Fragmentation and restoration of Southeast Asian Rainforest, seeing green in a sea of REDD

National Institute of Environmental Studies (NIES)
Tokyo, Japan, 25th September 2012, 15.50

Chris J. Kettle

David Burslem, Colin Maycock, Aline Finger, Sascha Ismail, Kirsty Nutt, Eyen Khoo, Pete Hollingsworth and Jaboury Ghazoul

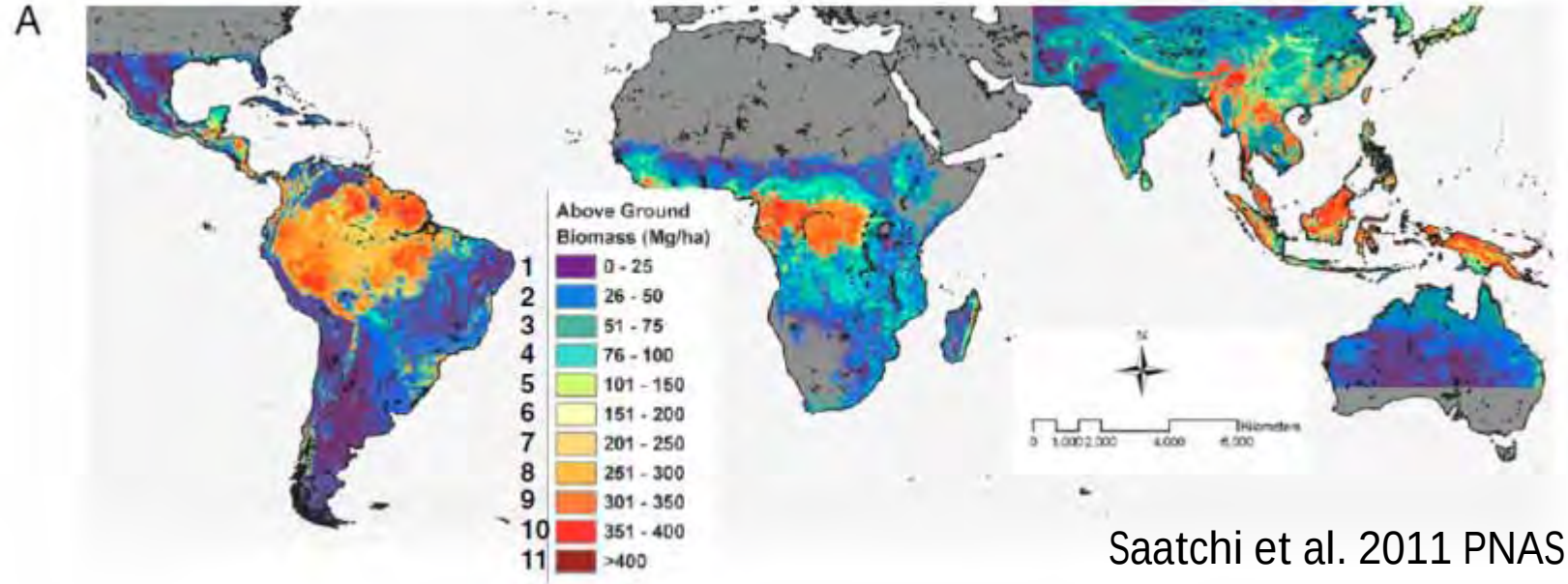
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

UNIVERSITY OF ABERDEEN

ROYAL BOTANIC GARDEN EDINBURGH

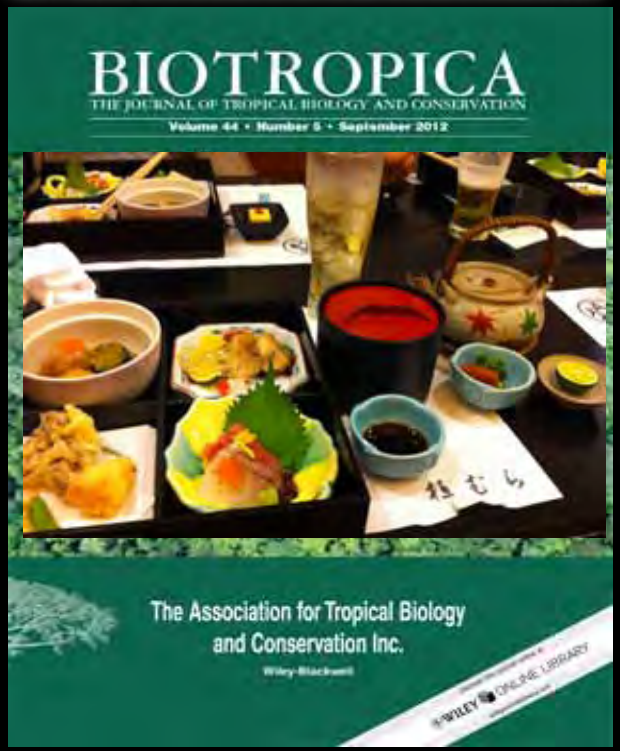
Global Centre of Biodiversity

Global Forest carbon sinks



Saatchi et al. 2011 PNAS

The Dipterocarpaceae



Pantropical

Dipterocarpoideae

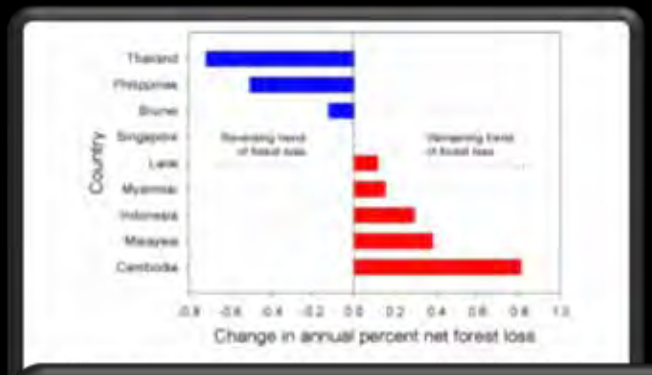
15 Genera
470 species

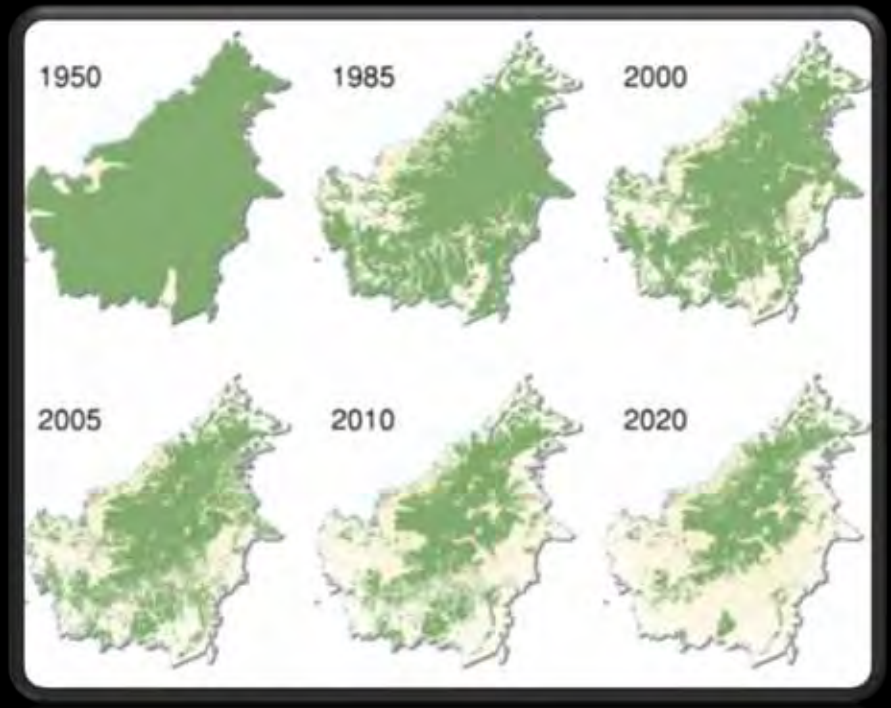
> 250 species
on Borneo

Natural resource

From this

Deforestation in Borneo





BIOTROPICA 0(0): 1–9 2012 10.1111/j.1744-7429.2011.00852.x

A Revised Conservation Assessment of Dipterocarps in Sabah

Colin R. Maycock[1,2,3], Chris J. Kettle[2], Eyen Khoo[1], Joan T. Pereira[1], John B. Sugau[1], Reuben Nilus[1], Robert C. Ong[1], Nashatul A. Amalodin[2], Mark F. Newman[4], and David F.R.P. Burslem[3]

