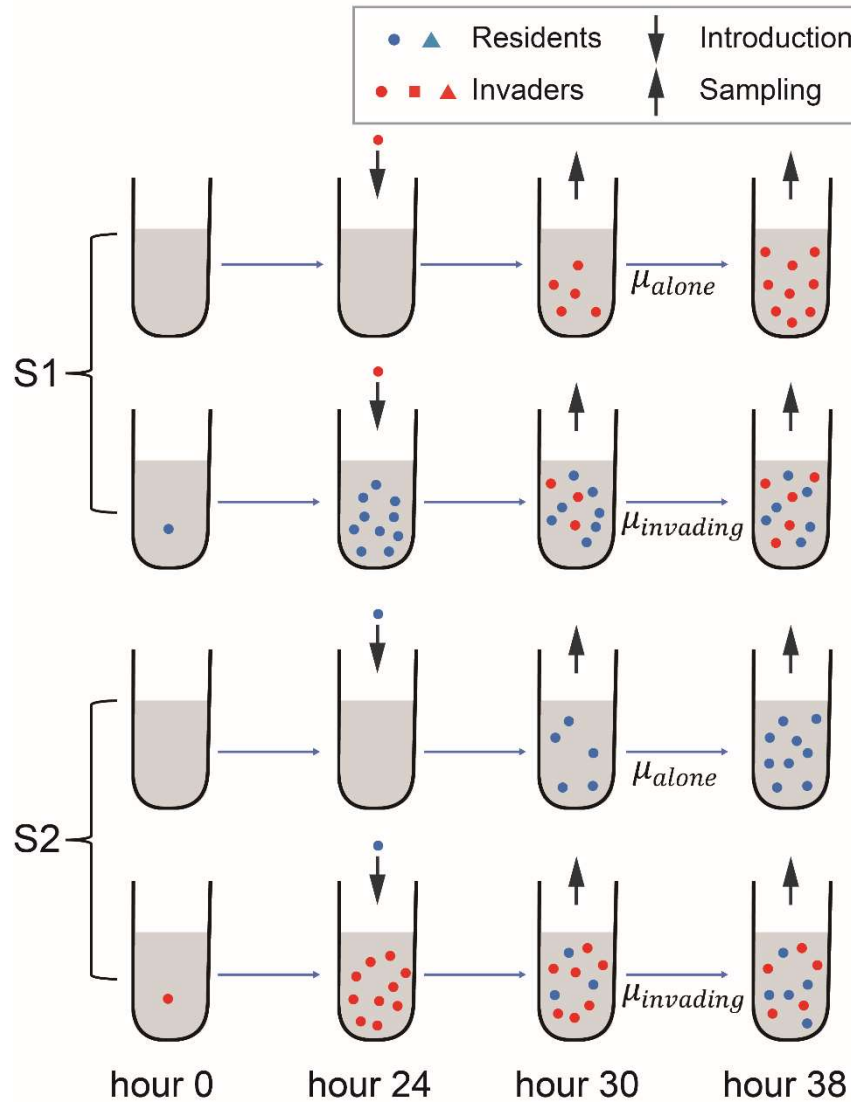


*Serratia marcescens* (SM)

**Invader species**



# Mutual invasion experiment



$\mu$  = growth rate

$$S_1 = (\mu_{alone} - \mu_{invading}) / \mu_{alone}$$

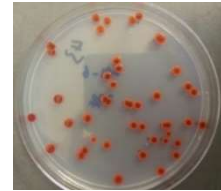
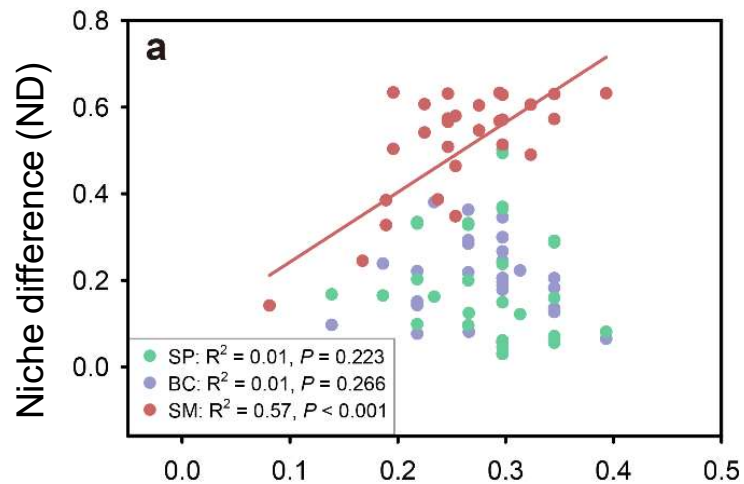
$$\text{Niche difference} = 1 - \sqrt{S_1 S_2}$$

