Dual values for biodiversity conservation in agricultural landscapes

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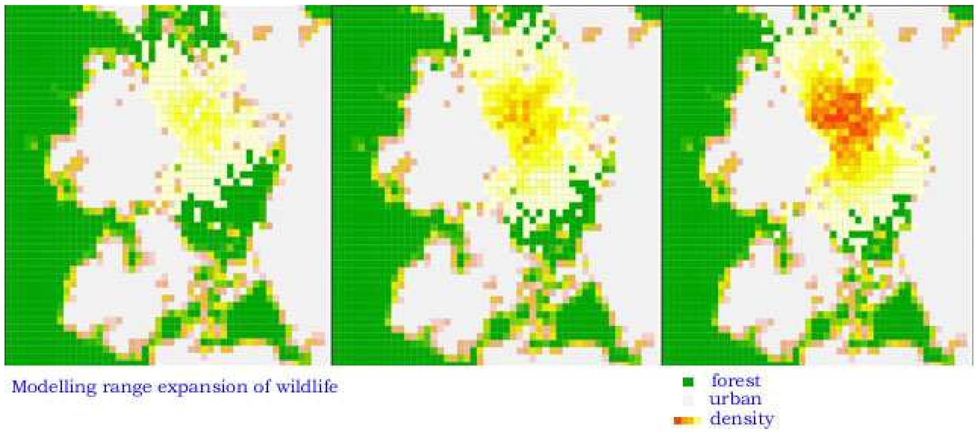
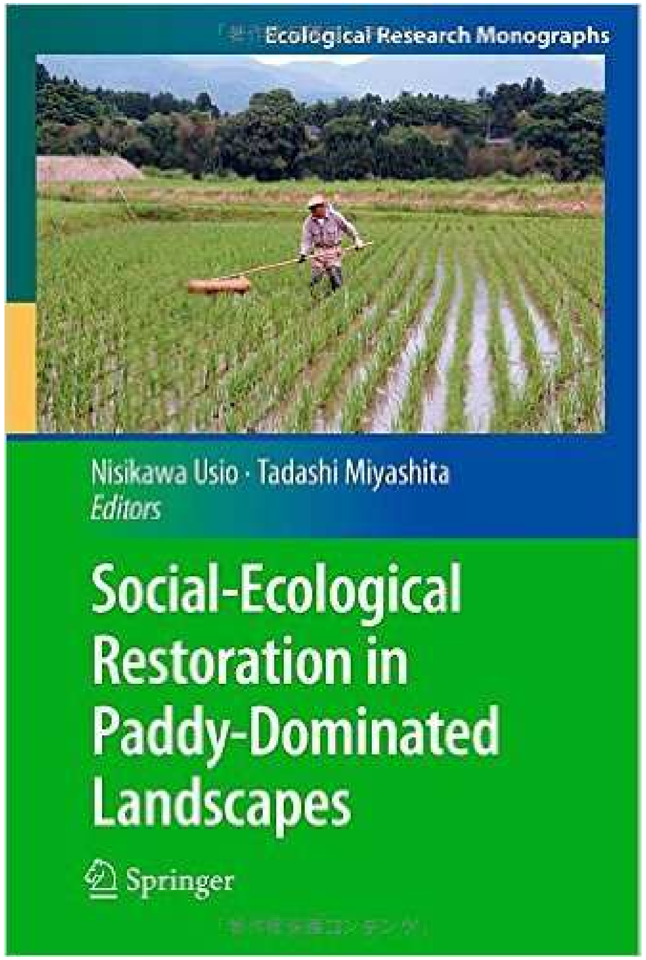


Simulation of range expansion of wildlife
(deer, wild boar)

Our research topic related to this symposium:

How biodiversity is maintained in heterogeneous paddy-dominated landscapes



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Dual values for biodiversity conservation in agricultural landscapes

1. Traditional agricultural landscapes harbor high species diversity, including endangered species.

--- There are plenty of evidence supporting this statement, but the general mechanisms are only recently being integrated.

2. Biodiversity and landscape heterogeneity could provide higher pest control and pollination services.

--- There are some evidence, but there exists context-dependencies.
--- In particular, only a few circumstantial evidence in paddy dominated landscapes.

Aichi Biodiversity Targets (CBD, 2010, Nagoya)

Target 11

By 2020, at least 17 % of terrestrial and inland water, and 10 % of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

However, not all endangered species live in pristine habitats. There are many endangered species that have adapted to rural landscapes maintained by traditional land-use activities.

Target 7

By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

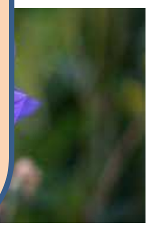
"Satoyama initiative"(COP10)

"Landscapes composed of forests, croplands, and grasslands maintained by traditional human activities are expected to decrease global biodiversity loss".

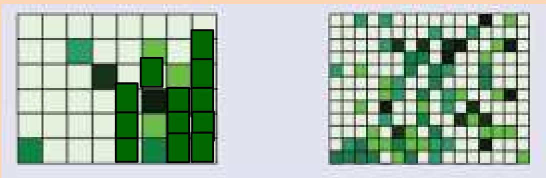
Agricultural ecosystem

- 38% of the total area
- 2 time crop production is required in 2050

Mosaic landscape



● The issue of "Land sparing" vs "Land sharing"



Land sparing ↔ Land sharing

Why do traditional agricultural landscapes harbor high species diversity?

1. **High species turn-over in space (or high β-diversity)**

   ---- Different ecosystems have different species assemblages.

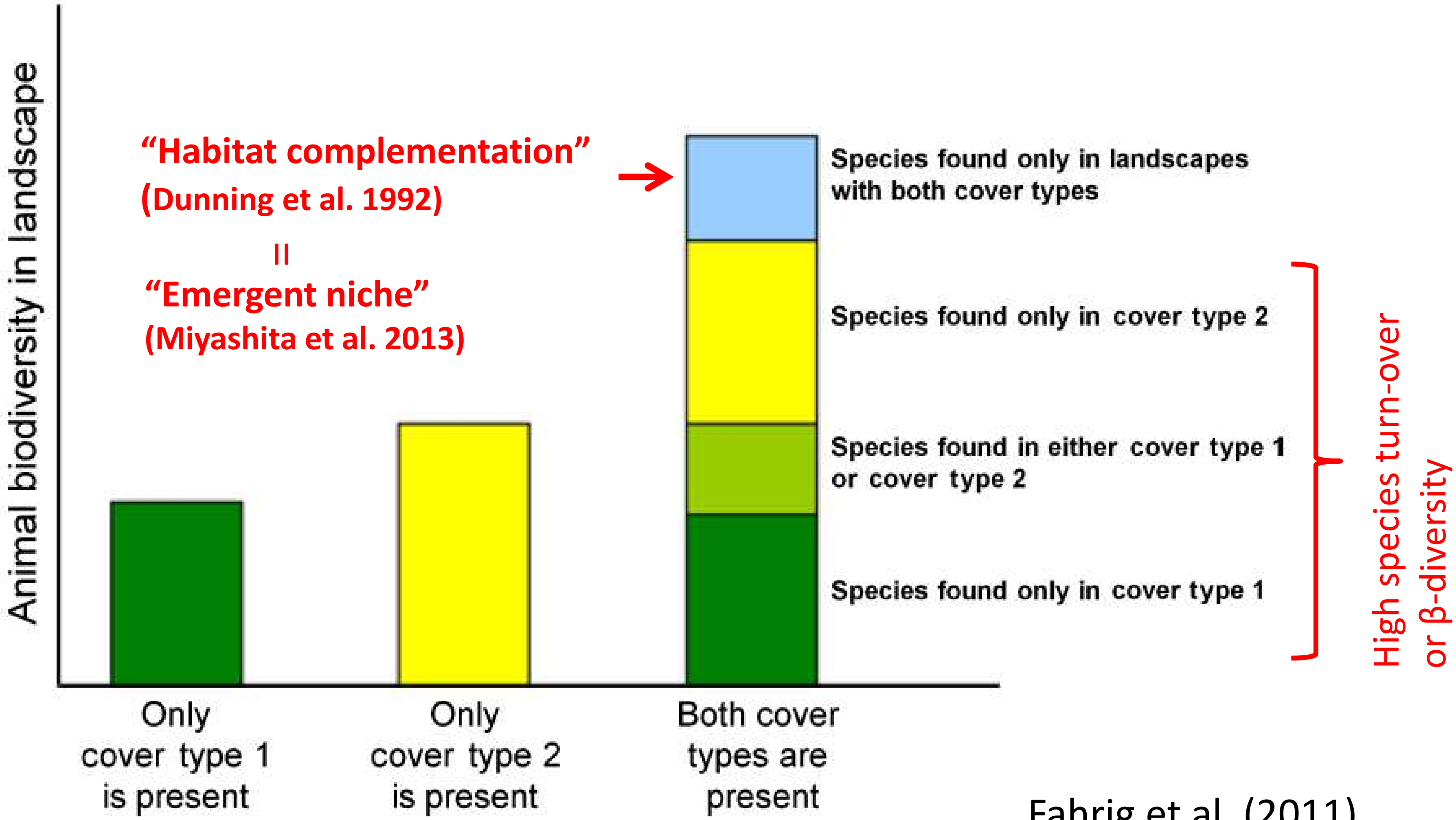
2. **“Habitat complementation” (Dunning et al. 1992)**

   ----- Some species maintain their populations by using multiple ecosystems.

3. **Intermediate levels of disturbance**

   ----- Competitive exclusion by superior species is prevented, resulting in a coexistence of many species in non-equilibrium state.