[1] Forest Research Centre, Sabah Forest Department, Sabah 90714, Malaysia

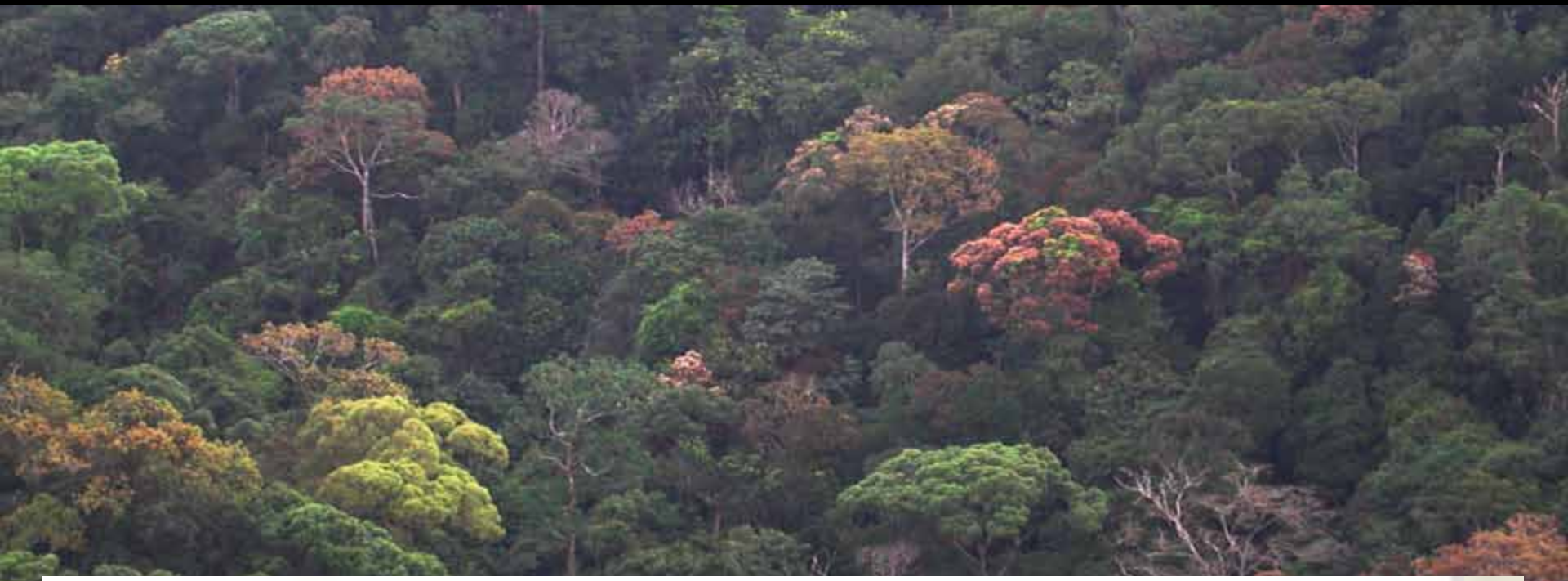
[2] Institute of Terrestrial Ecosystems, ETH Zürich, CHN G 73.1, Universitätstrasse 16, Zürich 8092, Switzerland

[3] Institute of Biological and Environmental Sciences, University of Aberdeen, Cruickshank Building, St Machar Drive, Aberdeen AB24 3UU, U.K.

[4] Royal Botanic Garden Edinburgh, 20A Inverleith Row, Edinburgh, EH3 5LR, U.K.

Maycock et al. 2012 *Biotropica*

General flowering and mast fruiting



POLICY PERSPECTIVE

Kettle et al 2011 Conservation Letters

Seeing the fruit for the trees in Borneo

Chris J. Kettle[1], Jaboury Ghazoul[1], Peter Ashton[2], Charles H. Cannon[3,19], Lucy Chong[4], Bibian Diway[4], Eny Faridah[5], Rhett Harrison[3], Andy Hector[6], Pete Hollingsworth[7], Lian Pin Koh[1], Eyen Khoo[8], Kanehiro Kitayama[9], Kuswata Kartawinata[10], Andrew J. Marshall[11], Colin Maycock[12], Satoshi Nanami[13], Gary Paoli[14], Matthew D. Potts[15], Ismayadi Samsoedin[16], Douglas Sheil[17], Sylvester Tan[4], Ichie Tomoaki[18], Campbell Webb[2], Takuo Yamakura[13] & David F.R.P. Burslem[12]

Seed storage not possible in dipterocarps

Kettle *et al* 2011 Science

LETTERS

Service ran afoul of Greenberg's Law: Don't ask the barber if you need a haircut (*5*).

EDWIN A. CHANDROSS

Materials Chemistry LLC, 14 Hunterdon Boulevard, Murray Hill, NJ 07974, USA. E-mail: [illegible]

References

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. R. S. Greenberg, "[illegible]," Saturday Review (25 November 1972), pp. 58–59.

An Unorthodox Approach to Forest Restoration

IN THEIR POLICY FORUM "RESTORATION SEED banks—A matter of scale" (22 April, p. 424), D. J. Merritt and K. W. Dixon highlight the importance of ecological restoration in meeting global conservation goals, and the urgency to scale up seed supplies from seed banks to achieve such endeavors. We support their call, but emphasize that seed banks will only facilitate the restoration of ecosystems dominated by species whose seeds can tolerate drying and long-term storage.

Seeds fall into two storage categories: orthodox seeds and recalcitrant (or unorthodox) seeds. Orthodox seeds tolerate desiccation without losing viability and germinate upon rehydration, making them highly amenable to storage in seed banks. Recalcitrant seeds have high moisture content and lose viability if moisture drops below a critical amount. The desiccation sensitivity of recalcitrant species means that restoration seed banks are ineffective for many plant species. Other methods, such as cryogenic storage, are unlikely to be scalable for restoration (*1*).

These limitations are noteworthy, given that many tropical and subtropical tree species have recalcitrant seeds (*2*). Many such species are ecologically and also economically important, with markets based on global tropical timber valued at nearly US$100 billion (*3*). For example, the data that exist on seed behavior in four of the globally most important timber families indicate that, on average, 60% are recalcitrant (*4*).

Restoration seed banks might contribute to the conservation and restoration of many orthodox plant species, but restoration of tropical forests and many other plant communities will require considerable additional investments in plant nurseries and seedling propagation to maintain the equally numerous, and perhaps ecologically more important, recalcitrant species (*5*). Expansion of seedling propagation for restoration of tropical forests will require overcoming ecological and financial, rather than technological, constraints (*6*).

CHRIS J. KETTLE,*† DAVID F. R. P. BURSLEM,‡ JABOURY GHAZOUL†

†Institute of Terrestrial Ecosystems, ETH Zürich, Universitätstrasse 16, Zurich 8092, Switzerland. ‡Institute of Biological and Environmental Sciences, University of Aberdeen, Cruickshank Building, St. Machar Drive, Aberdeen AB24 3UU, UK.

*To whom correspondence should be addressed. E-mail: chris.kettle@env.ethz.ch

References

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]

Response

KETTLE AND COLLEAGUES ARE CORRECT THAT recalcitrant seeds, many of which grow in tropical climates, cannot be stored long-

Kettle 2012

Biological Conservation 154 (2012) 34–41

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Special Issue Article: REDD+ and conservation

Seeding ecological restoration of tropical forests: Priority setting under REDD+

Chris J. Kettle*

Department of Environmental Science, ETH Zürich, CHN G75.1, Universitätstrasse 16, 8092 Zürich, Switzerland

