# Effects of population size and metapopulation structure on sexual reproduction and genetic variation in local populations of an endangered tree species, *Magnolia stellata*

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# Introduction

**Decline of population size**
**Population isolation**

- Shortage of mating partner and pollinators
- Inbreeding depression

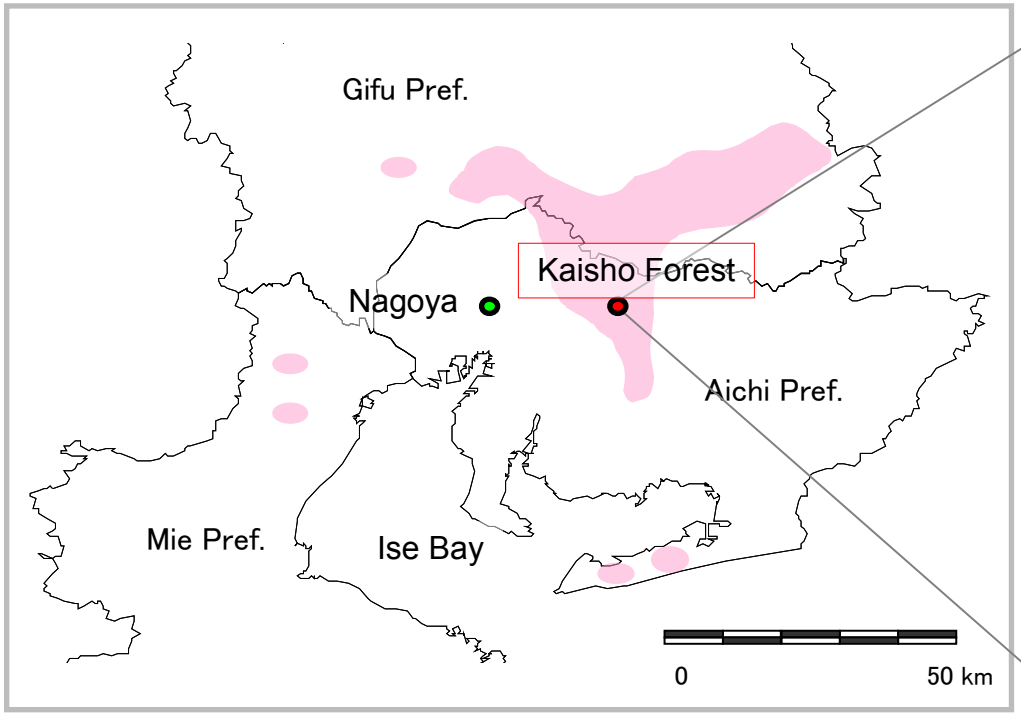
- Increase the effect of genetic drift
- Decrease the inter-population gene flow

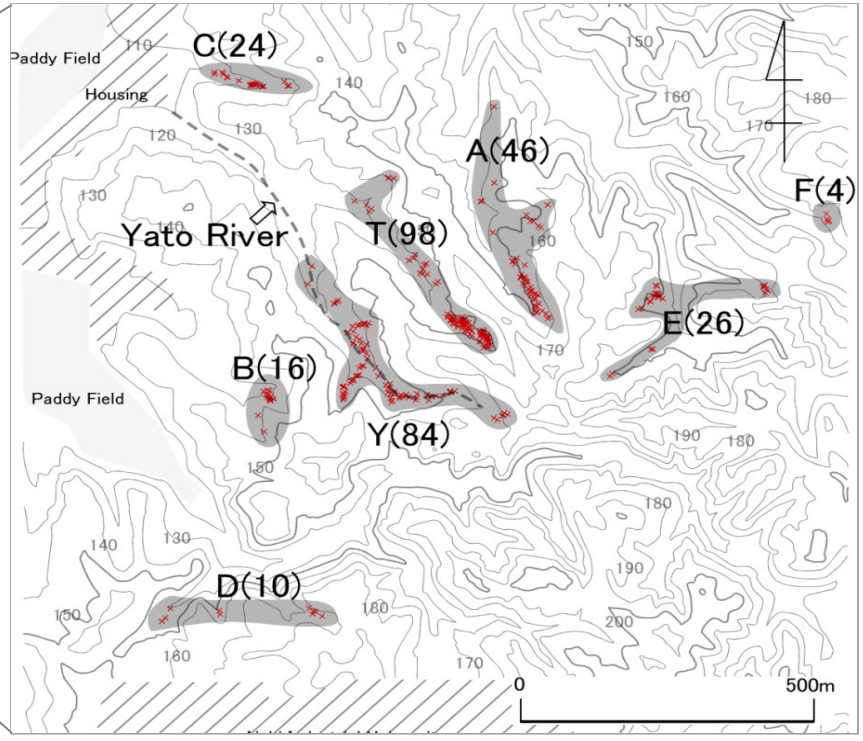
**Decrease the reproductive success**

**Decrease the genetic variation**

**Lose the evolutionary potential of species**
**Fragile to environmental variation**

# Natural distribution of *Magnolia stellata*



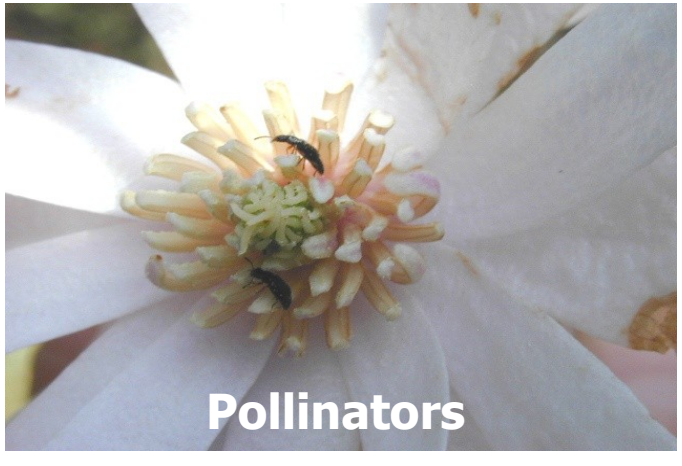

- Endemic to the area around Ise Bay in Japan, 'near threatened' (the Japanese red list)
- Most habitat is small marsh
  → **Population sizes are usually small**
- **Metapopulation structure**