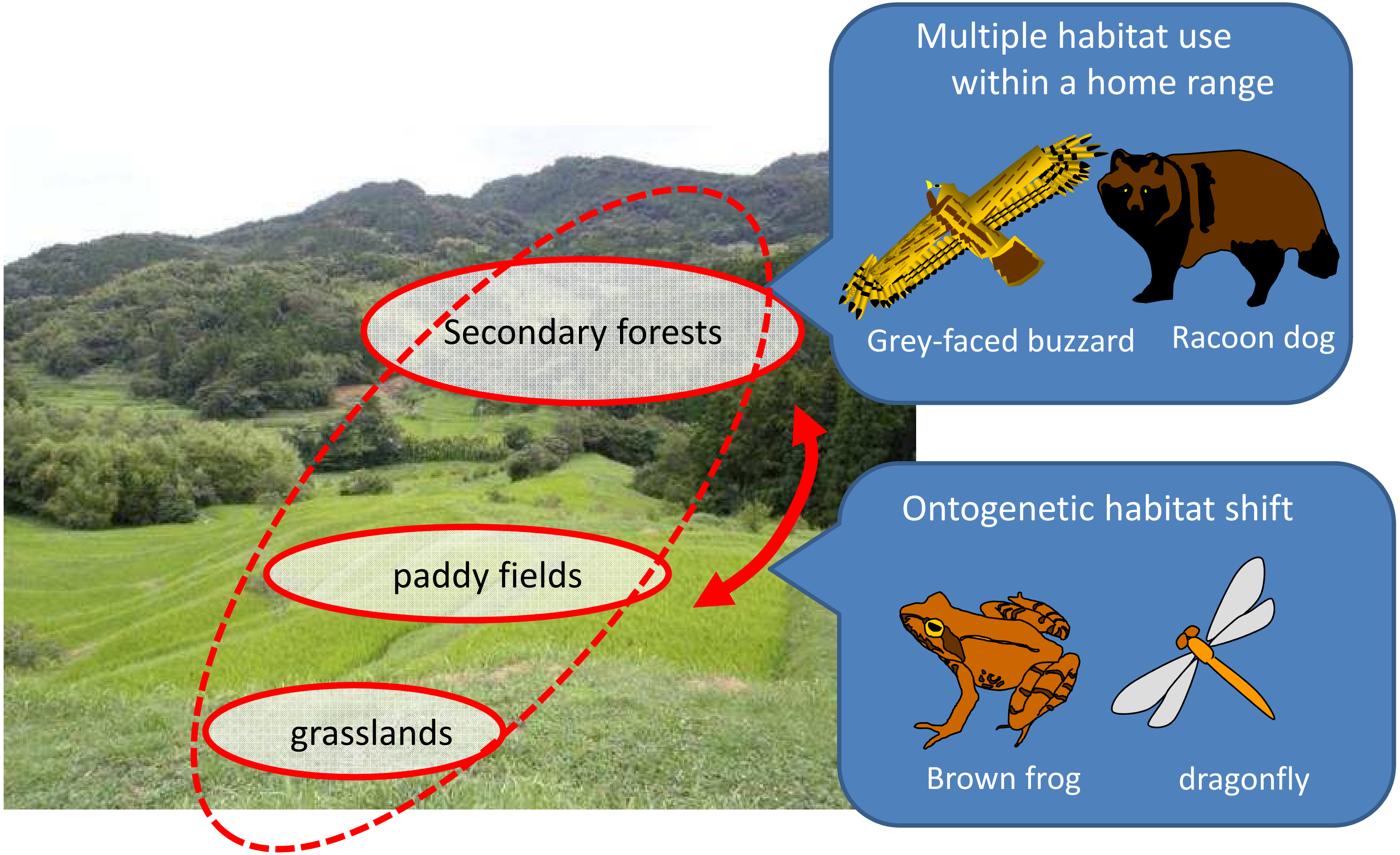
Graphical representation of how heterogeneous agricultural landscapes harbor high species diversity?



Fahrig et al. (2011)

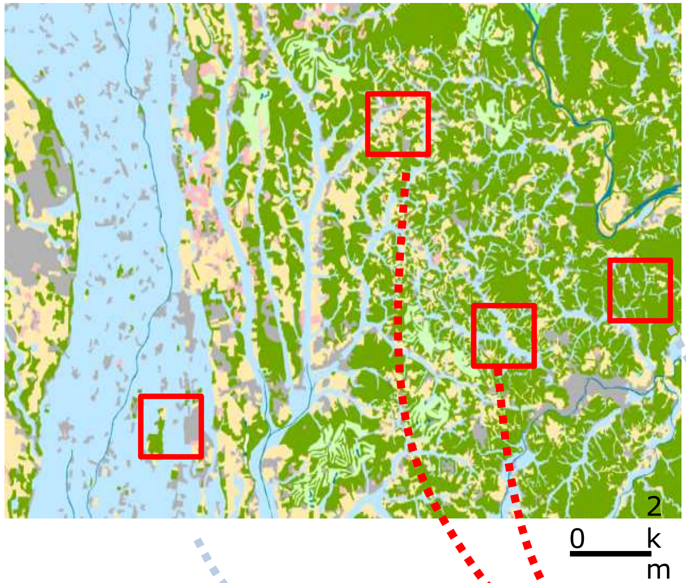
Organisms requiring multiple ecosystems

= "Habitat complementation"



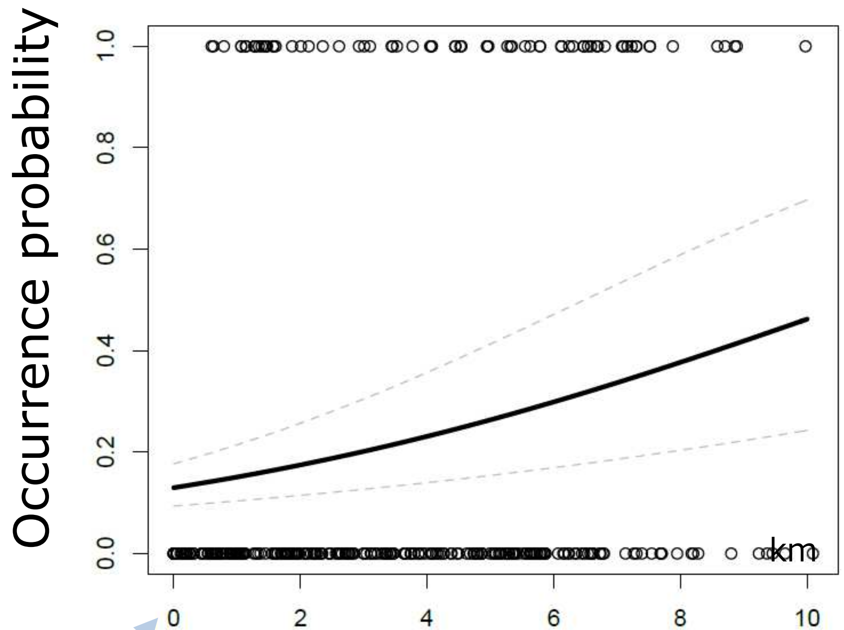
Distribution of grey–faced buzzard

http://www.birdfan.net/2010/10/01/5924/



Ichikai, Tochigi Prefecture

Boundary of secondary forests and farmlands enhance occurrence



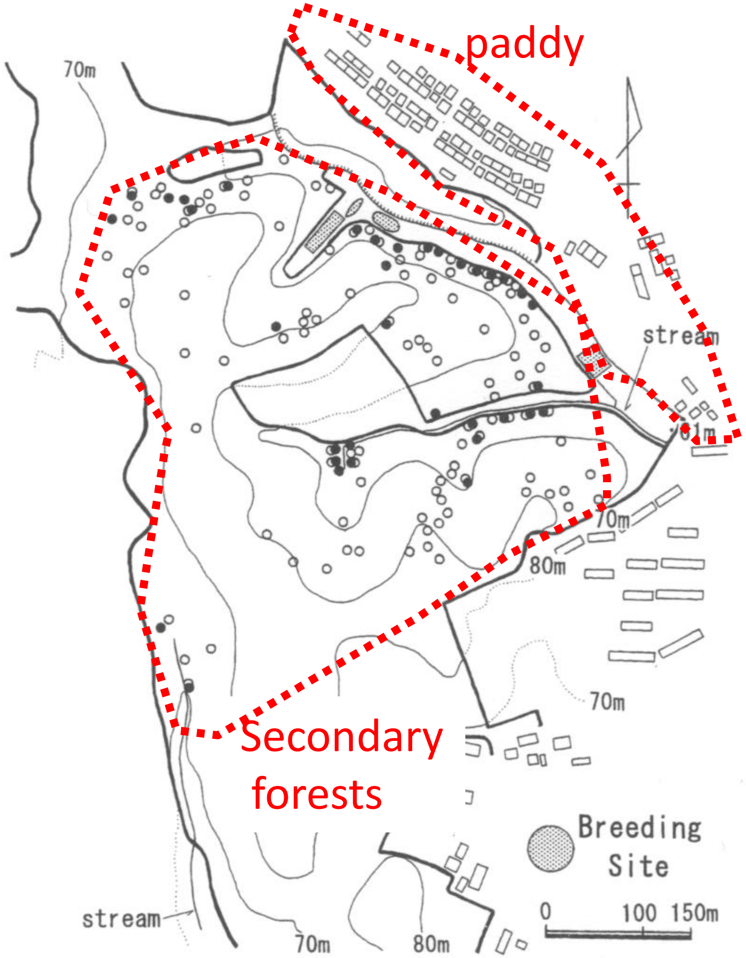
Length of forest edge adjacent to farmland

(Fujita et al unpublished)

An example of ontogenetic habitat shift

- Dispersal of a brown frog *Rana japonica* from breeding sites

ニホンアカガエル



Yokohama

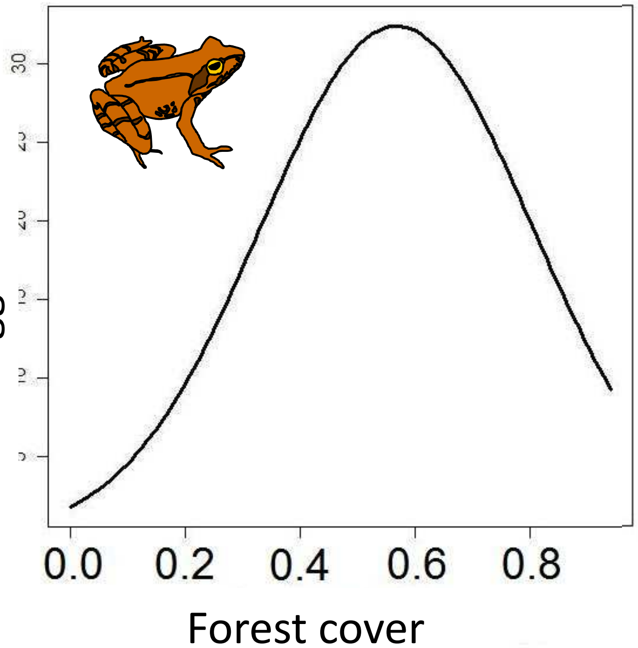
July-November 1999

- ● Adult
- ○ Yearling

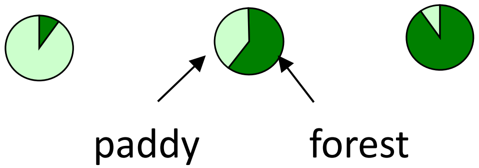
Osawa and Kastuno (2001)

Effect of surrounding landscape structures on the number of egg masses in paddy fields