The Fragmentation genetics paradox

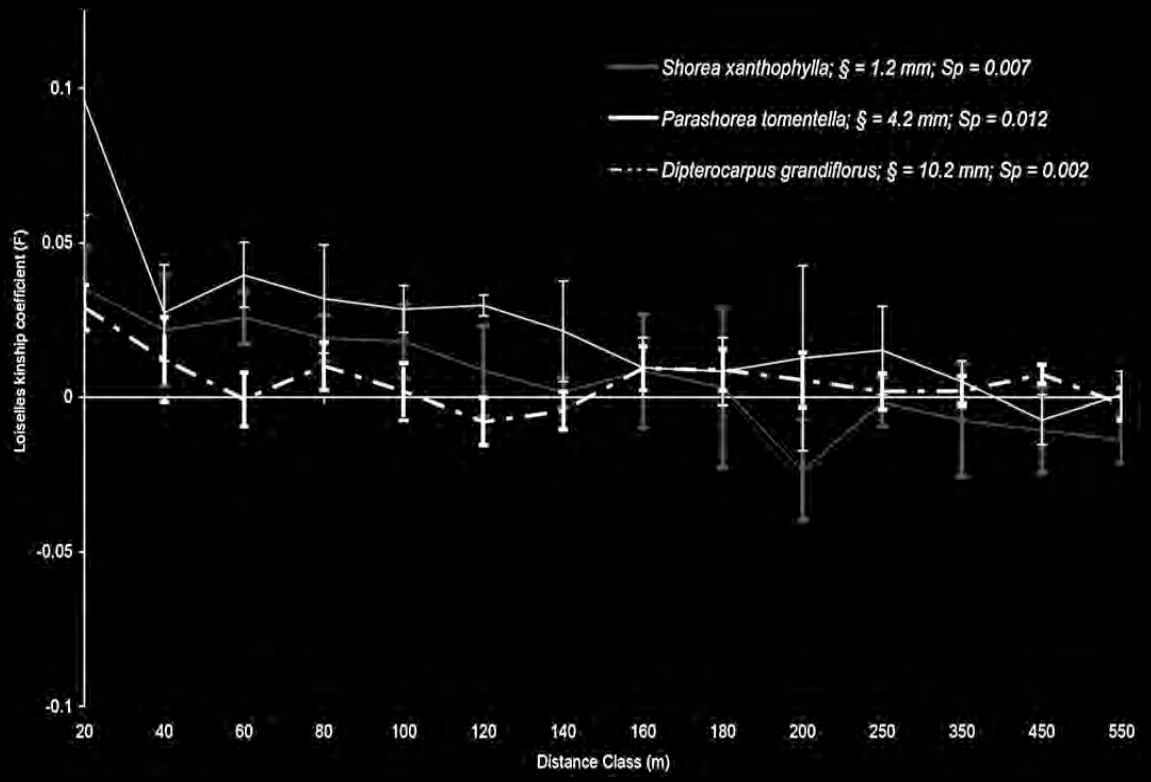
Kramer *et al* 2008

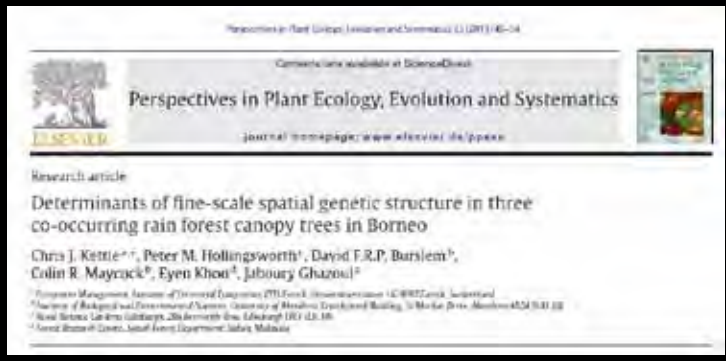
The implications of different flower size

Kettle et al 2011 PLoS ONE

Flower size appears to be a good surrogate for pollinator size

Fine-scale spatial genetic structure Kettle et al 2011



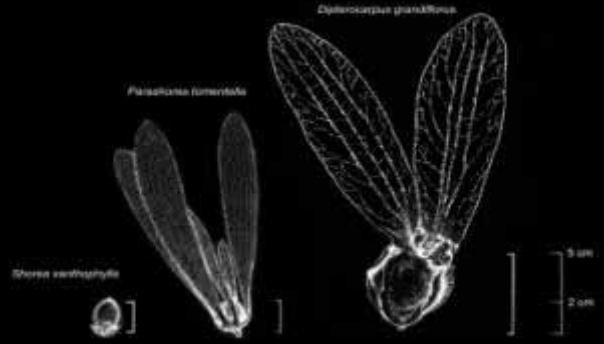


Perspectives in Plant Ecology, Evolution and Systematics

Research article

Determinants of fine-scale spatial genetic structure in three co-occurring rain forest canopy trees in Borneo

Chris J. Kettle, Peter M. Hollingsworth, David F.R.P. Burslem, Colin R. Maycock, Eyen Khoo, Jaboury Ghazoul



Harata *et al. Biotropica 2012*

Fine-scale spatial genetic structure common in dipterocarps

Special Section

Fine-scale Spatial Genetic Structure of Ten Dipterocarp Tree Species in a Bornean Rain Forest

Graduate School of Science, Osaka City University, Sugimoto 3-3-138 Sumiyoshi-ku, Osaka, 558-8585, Japan

Botanical Research Centre, Forestry, Sarawak Forestry Corporation, Sarawak, Malaysia

ABSTRACT

Flower size and pollen dispersal

Kettle et al 2011 PLoS ONE

Paternity analysis revealed that short distance mating events were more common among the smaller-flowered species

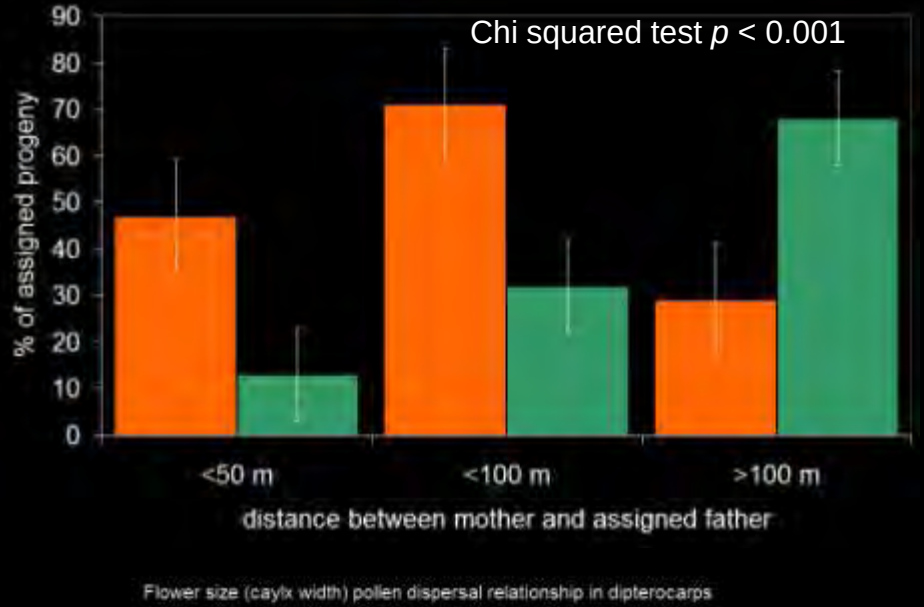
This pattern was consistent with three other published studies of pollen dispersal in dipterocarps with varying flower size Konuma *et al.* 2000, Kenta *et al.* 2004 Mol Ecol and Lee *et al.* 2006 Biol Con.

S. xanthophylla
1.2 mm

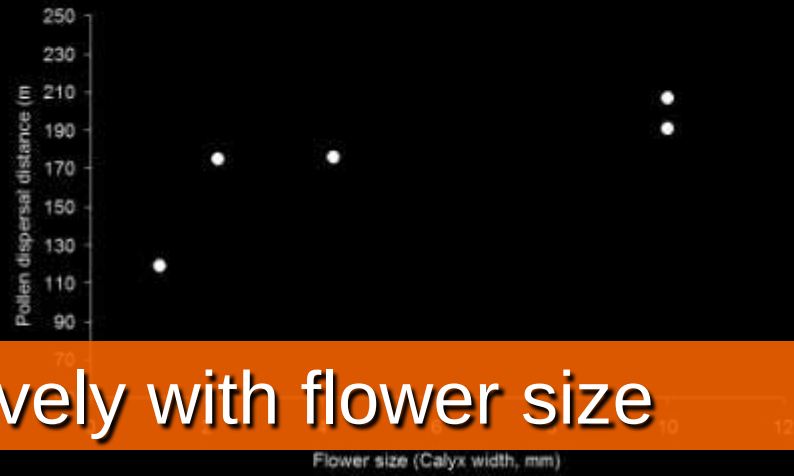
average pollen dispersal 119 m

P. tomentella
4.2 mm

average pollen dispersal 176 m



Flower size (caylx width) pollen dispersal relationship in dipterocarps



OPEN ACCESS Freely available online PLoS one

Ecological Implications of a Flower Size/Number Trade-Off in Tropical Forest Trees

Chris J. Kettle[1,2*], Colin R. Maycock[2], Jaboury Ghazoul[1], Pete M. Hollingsworth[3], Eyen Khoo[4], Rahayu Sukmaria Haji Sukri[2], David F. R. P. Burslem[2]

Pollen dispersal scales positively with flower size

Genetic costs to limited pollen dispersal

Kettle et al 2011 PLoS ONE

S. xanthophylla
1.2 mm

Based upon assigned paternity (9 microsatellite loci) we calculated the mean kinship coefficient (Loiselle *et al.* 1995) between mothers and assigned fathers using SpaGeDi (Hardy and Vekemans 2002).

Mean pairwise kinship between mothers and assigned fathers

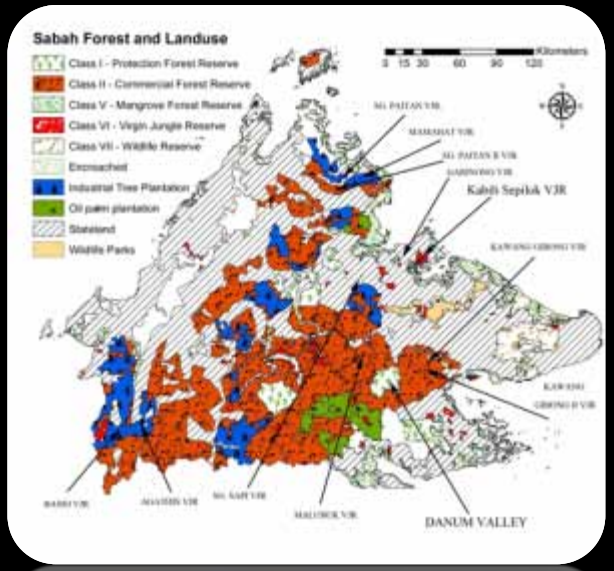
P. tomentella 4.2 mm

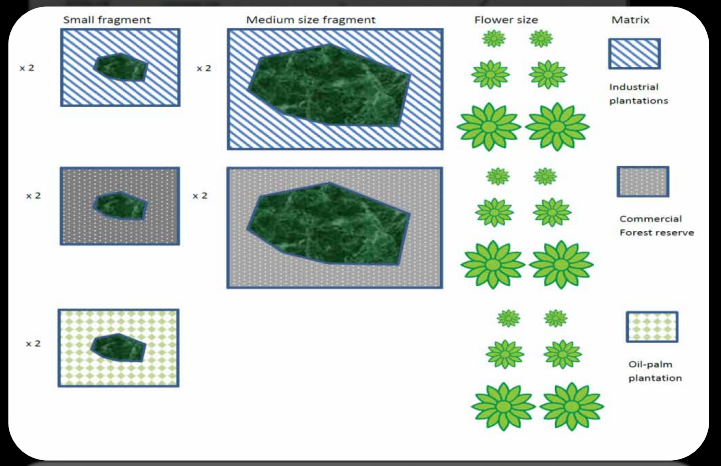
T-test, $P = 0.028$

Larger flower size is associated with less inbreeding

Gaps in our Knowledge

- How well can dipterocarps disperse pollen in fragmented landscapes?
- What are the implications of elevated inbreeding for fitness?
- Is flower size a useful proxy for vulnerability?
- What are the implications for tree community structure and ecosystem services?