$$\text{Relative fitness difference} = \sqrt{S_2 / S_1}$$

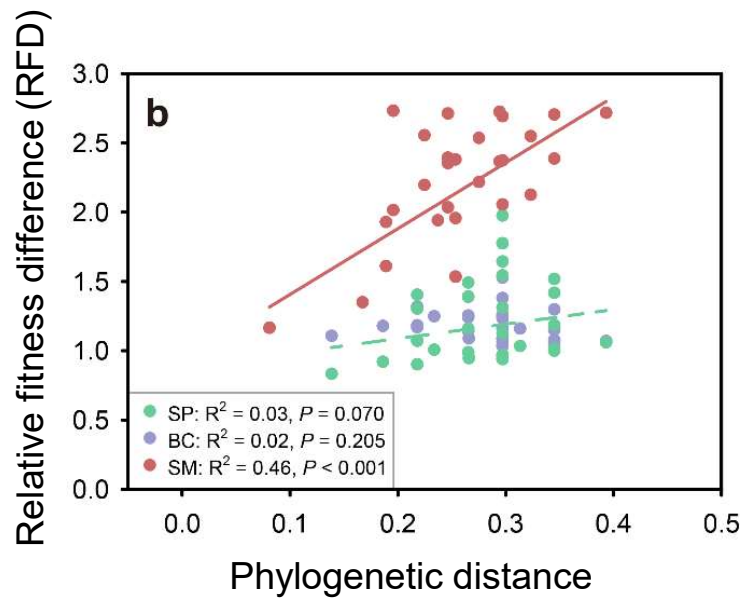
Narwani *et al.* 2013. *Ecology Letters*



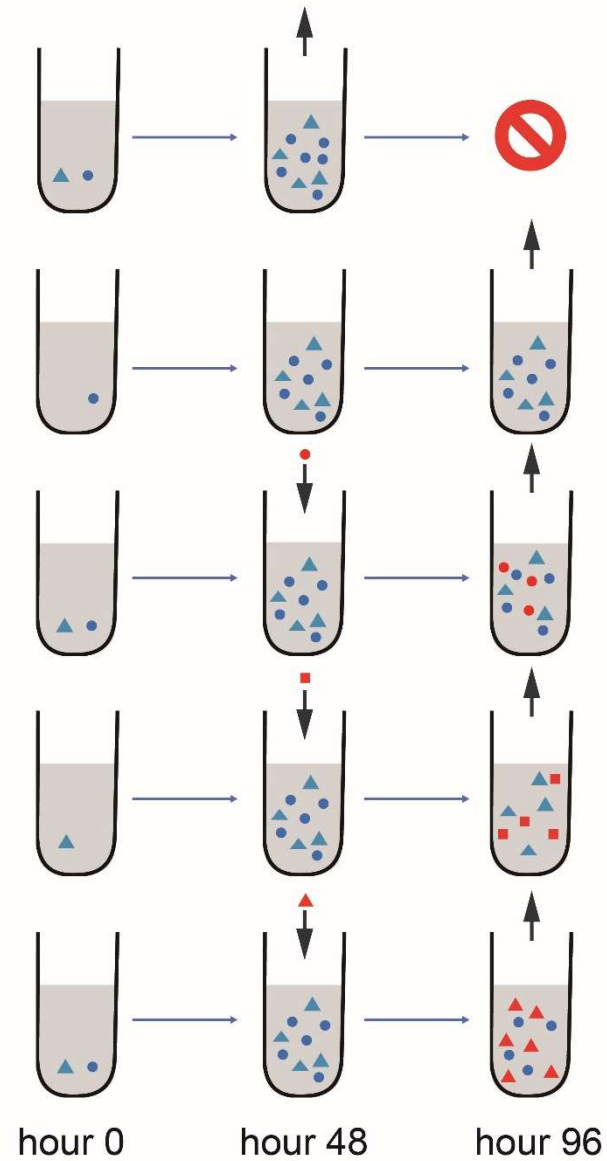
# From PD to ND and RFD



- PD could capture ND and RFD between *Serratia marcescens* and the natives, but not the other two invaders.