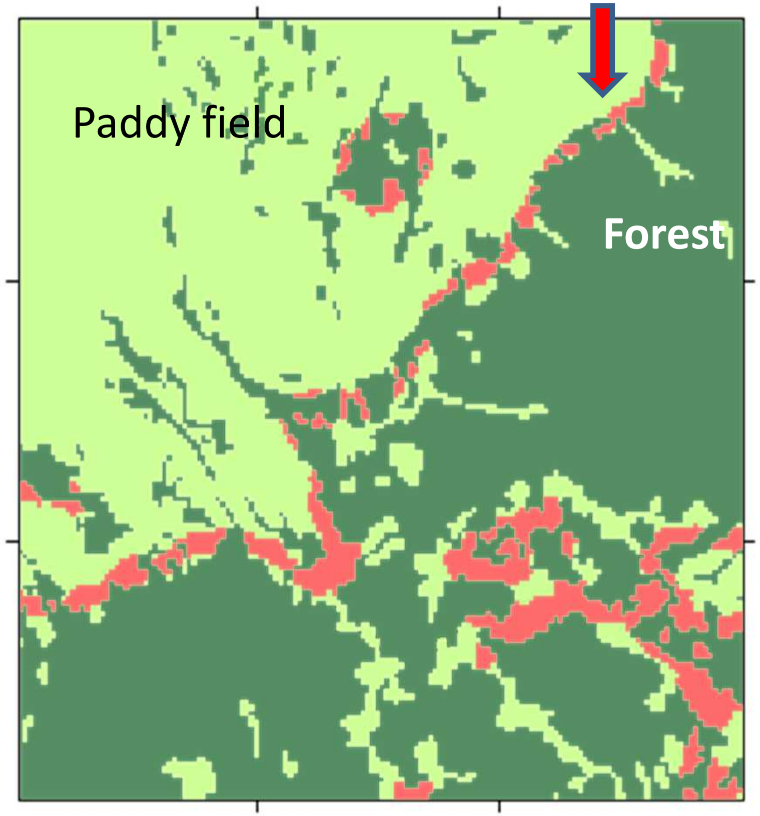
Best spatial scale: 300m radius



Kato et al. (2010)



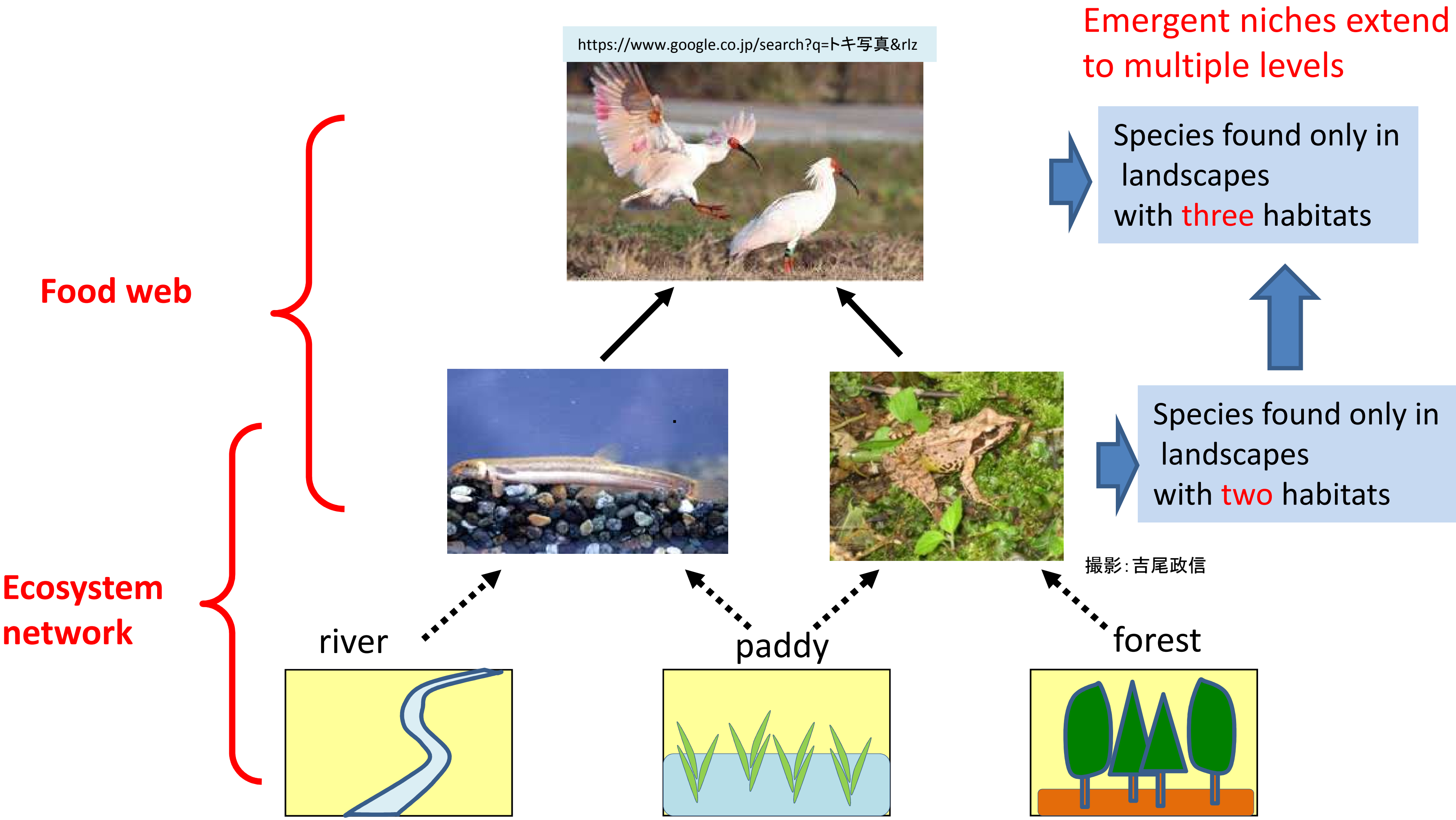
Suitable habitat (forest cover: 40-60% in 300m radius)



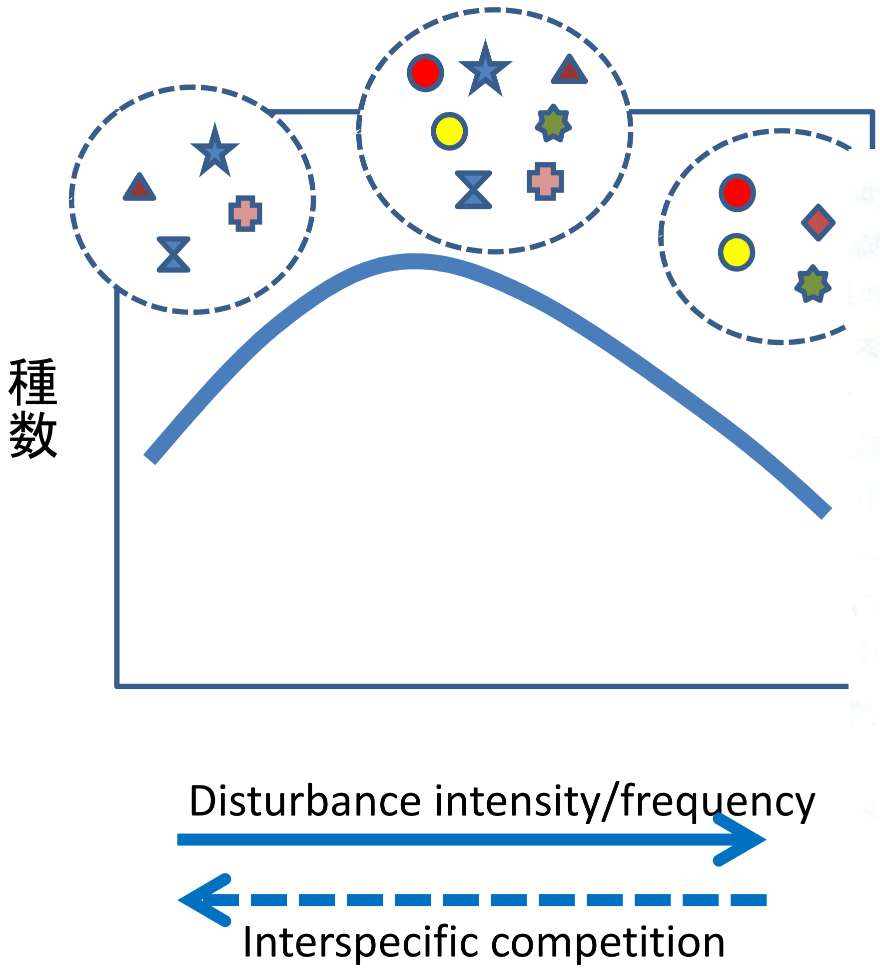
Brown frogs require landscape with a mixture of paddy and forest areas.

Top predators occasionally maintain their populations by “multiple habitat complementation”

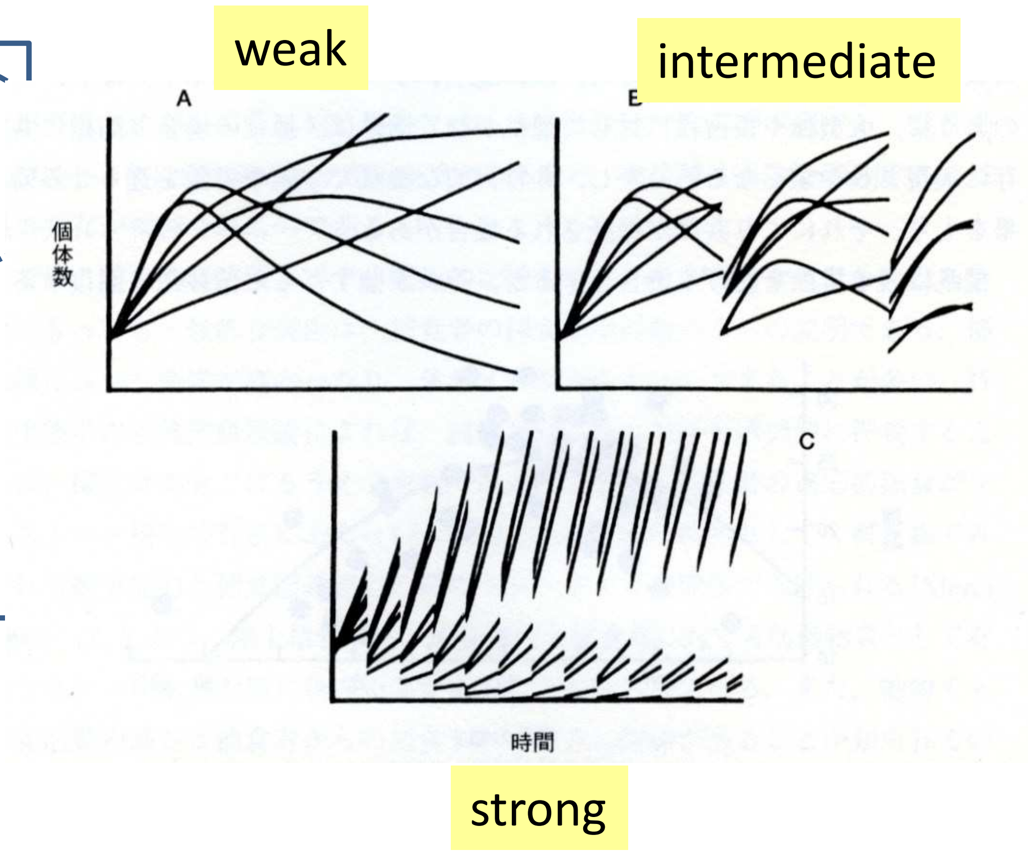
--- An example of a crested ibis (IUCN: Critically endangered)



How intermediate levels of disturbance maintain high species richness?