Gaps in our Knowledge

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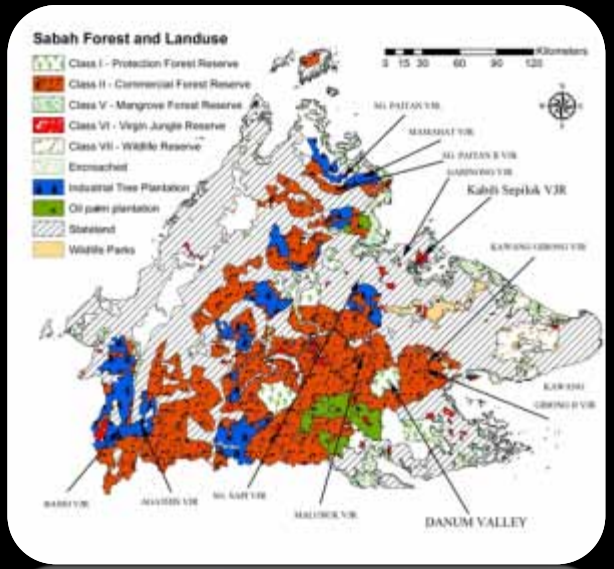
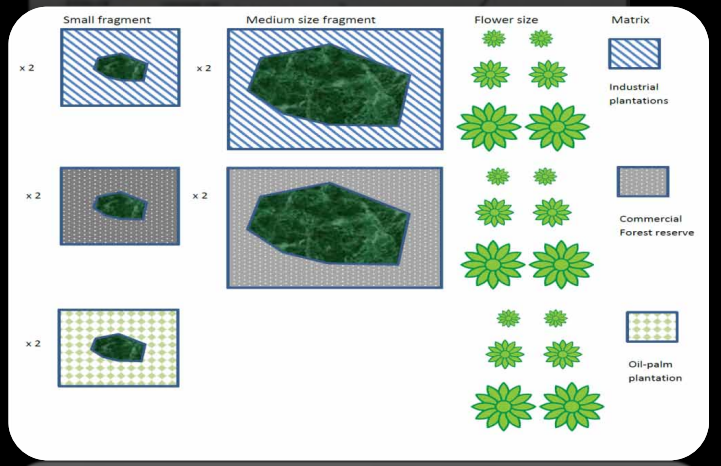


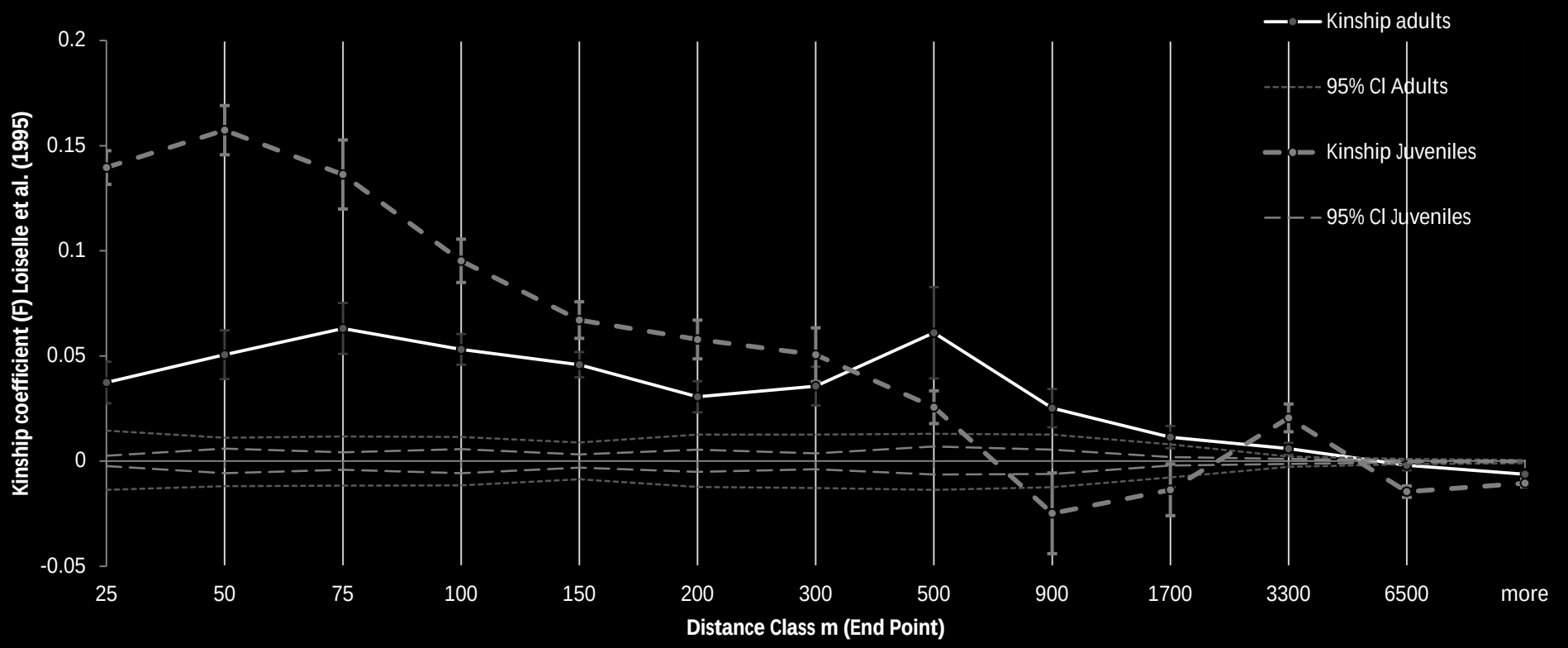


'Does long distance pollen dispersal preclude inbreeding in tropical trees?

Ismail et al. *in press* Molecular Ecology

Dysoxylum malabaricum

Fine scale spatial genetic structure?



Significant Fine scale genetic structure again!