# *Magnolia stellata*


Spruting


Layering


Protogynous flower


Pollinators


Fruits

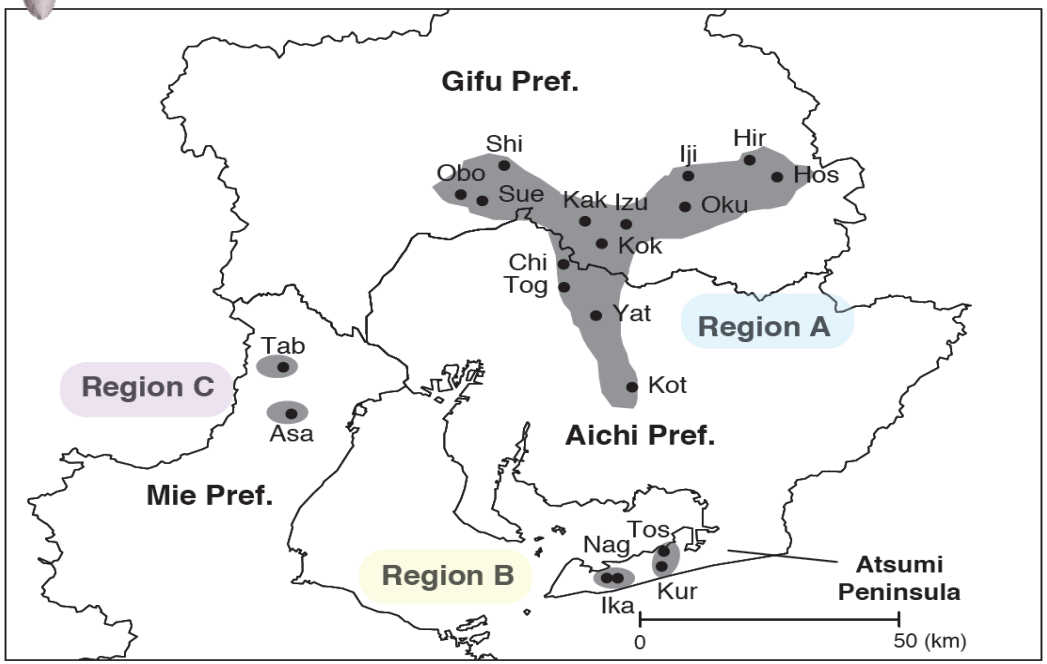

Seed disperser

# Contents

Effects of population size and population isolation on …

- within-population genetic variation
- reproductive success
  - Early-stage & late-stage inbreeding depression
- inter-population pollen flow

# Effects of population size and population isolation on within-population genetic variation




Gray area: Distribution of *M. stellata*

| Population Name | Code | Size | Sample size |
|---|---|---|---|
| 蛭川 | Hir | 101 | 29 |
| 星ヶ見 | Hos | 257 | 30 |
| 飯地 | Iji | 56 | 30 |
| 泉 | Izu | 70 | 29 |
| 柿下 | Kak | 54 | 31 |
| 虎渓山 | Kok | 339 | 30 |
| 大洞 | Obo | 42 | 27 |
| 大湫 | Oku | 69 | 67 |
| 志津野 | Shi | 61 | 32 |
| 須衛 | Sue | 156 | 30 |
| 築水池 | Chi | 108 | 34 |
| 琴平 | Kot | 79 | 30 |
| 東谷山 | Tog | 40 | 34 |
| 屋戸川 | Yat | 77 | 77 |
| 黒河 | Kur | 29 | 29 |
| 藤七原 | Tos | 130 | 30 |
| 伊川津 | Ika | 30 | 27 |
| 椛 | Nag | 53 | 29 |
| 旭谷 | Asa | 29 | 29 |
| 田光 | Tab | 51 | 31 |

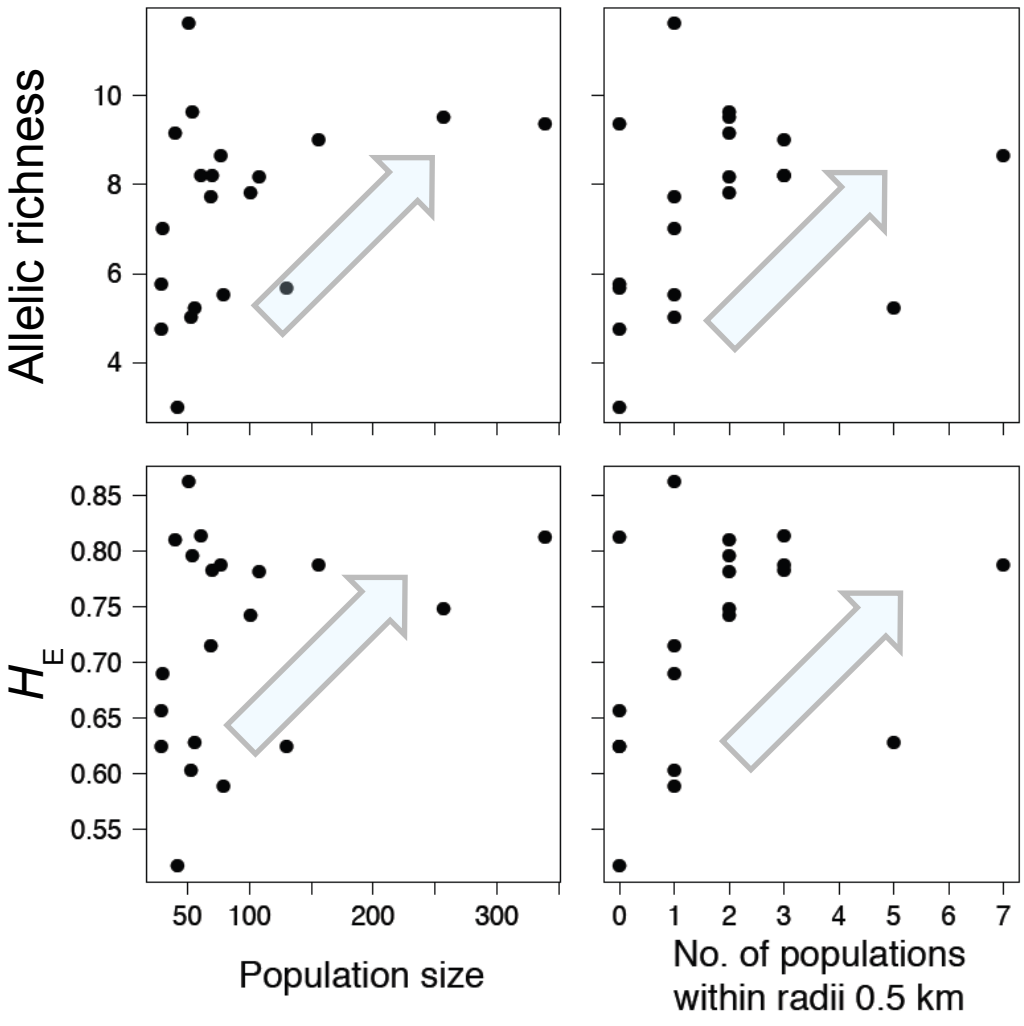
20 natural populations across the species range