Population dynamics of coexisting species under various disturbance levels



Recent change in the disturbance regime decreased abundance of various organisms inhabiting grasslands

Disturbance levels of paddy levees

Intensified
(or modern)

Moderate
(or traditional)

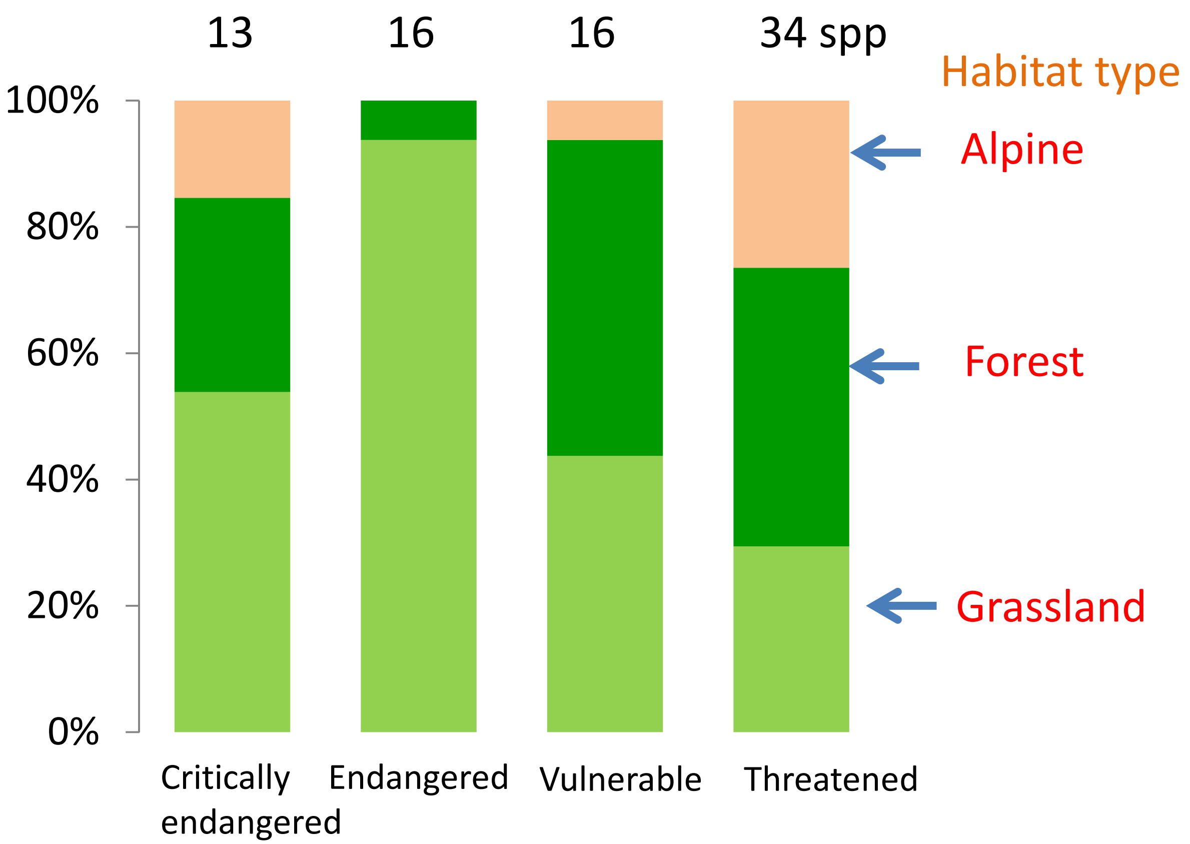
abandoned

Indigofera pseudotinctoria

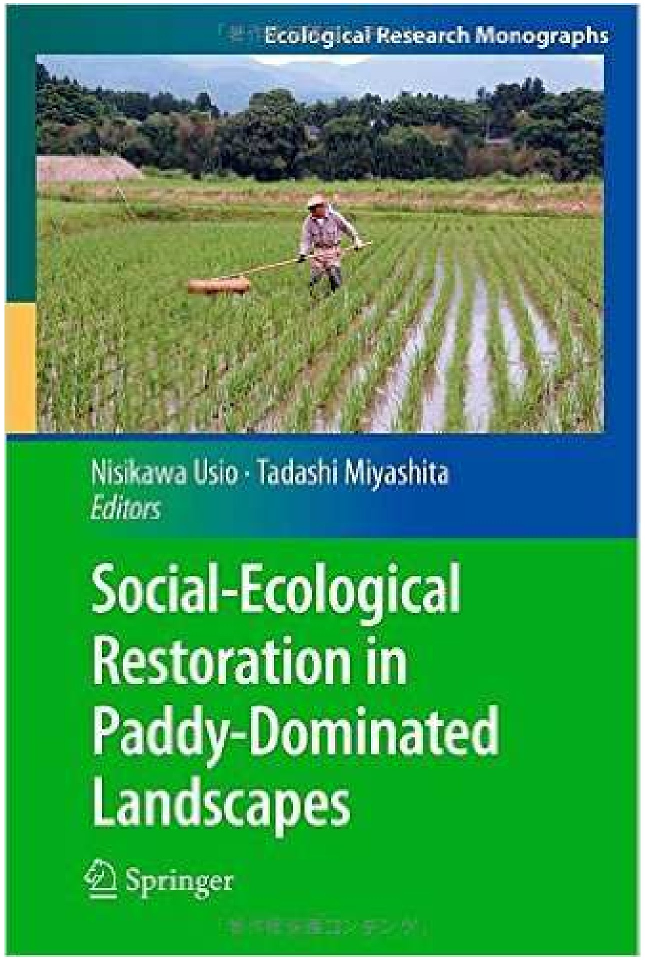
Lycaeides argyrognomom

Redlist species of butterflies in Japan

✓Grassland species occupy a substantial portion of CR and EN species.
✓Most of them were once widespread and common in Japan.
✓Both agricultural intensification and abandonment are the major drivers for decline



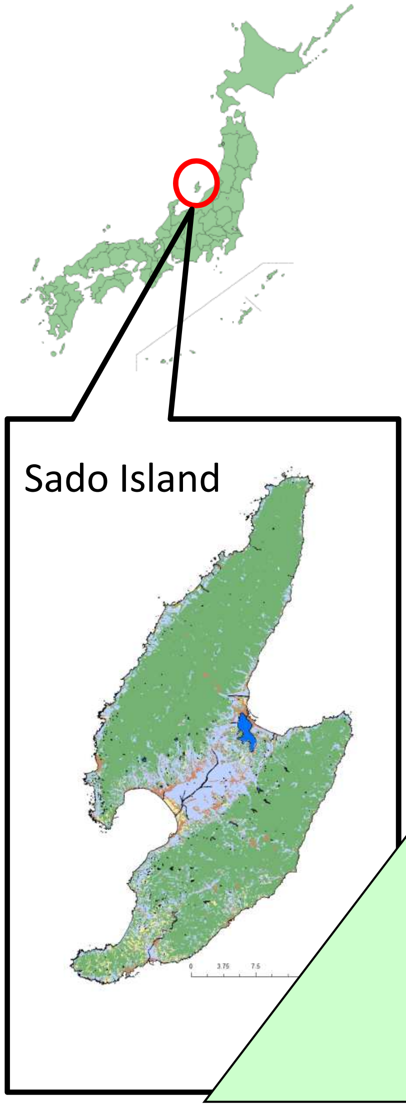
Restoration of biodiversity in paddy-dominated landscapes is increasing in Japan, using symbolic organisms

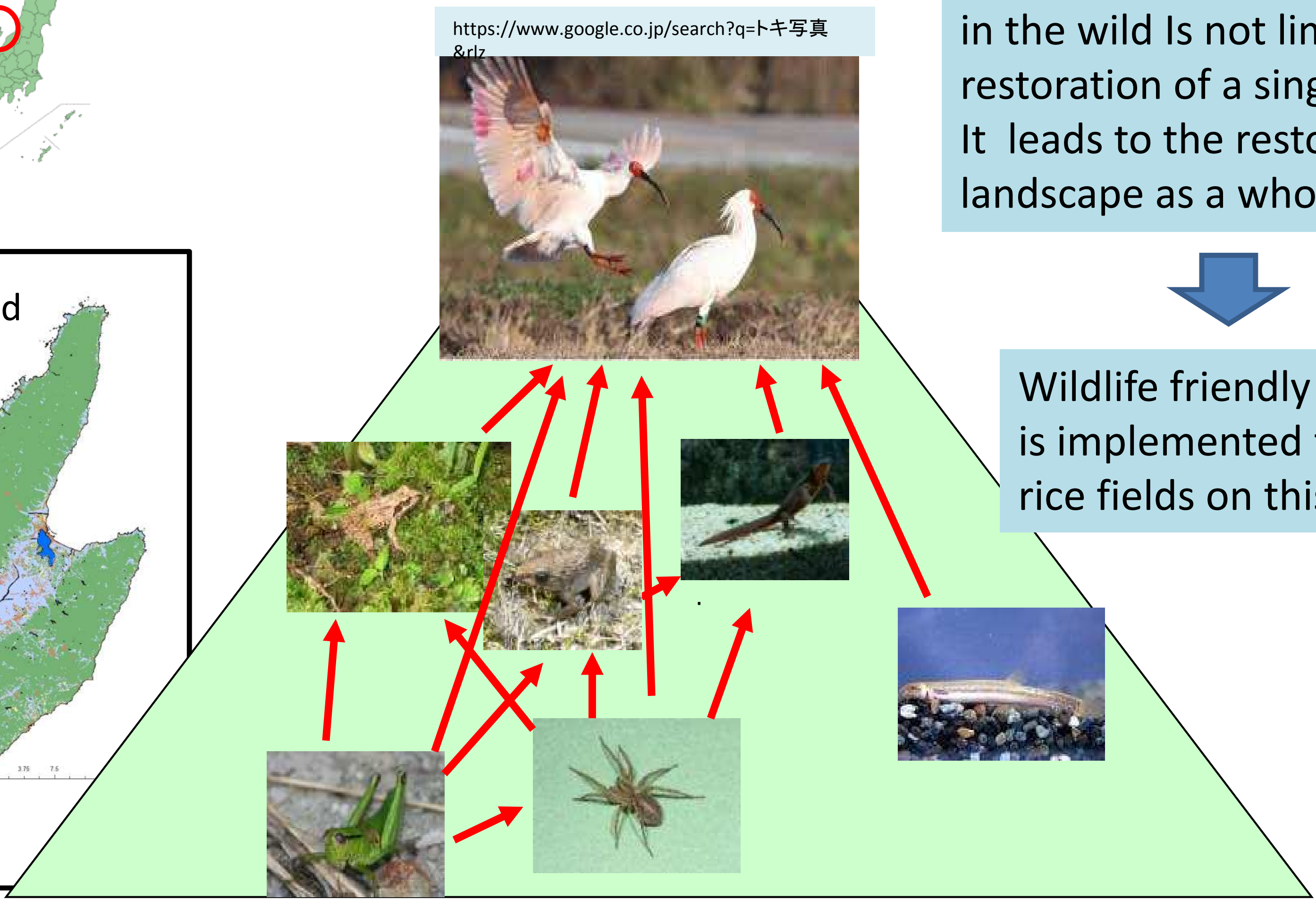


https://www.google.co.jp/search?q=トキ写真&rlz

https://ja-jp.facebook.com/kounotoribunkakan

Reintroduction project of the Crested Ibis on Sado Island and associated restoration practices of paddy fields





Restoration of the ibis population in the wild Is not limited to restoration of a single species;
It leads to the restoration of landscape as a whole.