Pollen flow over all samples

=5%

=1%

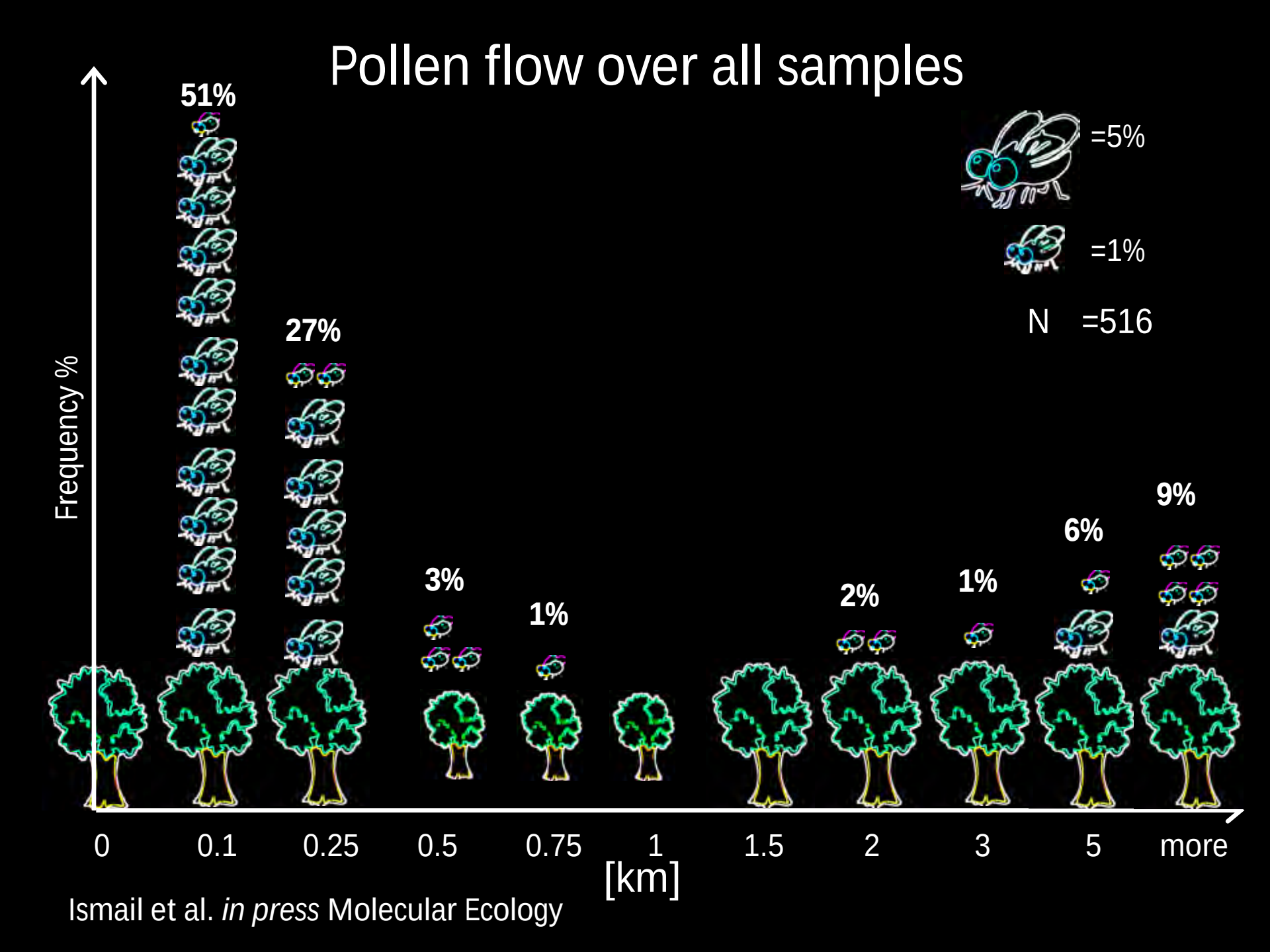
N =516

Frequency %

0 0.1 0.25 0.5 0.75 1 1.5 2 3 5 more

[km]

Ismail et al. *in press* Molecular Ecology


Pollen flow over all samples
51%
27%
3%
1%
2%
1%
6%
9%
=5%
=1%
N =516
Frequency %
0
0.1
0.25
0.5
0.75
1
1.5
2
3
5
more
[km]
Ismail et al. *in press* Molecular Ecology

Does the degree of spatial isolation matter?

15 mother trees within high local density groves (>6 in 500m)

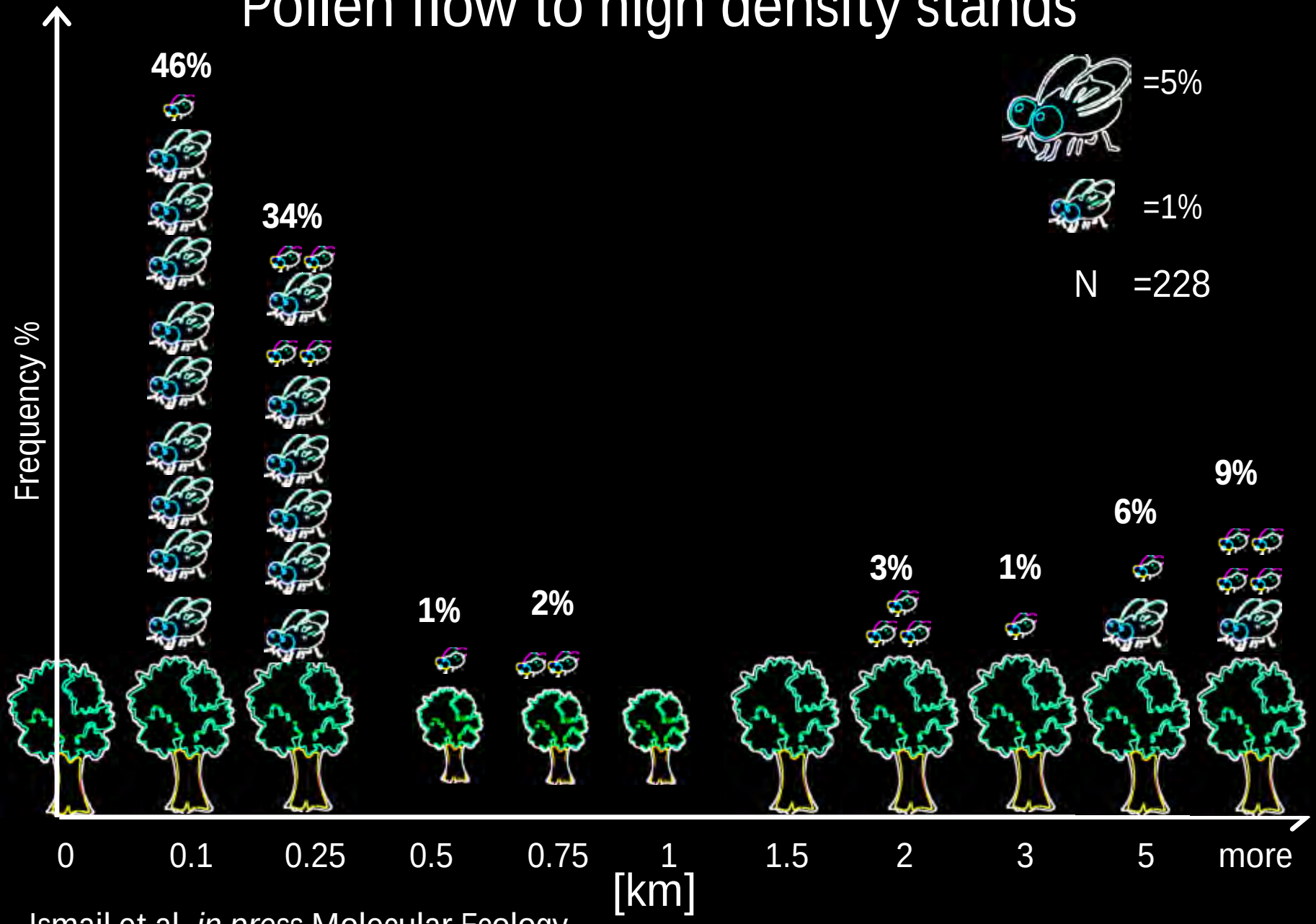
9 mother trees within low local density groves (<6 in 500m)

2 isolated mother trees
(no conspecifics with 500m)