- **Population size, population isolation**

  **Genetic variation**

  Allelic richness, Gene diversity($H_E$)...nuclear SSR

# Results: Effects of population size and population isolation on within-population genetic variation




GLMMs

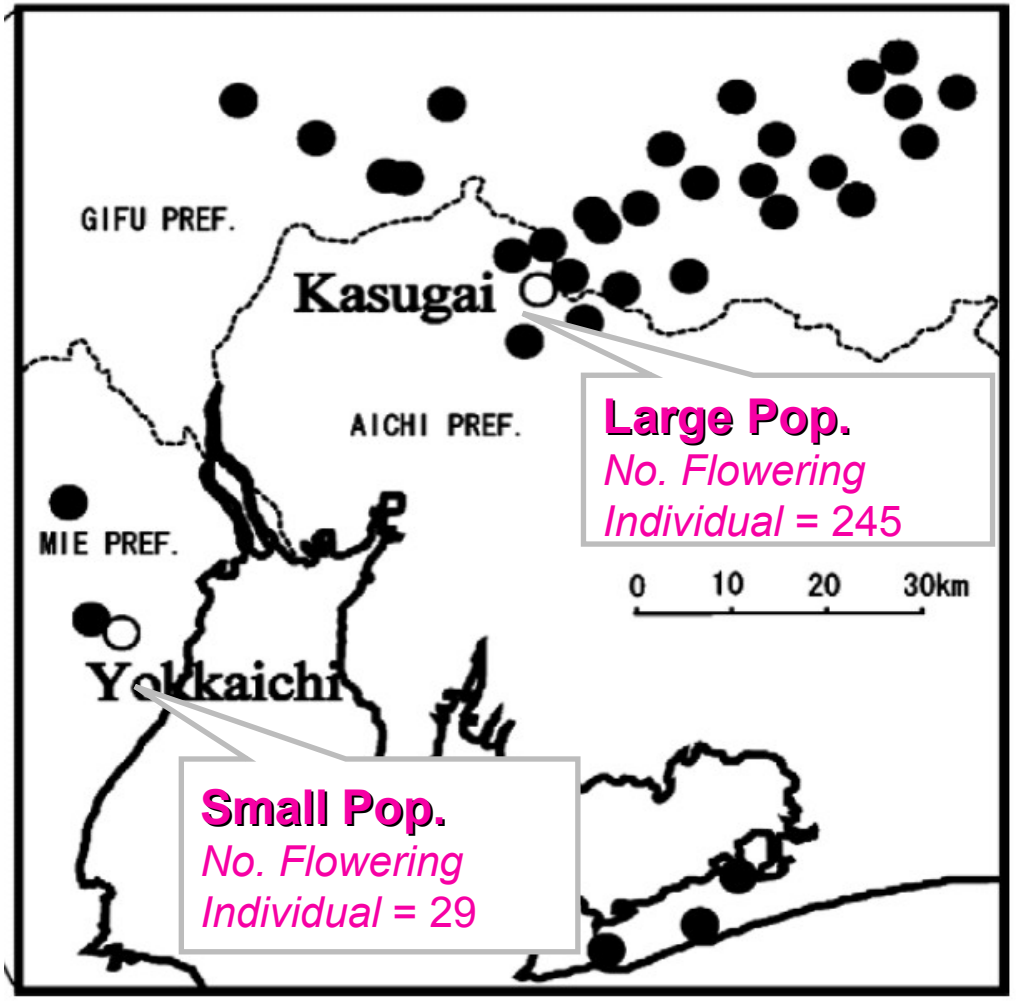
Large populations and high numbers of surrounding populations tend to have high levels of genetic variation