Wildlife friendly farming is implemented for >21% of rice fields on this island.

Certification system for Wildlife-friendly rice-farming on Sado Island

✔Essential: >50% agrochemical reduction
✔Optional: choose 1 of 4 types of habitat restoration

Label for certified rice

Winter flooding

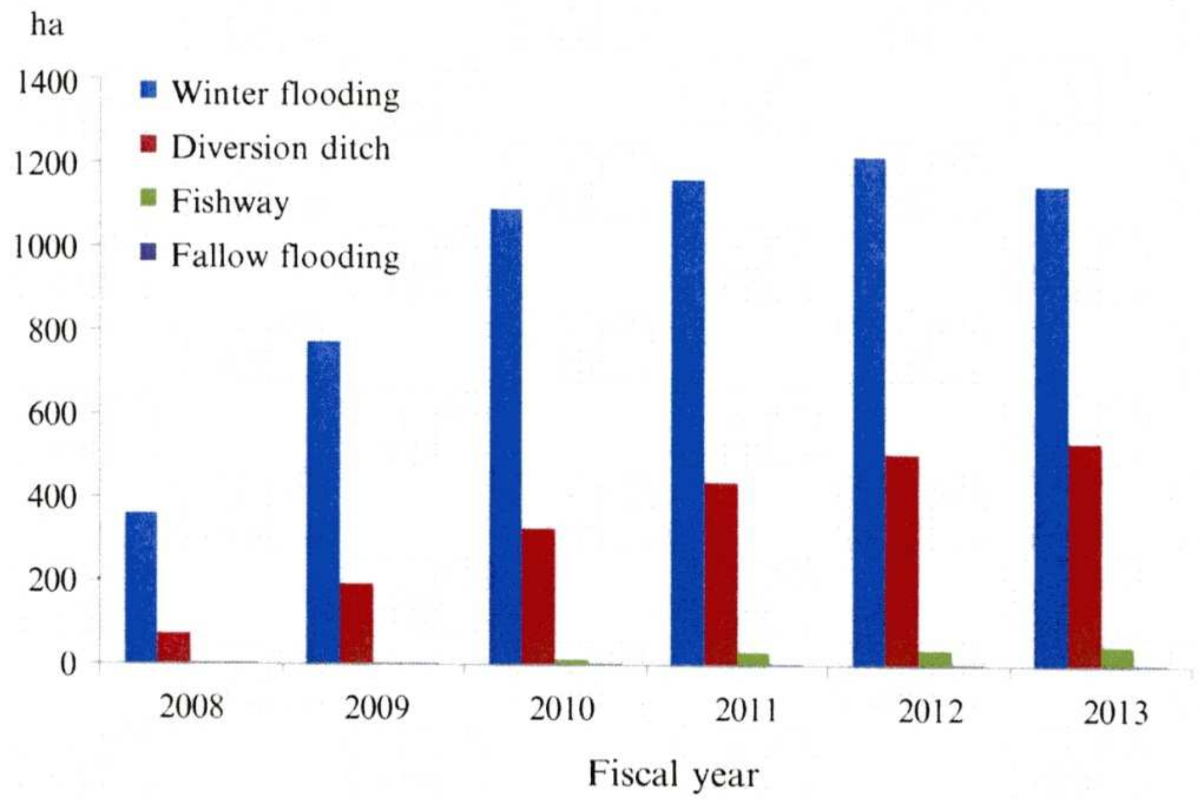
É (diversion ditch)

Photo: H Uruma

Fishway

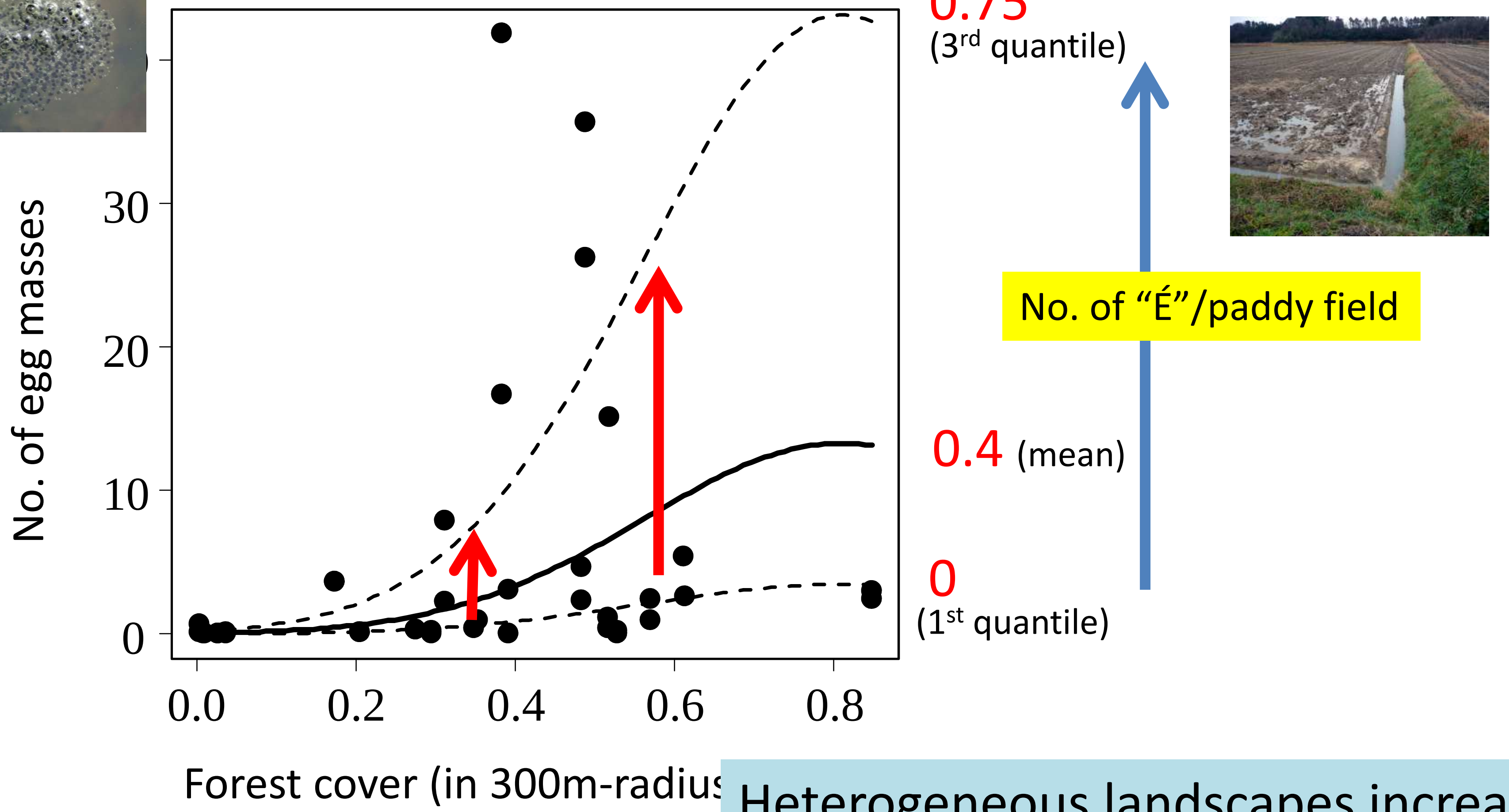
Fallow flooding

Cultivation areas of four wildlife-friendly farming practices on Sado Island



Nishikawa et al. (2015)

How does landscape structure affect the effectiveness of WFF? --- the presence of É on the brown frog abundance



Heterogeneous landscapes increase the effectiveness of EF farming

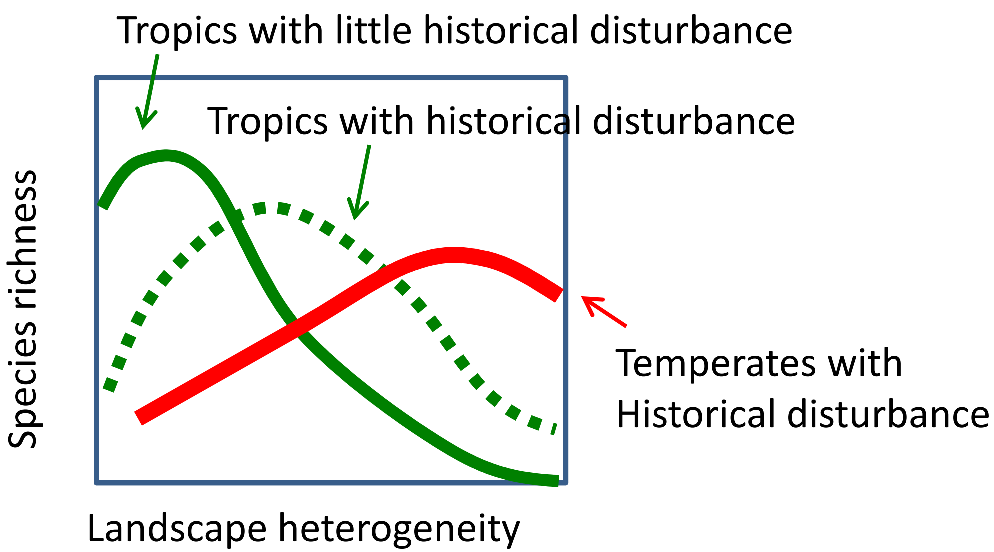
Uruma et al. (2012)

Future directions:

Exploring the general "species richness-heterogeneity" relationship

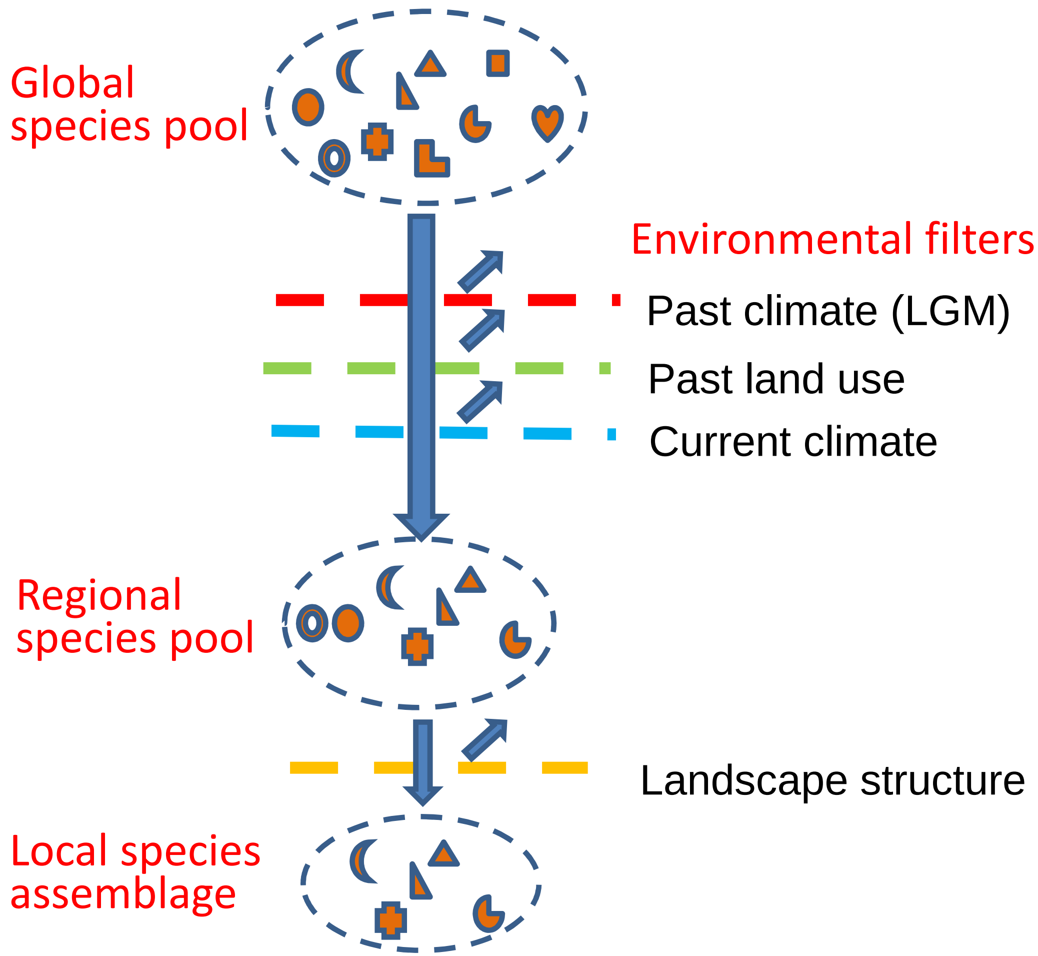
- Do heterogeneous landscapes always enhance high species diversity?
  - ✓ Positive effect: high β-diversity & habitat complementation
  - ✓ Negative effect: habitat fragmentation for habitat specialists

- More comprehensive explanation
  → Differences in the species pool, which are determined by past climate and human land-use history, govern "species richness-heterogeneity" relationship (Miyashita et al. 2012)



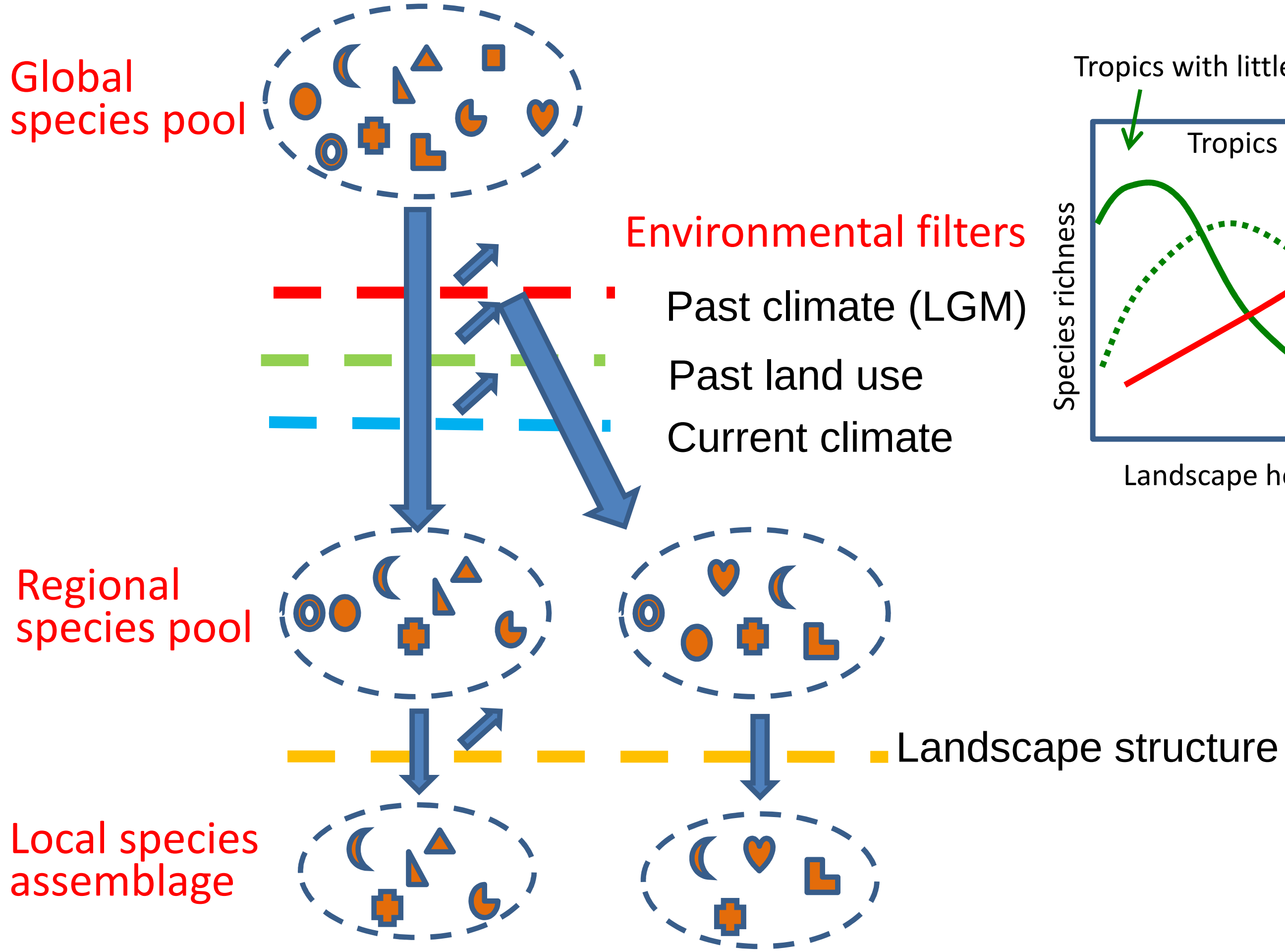
Future directions:

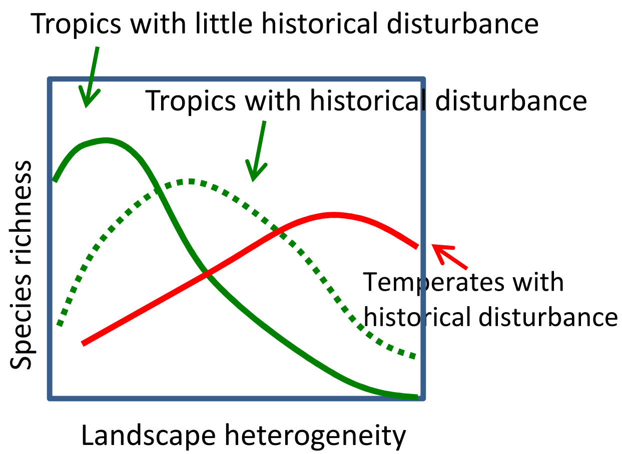
Mechanistic explanation of how regional species pool determines “species richness-heterogeneity” relationship at local scales



Future directions:

Exploring the general "species richness-heterogeneity" relationship





2. Biodiversity and landscape heterogeneity could provide higher pest control and pollination services.

Ecosystem services

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services. (UNEP Report)

Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Biodiversity *per se* matters

Supporting Services

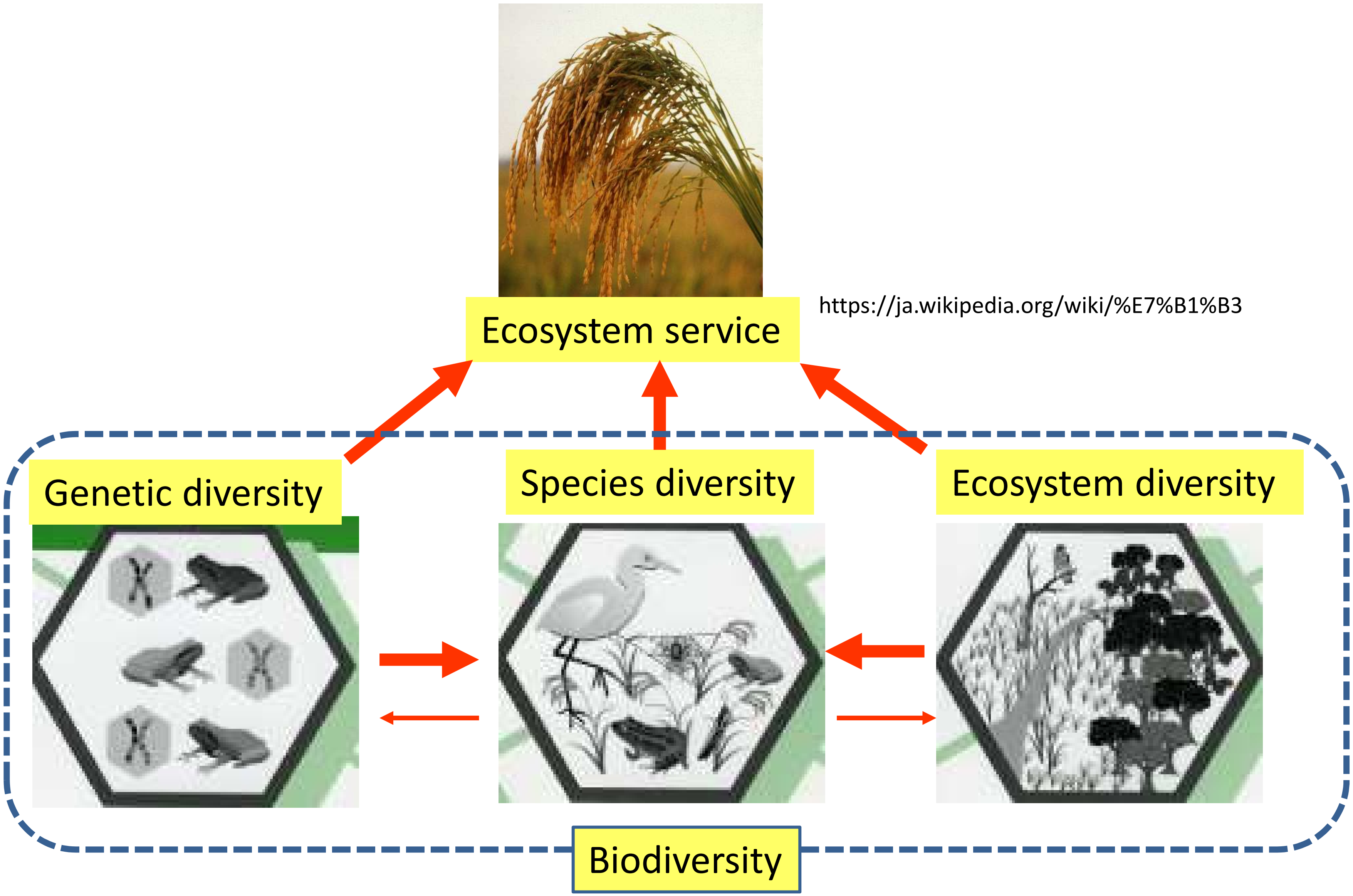
Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

✓Not all ecosystem services are related to biodiversity *per se*.