Ismail et al. *in press* Molecular Ecology

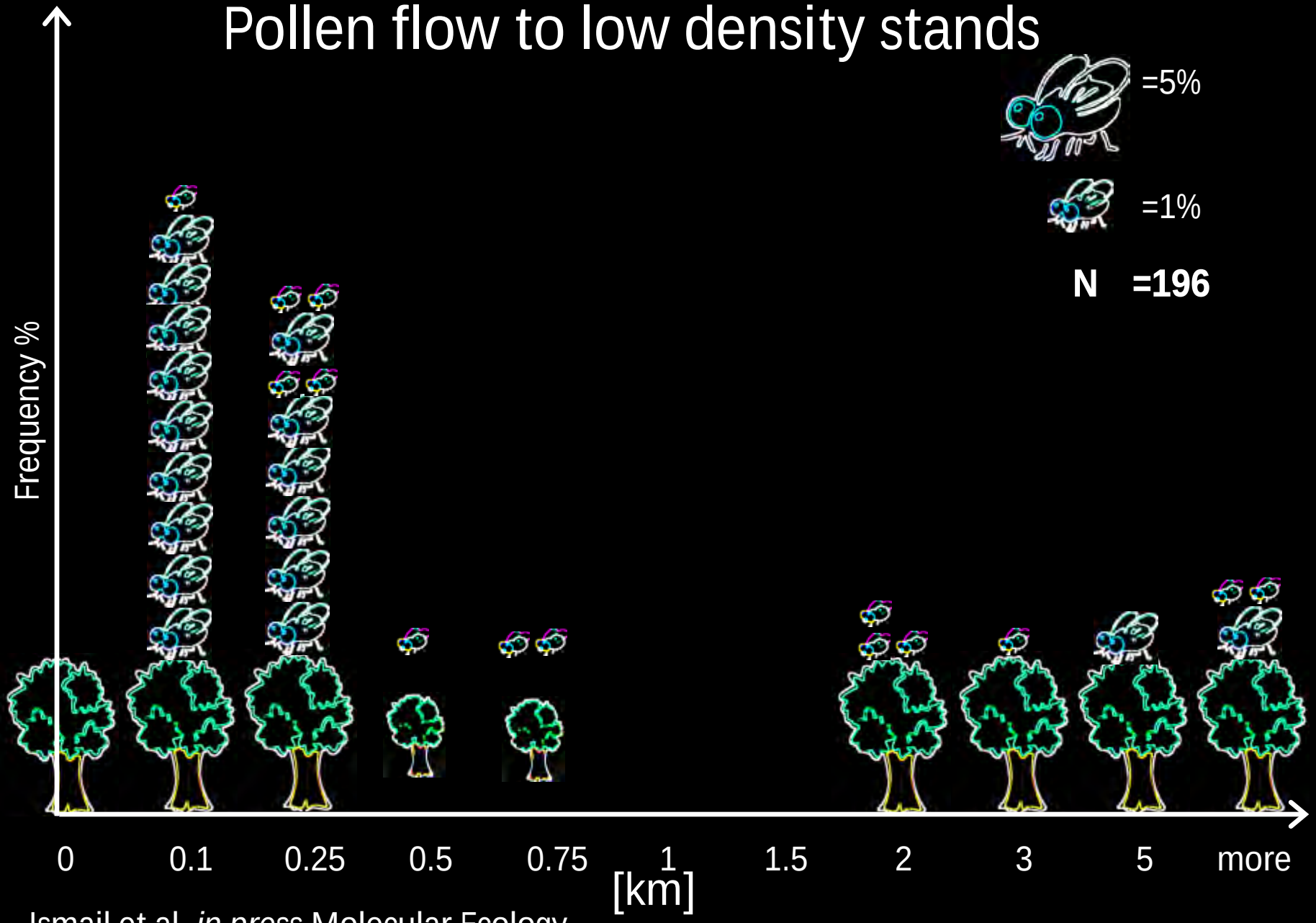
Dysoxylum malabaricum

Pollen flow to high density stands

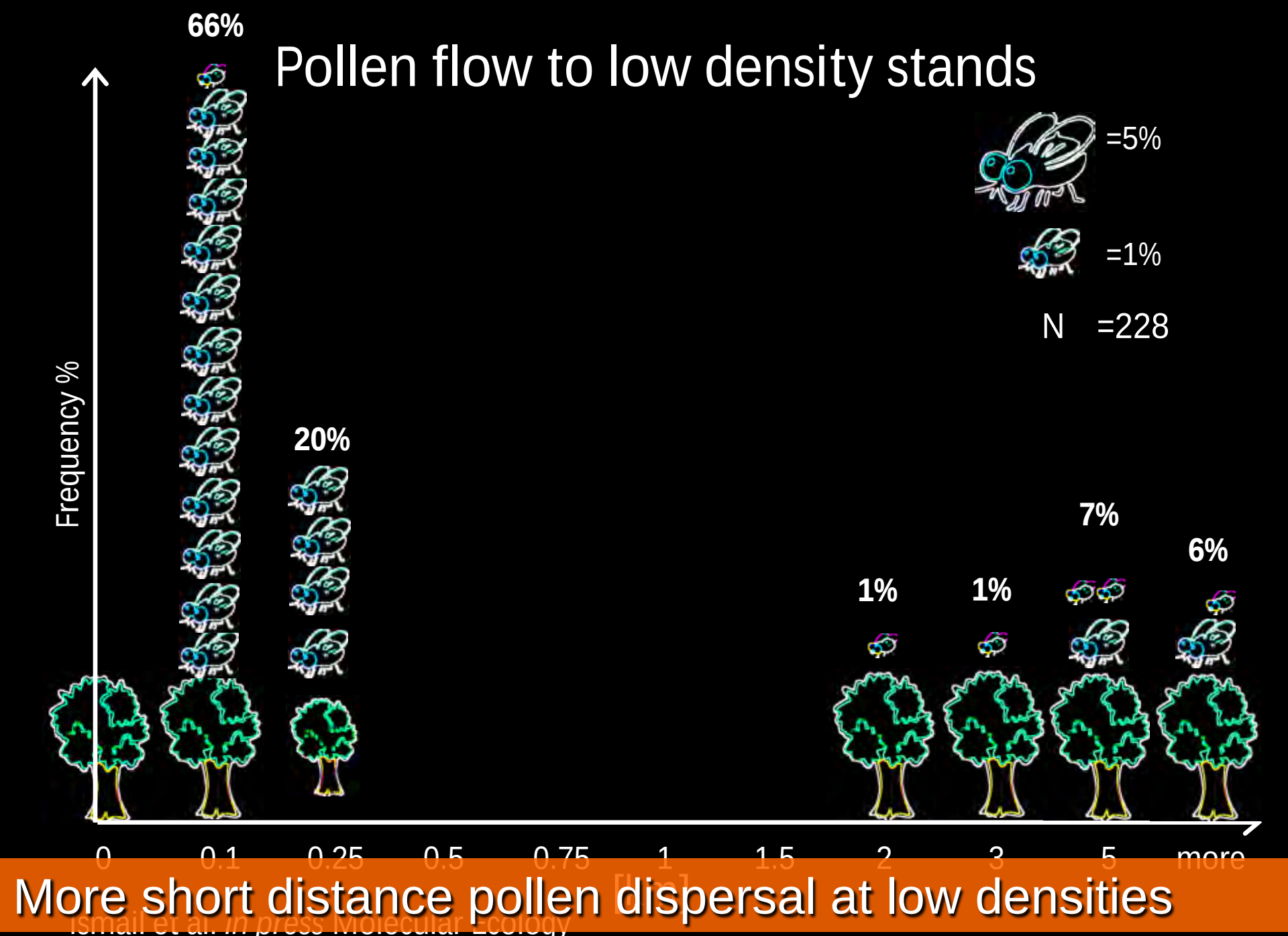


Ismail et al. *in press* Molecular Ecology

Pollen flow to low density stands



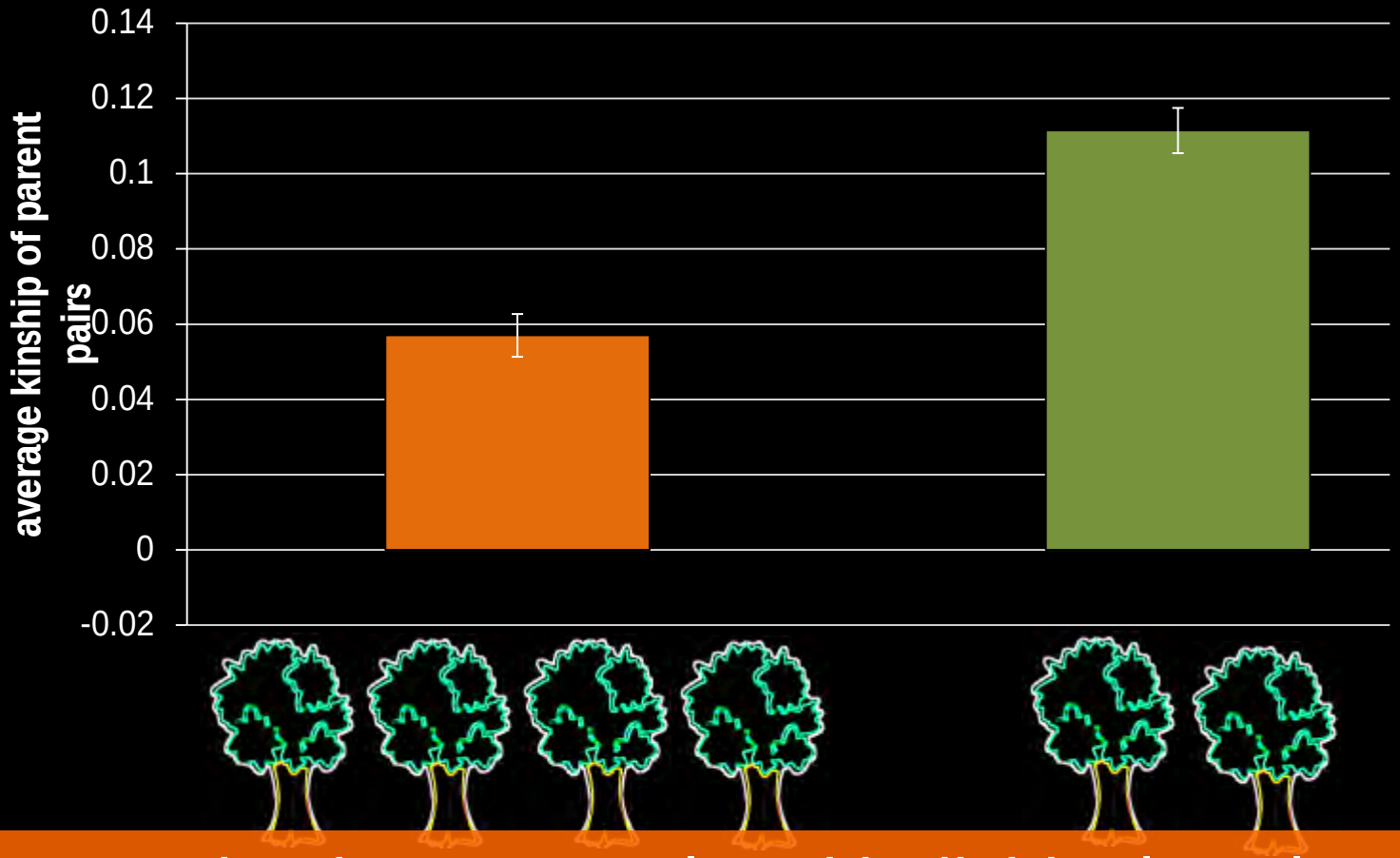
Ismail et al. *in press* Molecular Ecology