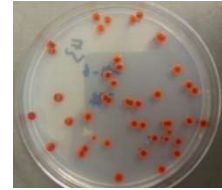
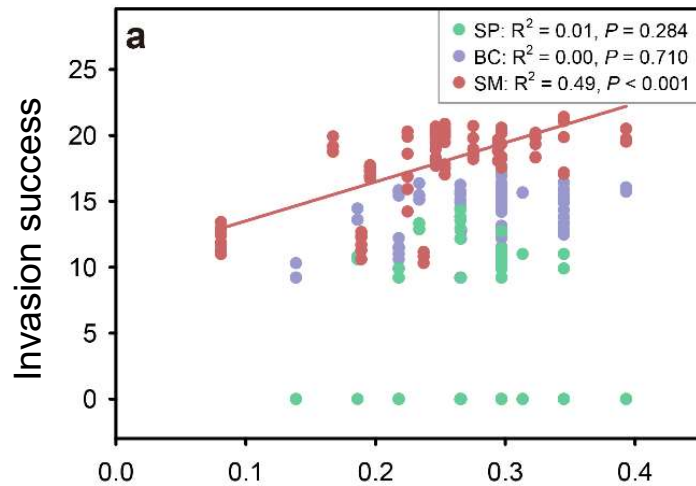
# Invasion success and impact experiment



Invasion success =  $\ln$  (invader density)

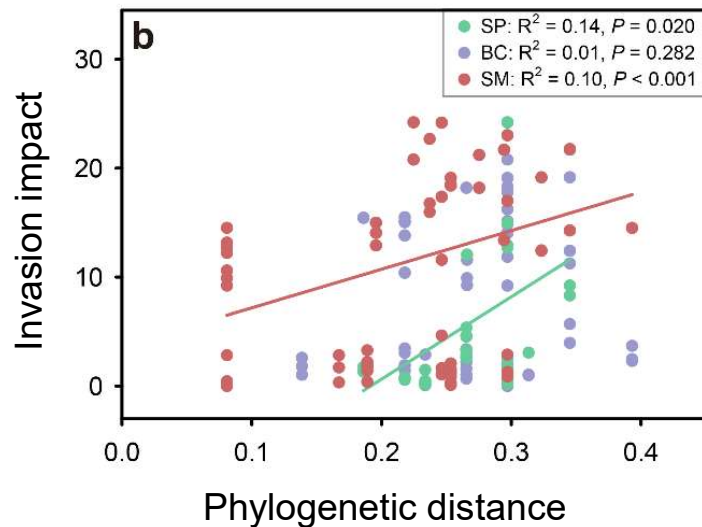
Invasion impact = changes in native density

# PD on invasion success and impact

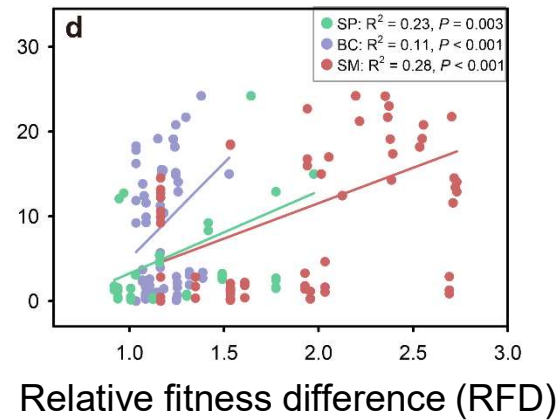
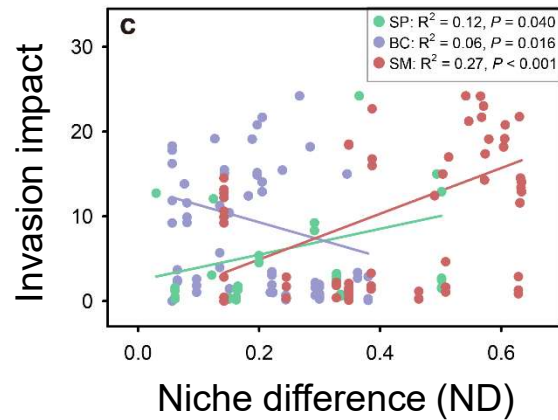
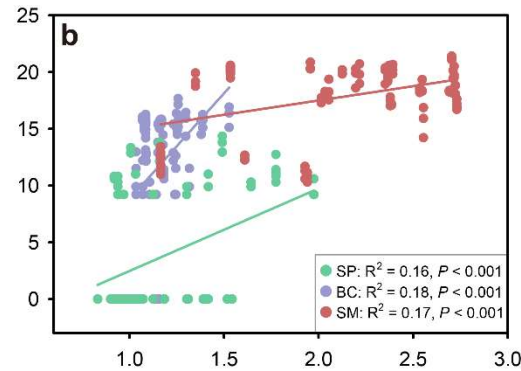
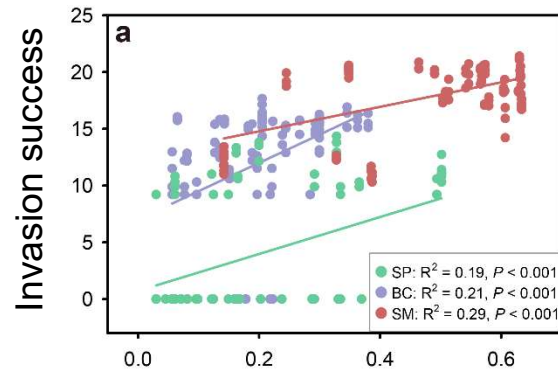