Allelic richness: No. of alleles standardized to the same sample size

Gene diversity ($H_E$): Expected heterozygosity

# Effects of population size on female reproductive success and early-stage inbreeding depression

From embryo to seed




- **Artificial pollination at large and small population**

  Cross pollination, self pollination, open pollination

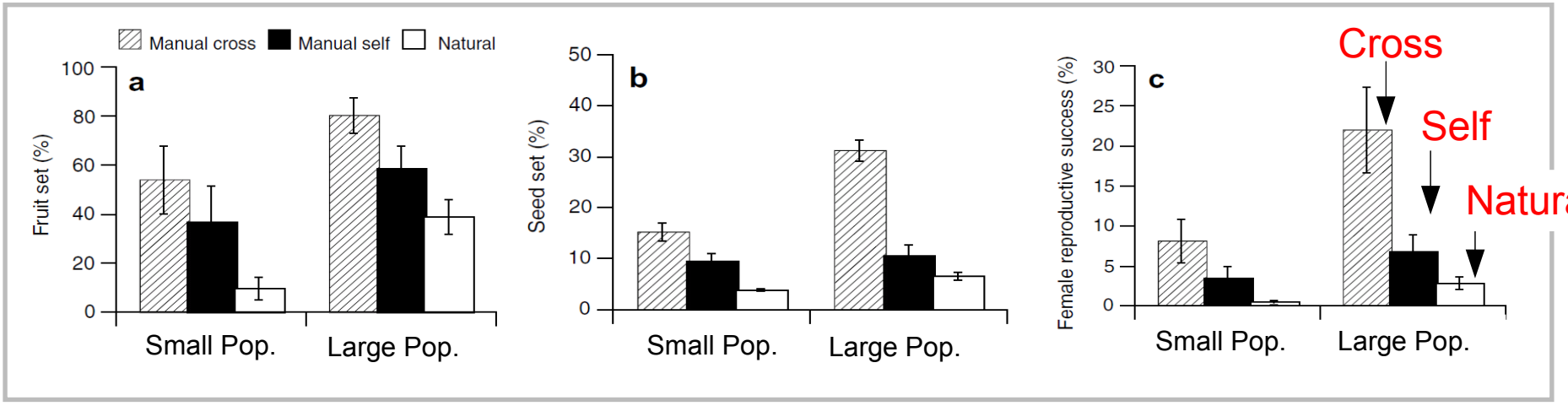
- **Population size**

  & Female reproductive success

  Early-stage inbreeding depression

  Pollen shortage

# Results: Effects of population size on female reproductive success and early-stage inbreeding depression




- **Reproductive success**

  Cross > Self > Natural, Large Pop. > Small Pop.

- **Early-stage inbreeding depression** ($\delta$)

  Large Pop.: 0.700 ± 0.085 > Small Pop.: 0.592 ± 0.221

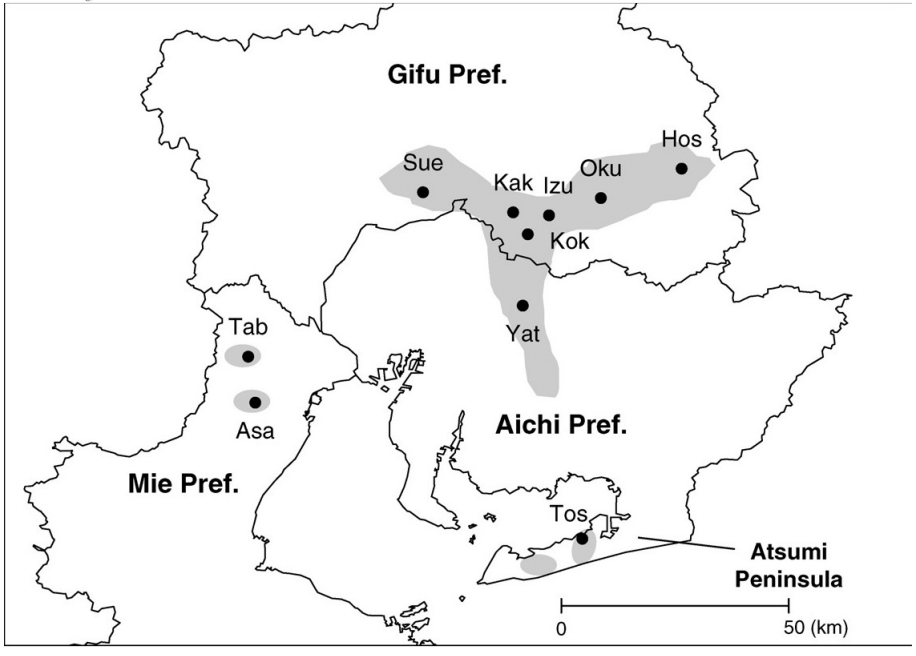
  Purge of deleterious alleles?
  Genetic deterioration by genetic drift?

- **Ovule mortality rate due to pollen shortage** ($u$)