More short distance pollen dispersal at low densities

Ismail et al. *in press* Molecular Ecology

Kinship of parent pairs

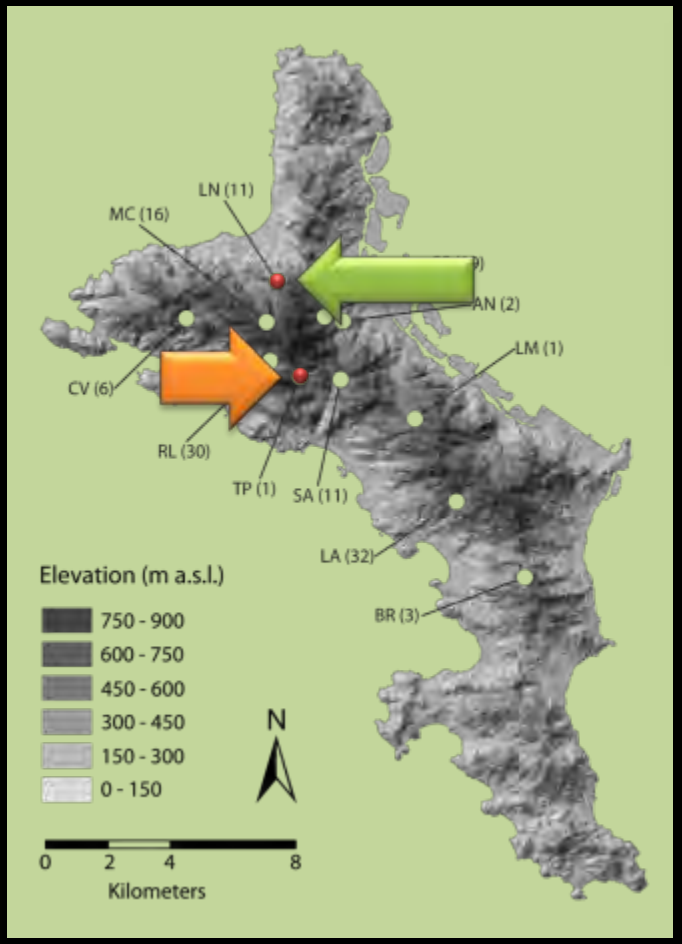


More mating between related individuals at low density

Ismail et al. *in press* Molecular Ecology

Importance of Mating system

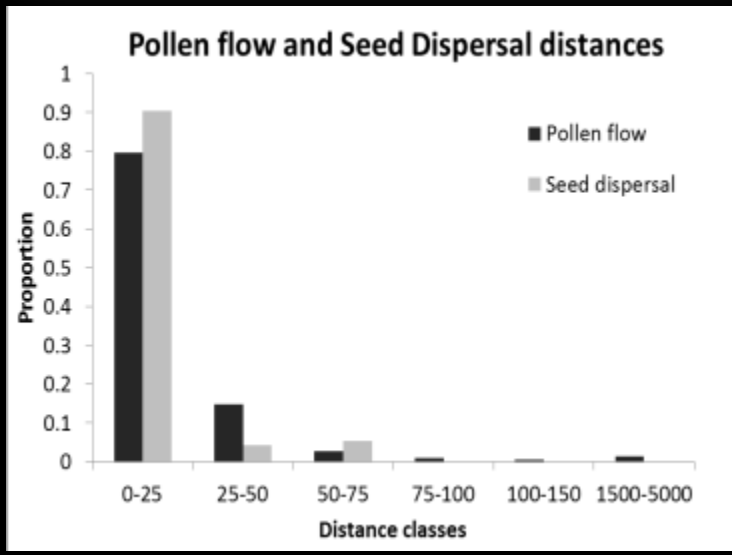
Finger *et al* 2012Molecular Ecology



MOLECULAR ECOLOGY

Forest fragmentation genetics in a formerly widespread island endemic tree: *Vateriopsis seychellarum* (Dipterocarpaceae)

A. FINGER,* C. J. KETTLE,* C. N. KAISER-BUNBURY,*† T. VALENTIN,‡ J. MOUGAL‡ and J. GHAZOUL*



Seychelles endemic dipterocarp
Vateriopsis seychellarum

What are the fitness costs?

Kirsty Nutt (*in prep*)

Summary

- Masting and recalcitrant seeds presents considerable constraints for restoration of Southeast Asian rainforest
- Limited dispersal is a critical factor for forest recovery in fragmented landscapes.
- Dipterocarps may be very vulnerable to genetic consequences of habitat fragmentation.
- Small flowered dipterocarp species may be especially vulnerable.
- Elevated inbreeding may lead to reduced performance and lower survival.
- Density of adult trees in fragments may impact on levels of inbreeding.
- Mating system of the species is important factor in determining vulnerability in the short term.
- Ecological restoration will have co-benefits for climate change mitigation, biodiversity conservation and poverty alleviation

Acknowledgements

The government of Malaysia and the state of Sabah. The Sabah Forest Dept. and all the Staff at FRC Sabah.

Seychelles Island foundation, and Colleagues in Seychelles

Prof Uma Shaanker and Colleagues at the University of Bangalore and ATREE India

Field work: Jeisin and Anis and Mike Charkov (field assistance)

Lab work, Kirsti Määtänen,

For references visit: www.chris-kettle.com

British Ecological Society
Advancing ecology and making it count

NATURAL ENVIRONMENT RESEARCH COUNCIL

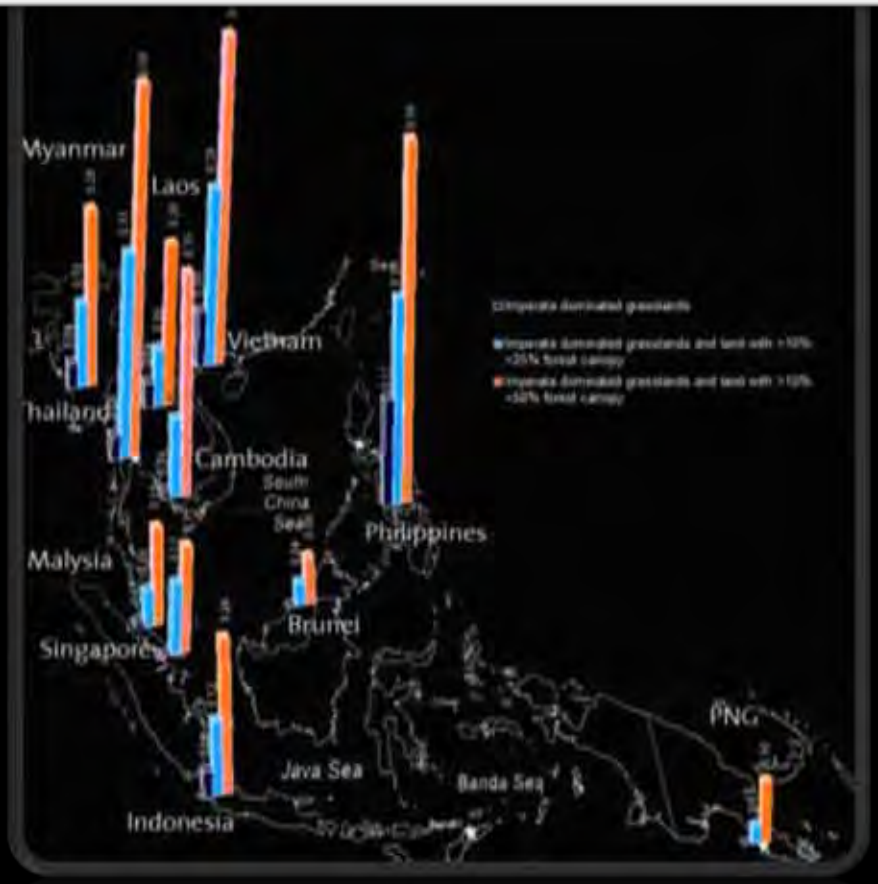
ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

GDC Genetic Diversity Centre Zurich

Thank you our attention!

Proportion of total land area potentially available to forest restoration

Kettle *Biodiv & Cons* 2010



ORIGINAL PAPER

Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia

Chris J. Kettle

>15 – 30% of total land may be amenable to forest restoration 50 – 130 million Ha

Probably an awful lot!