The effect of PD on invasion were species-specific:

- PD is a good predictor of invasion success and impact for *Serratia marcescens*, but not the other two invaders.



# ND and RFD on invasion success and impact



For all three invaders:

- Invasion success increased with ND and RFD;
- Invasion impact increased with RFD.

# ND and RFD on invasion success and impact

When three invaders were considered together:

- ND is a single best explanatory variable of invasion success;
- RFD is a single best explanatory variable of invasion impact.

**Table 1.** MCMCglmm results for univariate models.

Variable	Posterior mean	Low 95% CI	Upper 95% CI	$P_{MCMC}$	DIC
<b>Invasion success</b>					
species richness	-0.49	-1.74	0.73	0.427	1920.40
PD	7.13	-56.49	65.57	0.713	1896.19
<b>ND</b>	<b>15.30</b>	<b>12.01</b>	<b>18.74</b>	<b>&lt;0.001</b>	<b>1849.69</b>
RFD	4.25	2.84	5.57	<0.001	1886.29
<b>Invasion impact</b>					
species richness	1.13	-1.40	3.31	0.345	1672.89
PD	30.02	8.05	51.28	0.022	1658.22
ND	15.45	9.23	21.91	<0.001	1655.14
<b>RFD</b>	<b>8.70</b>	<b>6.40</b>	<b>11.20</b>	<b>&lt;0.001</b>	<b>1622.13</b>

# Take home message

- Invasion success largely depended on invader-native niche differences;
- Invasion impact largely depended on the fitness advantage of the invaders relative to natives.
- Darwin's naturalization hypothesis is valid if phylogenetic distance could capture niche difference that determines invasion success.

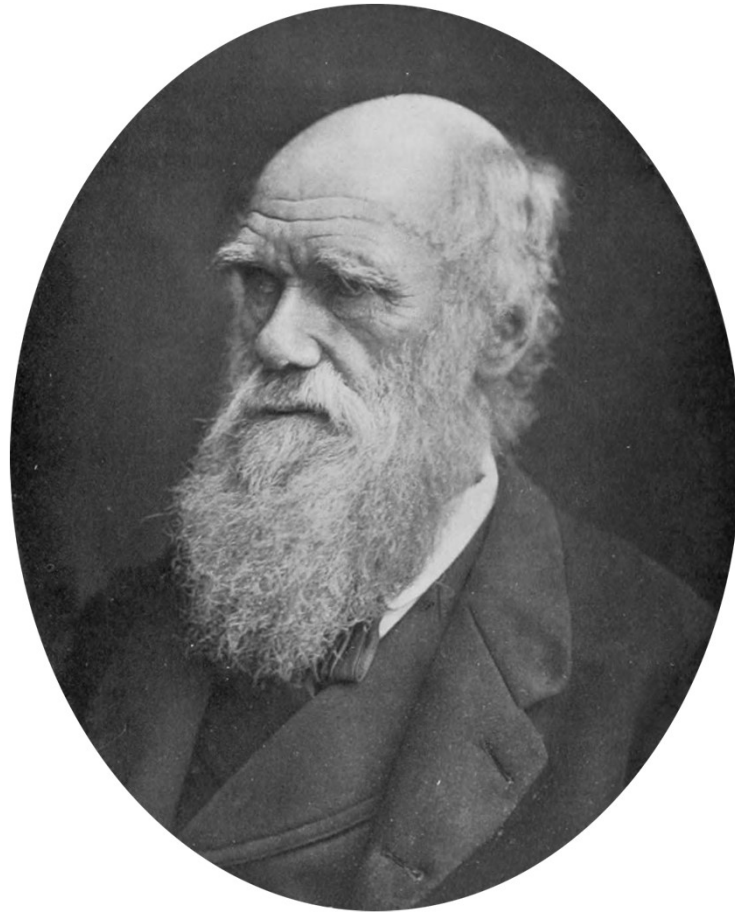
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