✓There is often a tradeoff relationship between provisioning and other ecosystem services.

Linkage between biodiversity and ecosystem services



How are the positive associations between “species diversity” and ecosystem services created ?

1. Sampling effect

   Species with high performance are more likely to be included in diverse communities

2. Niche complementation

   Different species occupy different niche space, resulting in a more efficient use of total resources.

3. Facilitation effect

   Positive interactions between species result in higher performance.

4. Response diversity (insurance hypothesis)

   Different responses to environment change between species result in temporal stability of ecosystem services.

Global evaluation of pollination services

--- To what extent are wild pollinators important ?

Honey bee

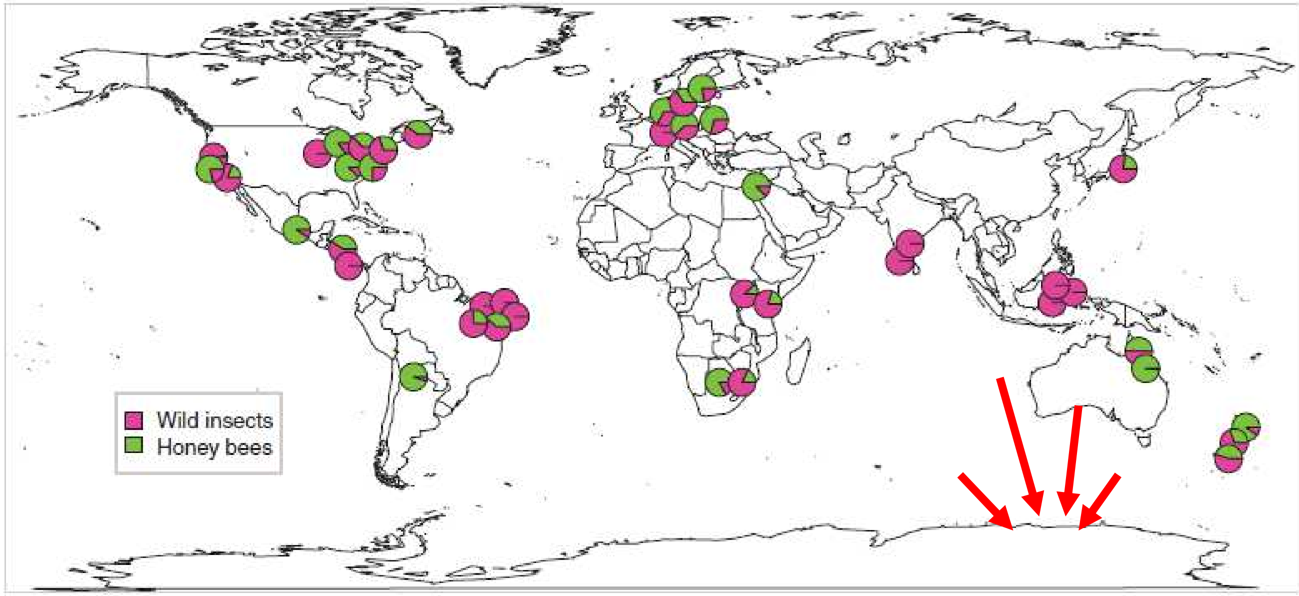
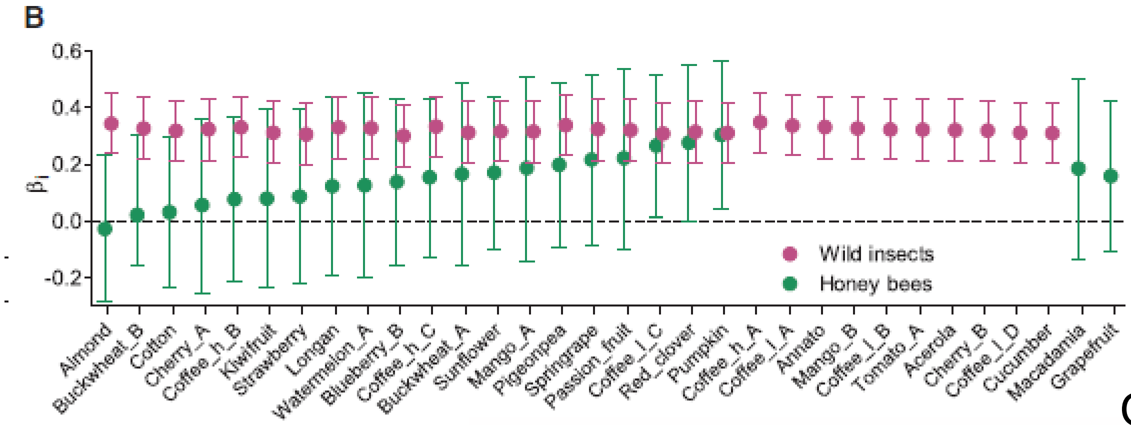
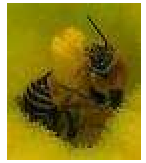
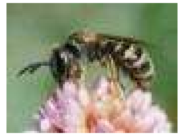


Fig. 1. Relative visitation by honey bees and wild insects to flowers of 41 crop systems on six continents. Honey bees occur as domesticated colonies in transportable hives worldwide, as a native species in Europe (rarely) and Africa, or as feral populations in all other continents except Antarctica.

Effect size on pollination







Wild insects

Galibaldi et al. 2013

Bee species richness increases pumpkin seed production

(Sulawesi, Indonesia)

http://www.hana300.com/kaboch.html

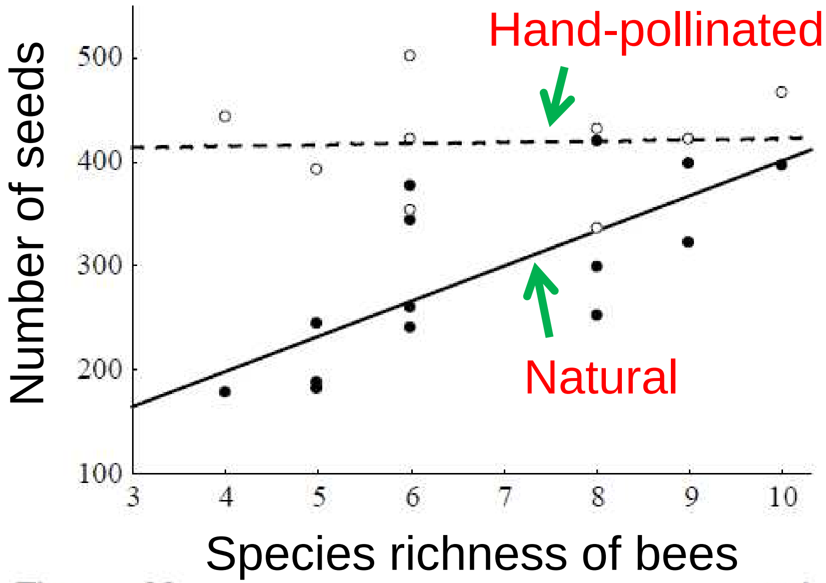


Figure 1. Mean number of seeds per fruit per pumpkin patch in relation to the number of bee species per pumpkin patch. Results for open-pollinated flowers are shown with filled circles and solid line and that for hand-pollinated bagged control flowers in nine plots are shown with filled circles and dashed line.

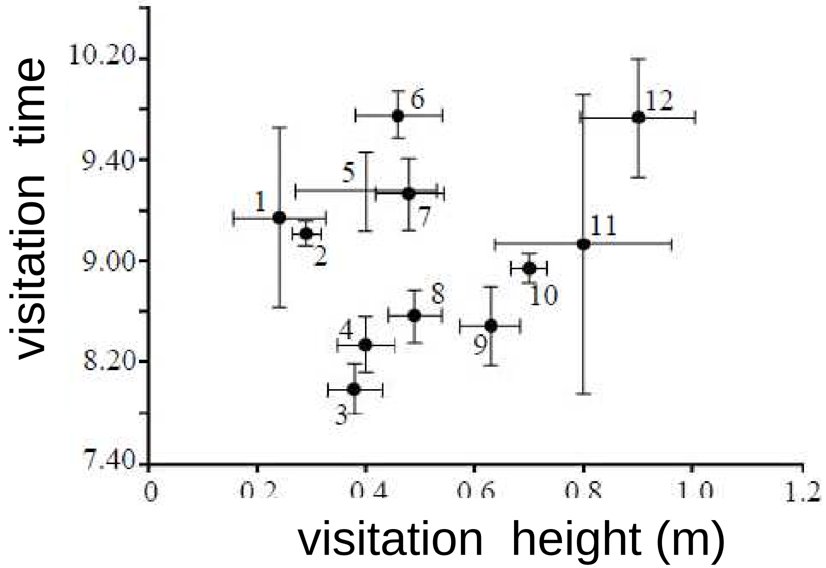


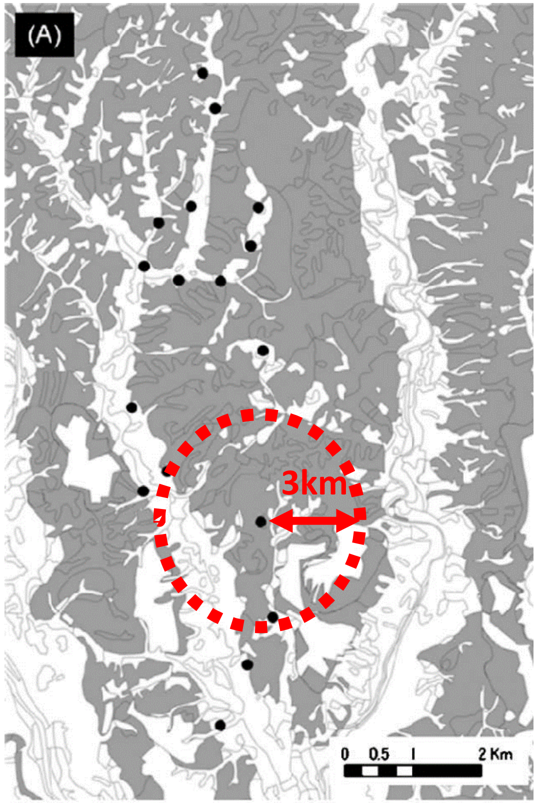
Figure 2. Height and time of flowers preferred by each bee species. Arithmetic means ± s.e. are given. For mean values, standard error and significance levels, see table 2. Numbers represent species identity: 1, *N. concinna*; 2, *Lasioglossum* sp.; 3, *A. cerana*; 4, *X. dejeani*; 5, *N. fulvata*; 6, *C. cognata*; 7, *Trigona* sp.; 8, *Amegilla* sp.; 9, *X. confusa*; 10, *L. halictoides*; 11, *A. dorsata*; 12, *X. nobilis*.