  Large Pop.: 0.833 ± 0.064 < Small Pop.: 0.947 ± 0.019

  Severe pollen shortage in small population

# Effects of population size and population isolation on late-stage inbreeding depression



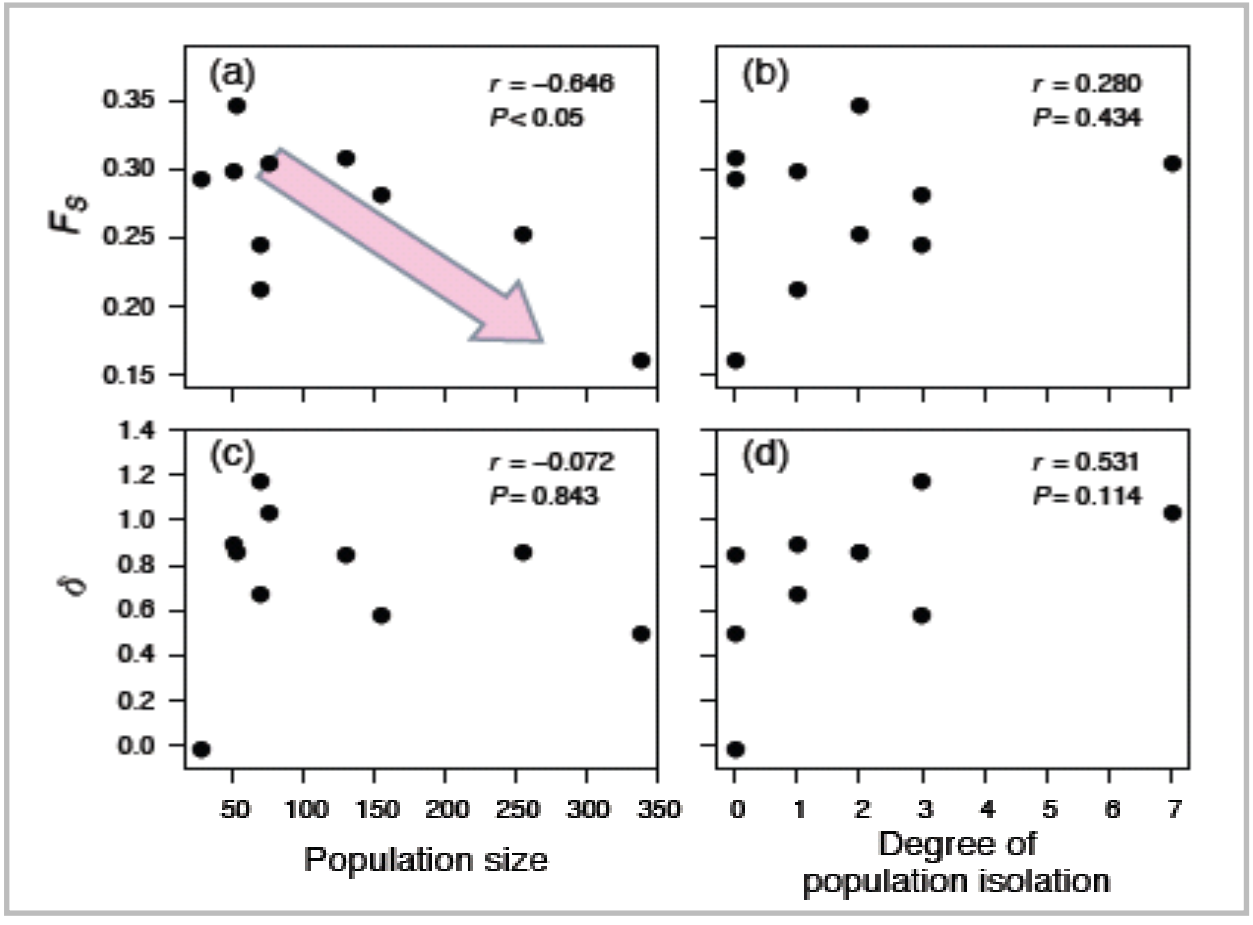

From seed to adults

| Populaiton | | | No.of samples | |
|---|---|---|---|---|
| Name | Code | Size | Tree | Seed |
| 星ヶ見 | Hos | 257 | 19 | 159 |
| 大洩 | Oku | 69 | 11 | 99 |
| 泉 | Izu | 70 | 14 | 97 |
| 虎渓山 | Kok | 339 | 16 | 142 |
| 柿下 | Kak | 54 | 10 | 64 |
| 須衛 | Sue | 156 | 18 | 171 |
| 屋戸川 | Yat | 77 | 10 | 106 |
| 藤七原 | Tos | 130 | 15 | 139 |
| 旭谷 | Asa | 29 | 13 | 74 |
| 田光 | Tab | 51 | 16 | 165 |
| Average | | | 14.2 | 121.6 |

10 natural populations across the species range

- Population size, population isolation
  & Inbreeding (Inbreeding coefficient)
  Inbreeding depression ($\delta$)

# Results: Effects of population size and population isolation on late-stage inbreeding depression




$\delta = 1 - [(1 - F_S) F_A / F_S (1 - F_A)]$

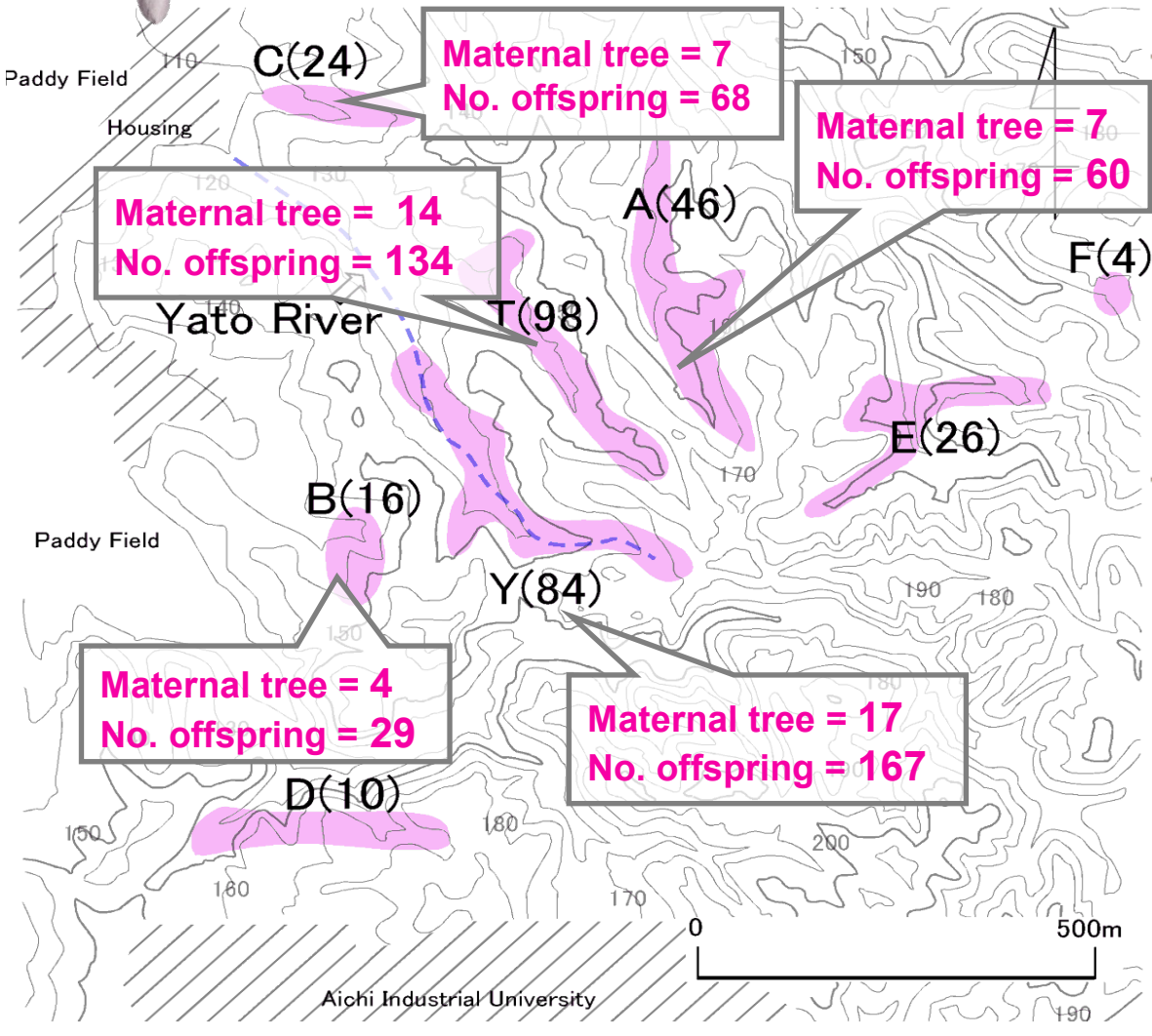
Ritland (1990)