Summary

- Dipterocarps unable to colonise degraded areas far from forest patches.
- Smaller flowered dipterocarps may be less able to disperse pollen among fragments.
- Density of conspecifics is likely to influence patterns of inbreeding.
- Elevated inbreeding is predicted in smaller more isolated forest patches
- Elevated inbreeding can lead to reduce performance and survival
- The mating system of the species is important to determining its vulnerability in the short term

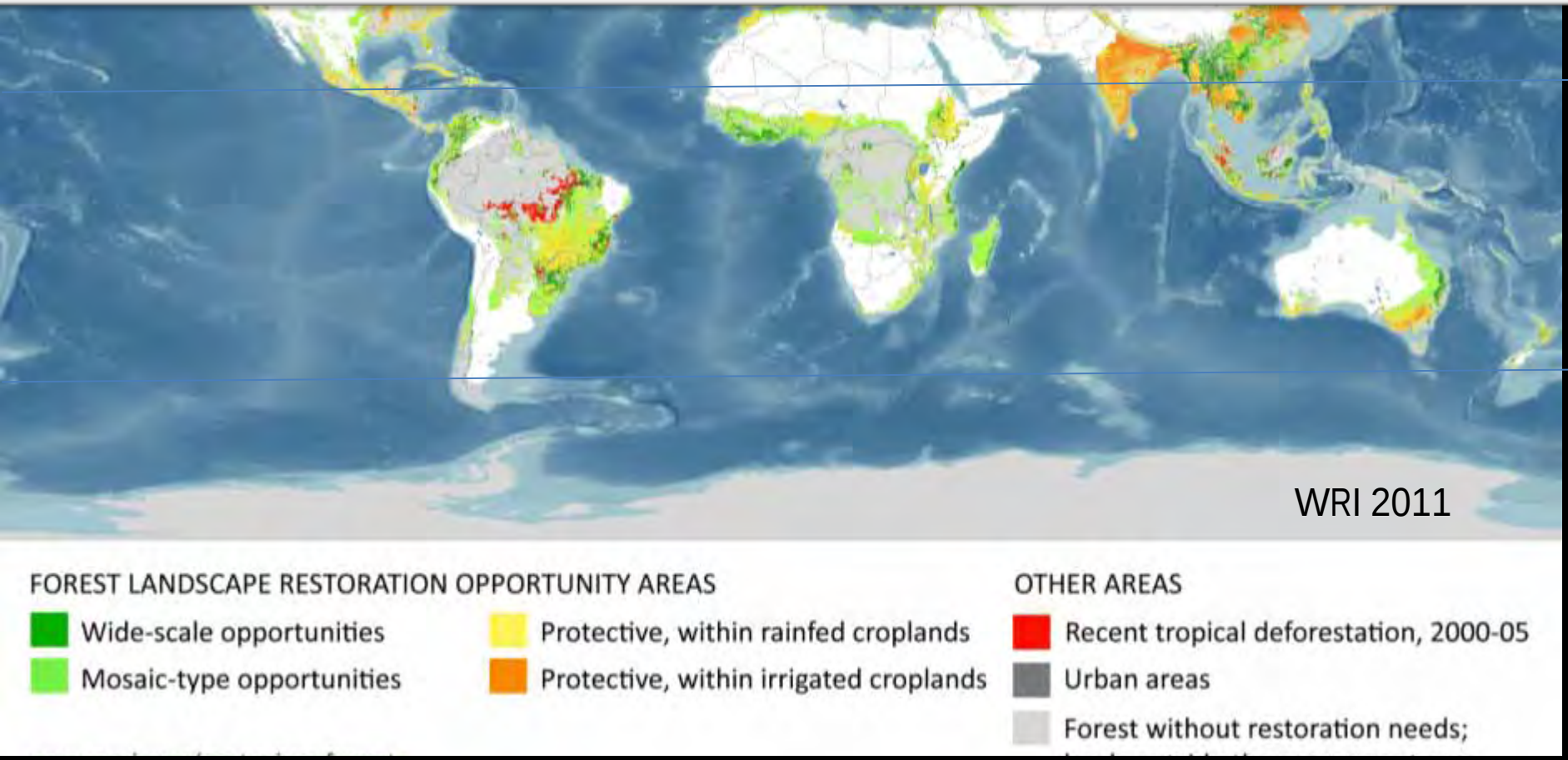
Seed dispersal in tropical tree species

Kettle 2012 *Biological Conservation*

- Seed dispersal can be restricted for several reasons
  - Loss of dispersers
  - Naturally limited
  - Fragmentation
- We still have a poor knowledge of realised seed dispersal in tropical trees
- The limited data suggests at seed dispersal in generally relatively short distance < 100 m

Reversing the trend

A World of opportunity!



Estimated to be more than a Billion Ha of land amenable for forest landscape restoration

Masting in tropical tree species

Kettle et al 2011 Conservation Letters

- Mast fruiting presents a major logistical challenge for restoration
- Need for monitoring and the infrastructure to be able quick response to masting events.
- Southeast Asian rain forest are notorious for general flowering and mast fruiting events.
- But, many commercially and ecologically important tree species in Africa and Neo-trpics also mast fruit.

Some critical factors

- Flowering and Fruit production **Masting events**
- **Seed storage** and longevity
- **Seed dispersal**

Kettle 2012

Biological Conservation

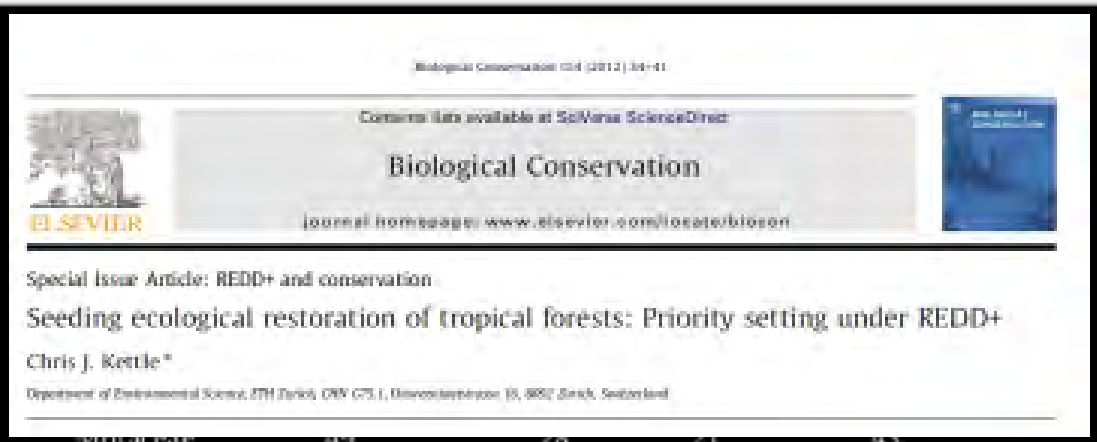
journal homepage: www.elsevier.com/locate/biocon

Special Issue Article: REDD+ and conservation

Seeding ecological restoration of tropical forests: Priority setting under REDD+

Chris J. Kettle*

Seed storage in tropical tree species



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Special Issue Article: REDD+ and conservation

Seeding ecological restoration of tropical forests: Priority setting under REDD+

Chris J. Kettle*

Burseraceae	12	9	3	25
Dipterocarpaceae	95	2	93	98
Vochysiaceae	3	3	0	0
Caesalpinioideae	0	0	0	0
Meliaceae	58	26	32	55
Euphorbiaceae	9	9	0	0
Malvaceae	24	22	2	8
Rubiaceae	29	27	2	7
Ulmaceae	0	0	0	0
Irvingaceae	0	0	0	0
Olacaceae	1	1	0	0
Africa	93	85	8	9
Neotropics	110	62	48	44
Asia	141	16	125	89
Total	345	164	181	52

Kettle 2012

- From 15 families > 50% of tree species recalcitrant
- Dominated by internationally important commercial timber families
- Dipterocarps especially recalcitrant

The implications of different flower size

Kettle et al 2011 PLoS ONE

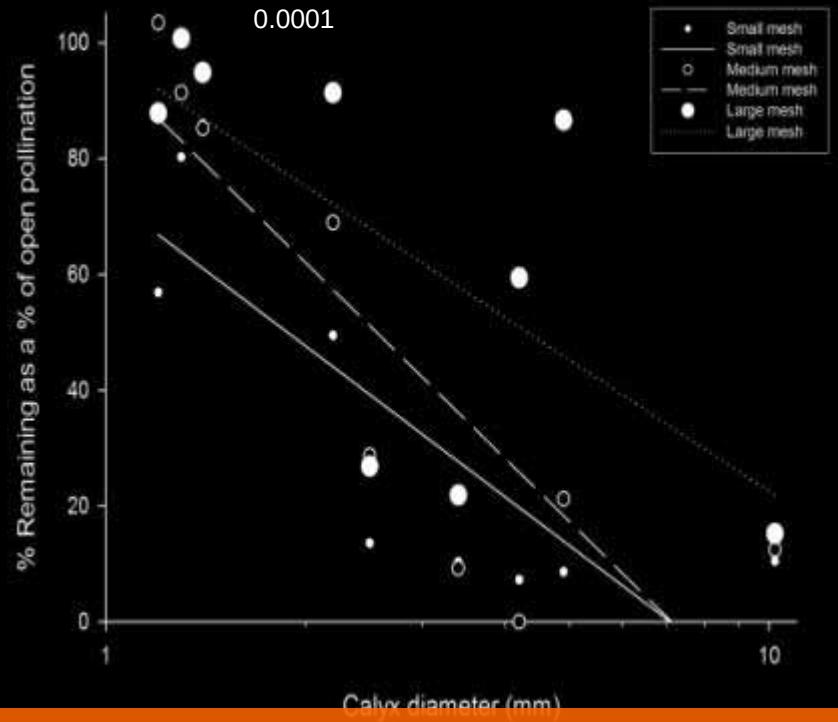
OPEN ACCESS Freely available online

PLoS one

Ecological Implications of a Flower Size/Number Trade-Off in Tropical Forest Trees

Chris J. Kettle[1,2*], Colin R. Maycock[2], Jaboury Ghazoul[1], Pete M. Hollingsworth[3], Eyen Khoo[4], Rahayu Sukmaria Haji Sukri[2], David F. R. P. Burslem[2]

GLM: flower size effect $t = -6.18$, $P < 0.0001$



Flower size appears to be a good surrogate for pollinator size