$F_A$: Adult stage inbreeding coefficient

$F_S$: Seed stage inbreeding coefficient

- Inbreeding tend to be greater in small populations
- Inbreeding depression did not significantly correlated with population size

# Effects of population size and population isolation on inter-population pollen flow




- **Paternity analysis** of seeds collected from 5 local population, differ in size

- **Population size, population isolation**

**& Inter-population pollen flow**

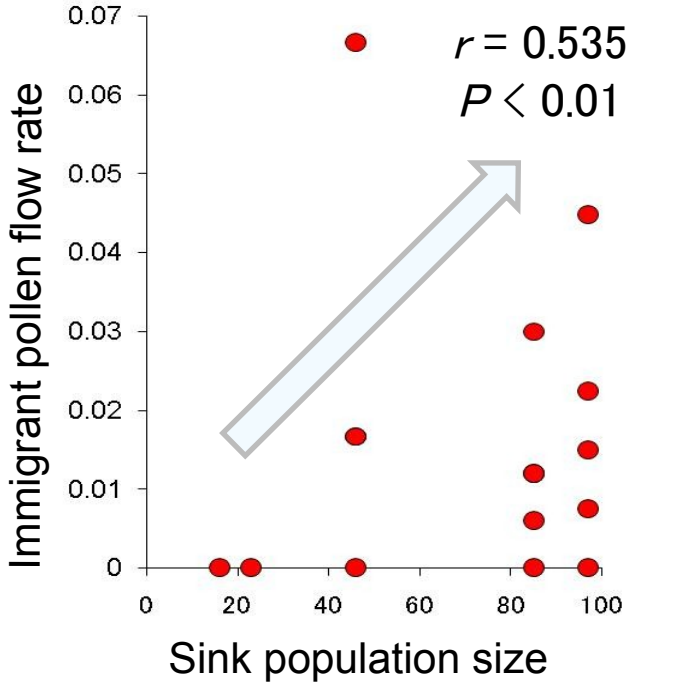
### Immigrant pollen flow

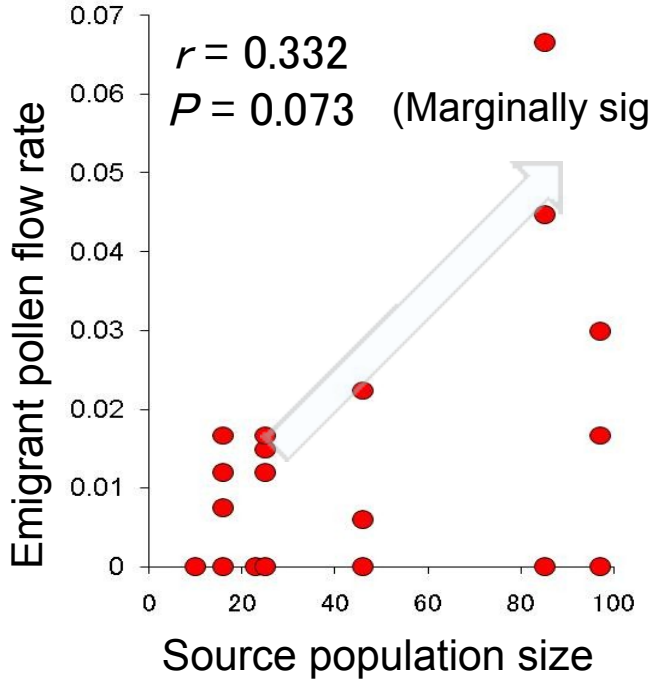
Pollen which flow in from outside the local population

### Emigrant pollen flow

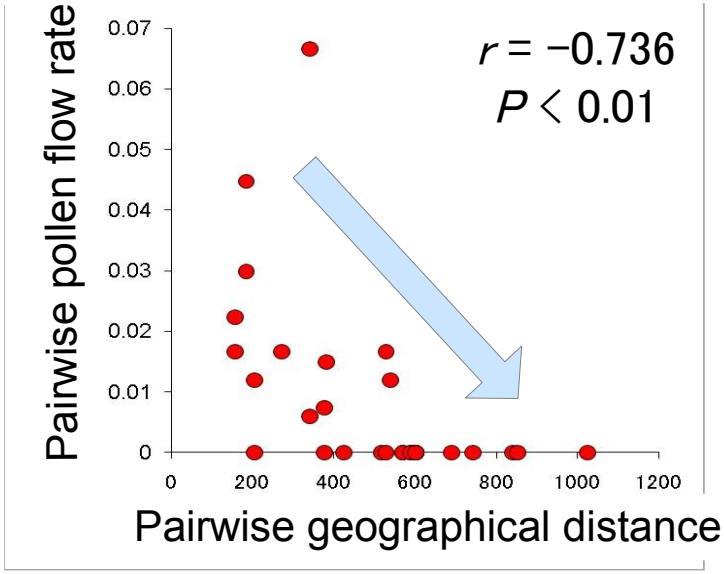
Pollen which flow out to outside the local population

# Results: Effects of population size and population isolation on inter-population pollen flow



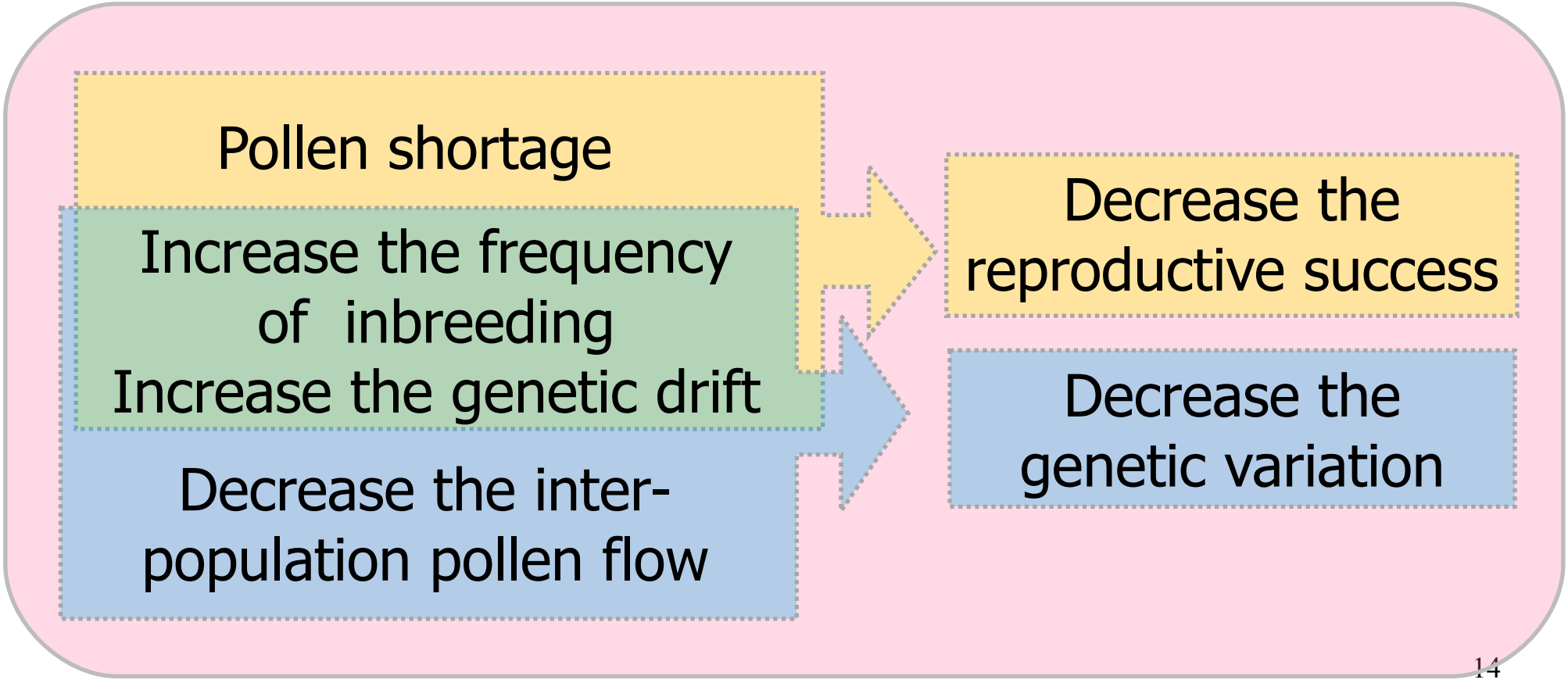

Large populations contribute as both source and sink of pollen




Inter-population pollen flow decreases by population isolation

# Conclusion

Decline of population size and population isolation...



- **Early-stage inbreeding depression** ($\delta$)

$\delta$ = 1 – (Ovule survival rate of self pollination / Ovule survival rate of cross pollination)

- **Ovule mortality rate due to pollen shortage** ($u$)

$v = (1 - u)(1 - g)(1 - r)$

$v$: Ovule survival rate of natural pollination

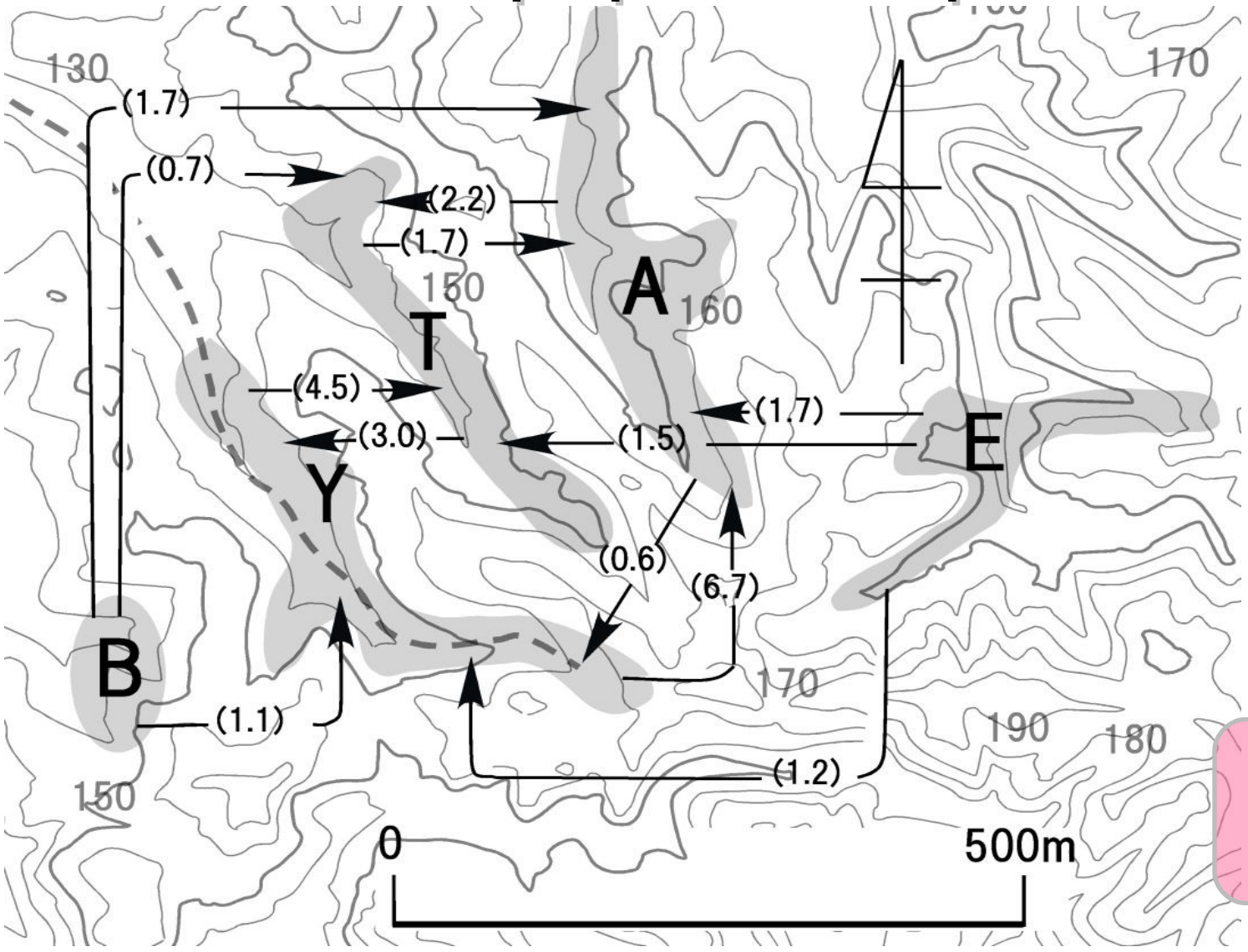
$u$: Ovule mortality rate due to natural pollination

$g$: Ovule mortality rate due to self pollianation

$$g = \delta [(1 - t_m) / (1 - t_m \delta_e)]$$

$r$: Ovule mortality rate due to natural cross pollination

# Inter-population pollen flow



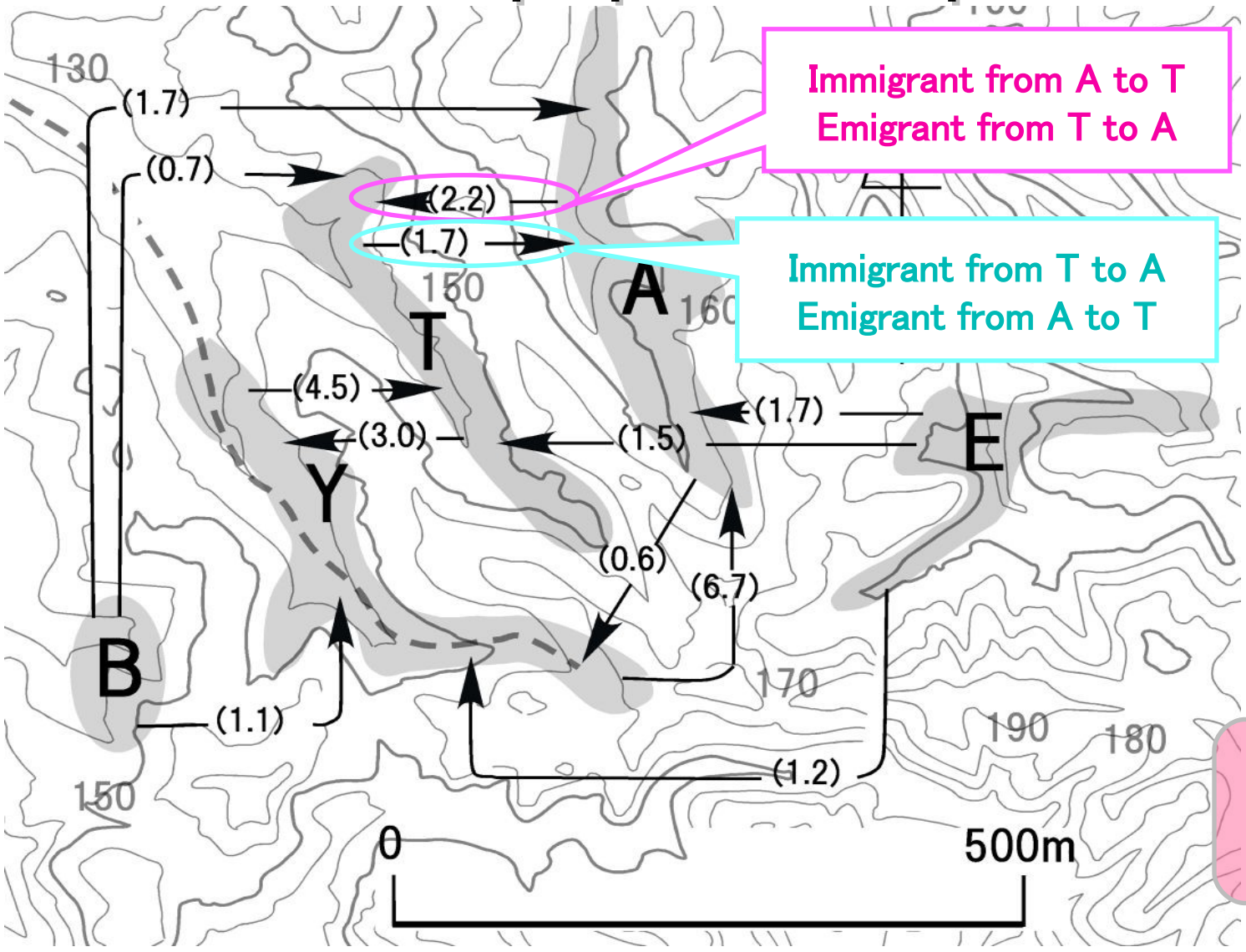

Source

(Pollen Flow Rate %)

Sink

Among population pollen flow
0 – 6.7 %

# Inter-population pollen flow




Source

(Pollen Flow Rate %)

Sink

Among population pollen flow
0 – 6.7 %