Hoehn et al. (2008)

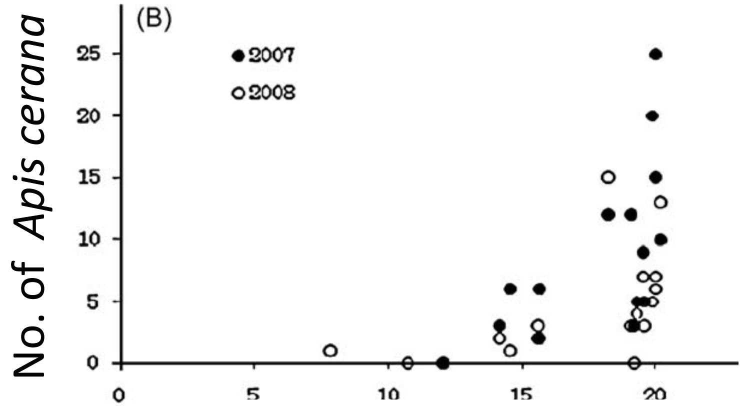
Landscape heterogeneity increases pollination services

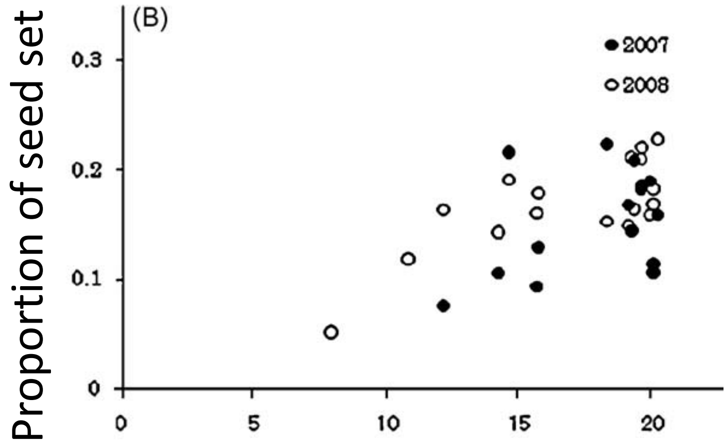
--- buckwheat pollination by Japanese honey bees

http://www.nhp-photo.co.jp/products/detail.php?product_id=38745



Taki et al, (2008)





Landscape heterogeneity increases pest control services

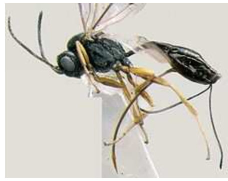
Oilseed rape

http://www.hana300.com/nanoha.html

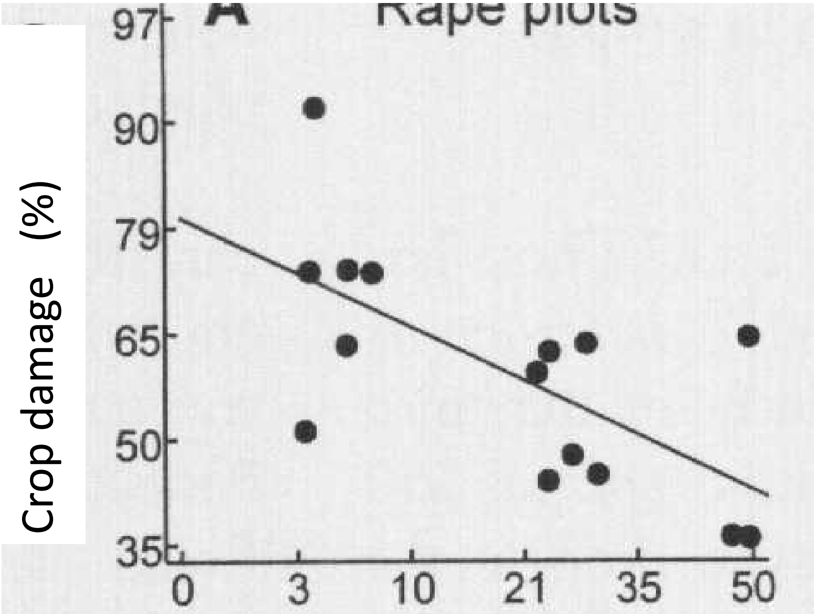
Pollen beetle
(*Meligethes aeneus*)

http://www.cabi.org/isc/datasheet/33259

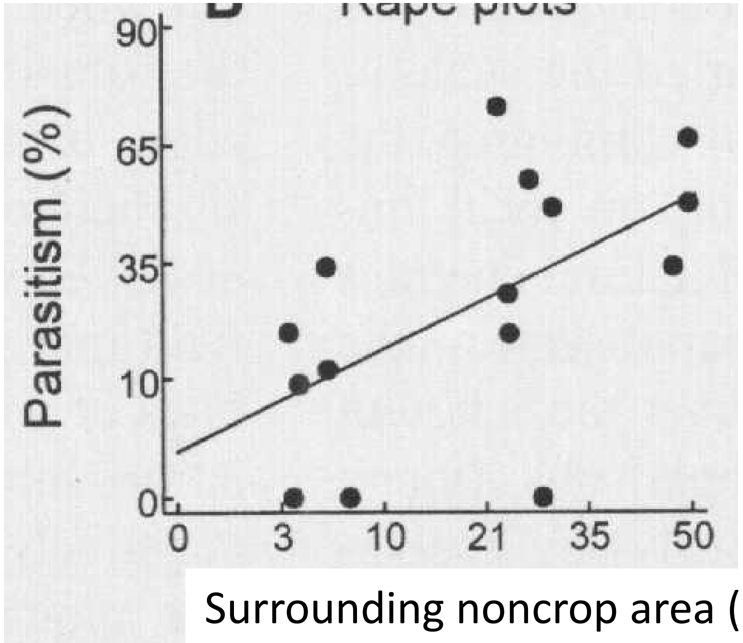
Parasitic wasp
(*Tersilochus sp.*)



https://en.wikipedia.org/wiki/Tersilochus



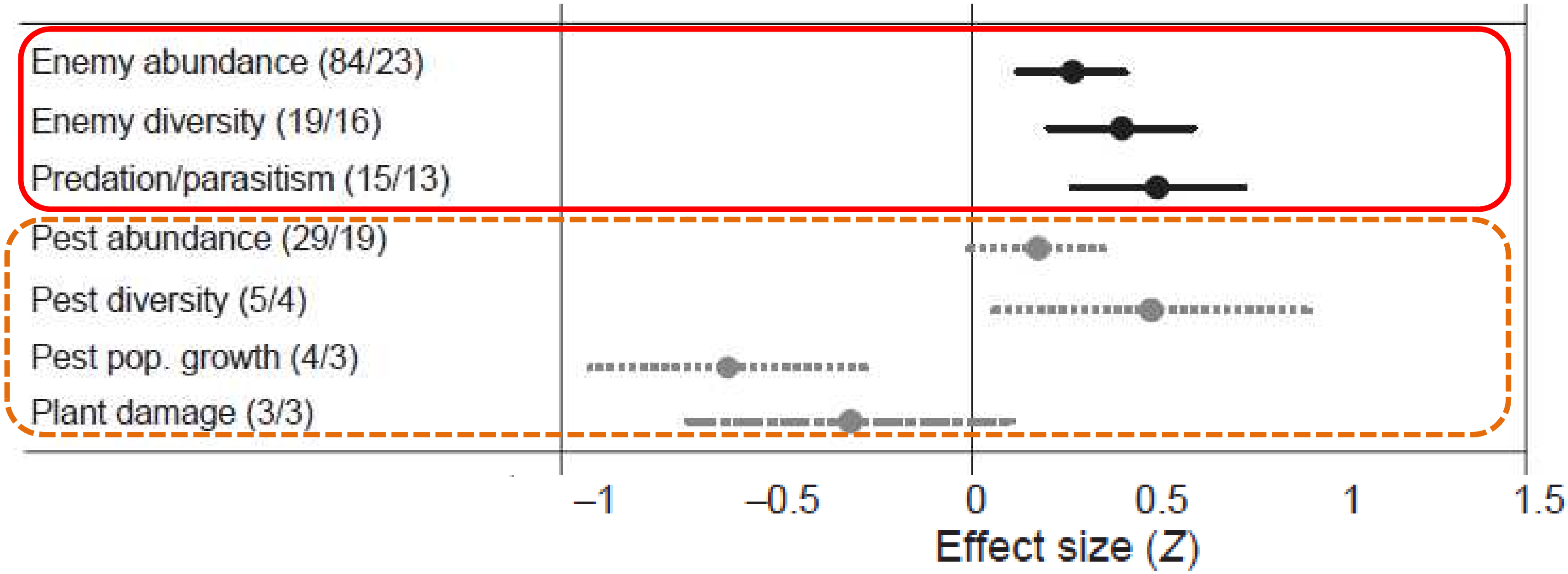
Surrounding noncrop area (%)



Thies & Tscharntke (1999)

Responses of natural enemies and crop pests to landscape heterogeneity: meta-analysis

Chaplin-Kramer et al. (2011)



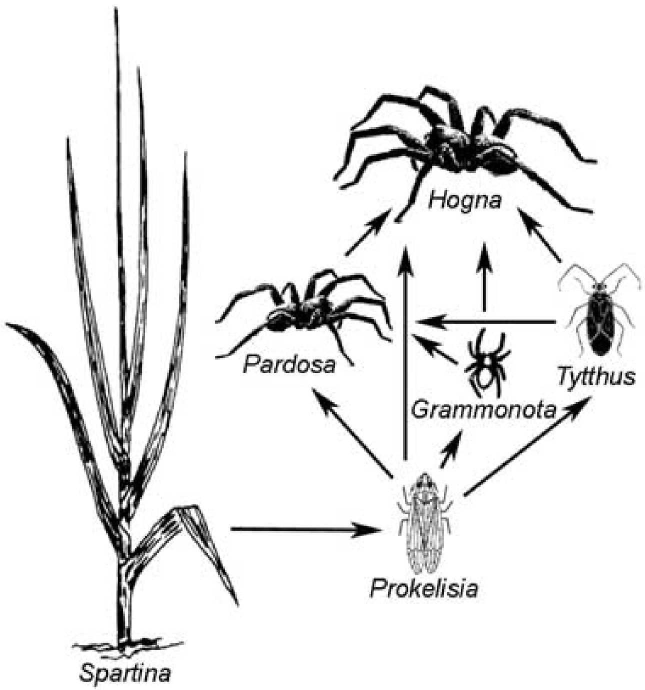
Effect of landscape structure is generally positive for natural enemies, but its effect is idiosyncratic for pest insects.

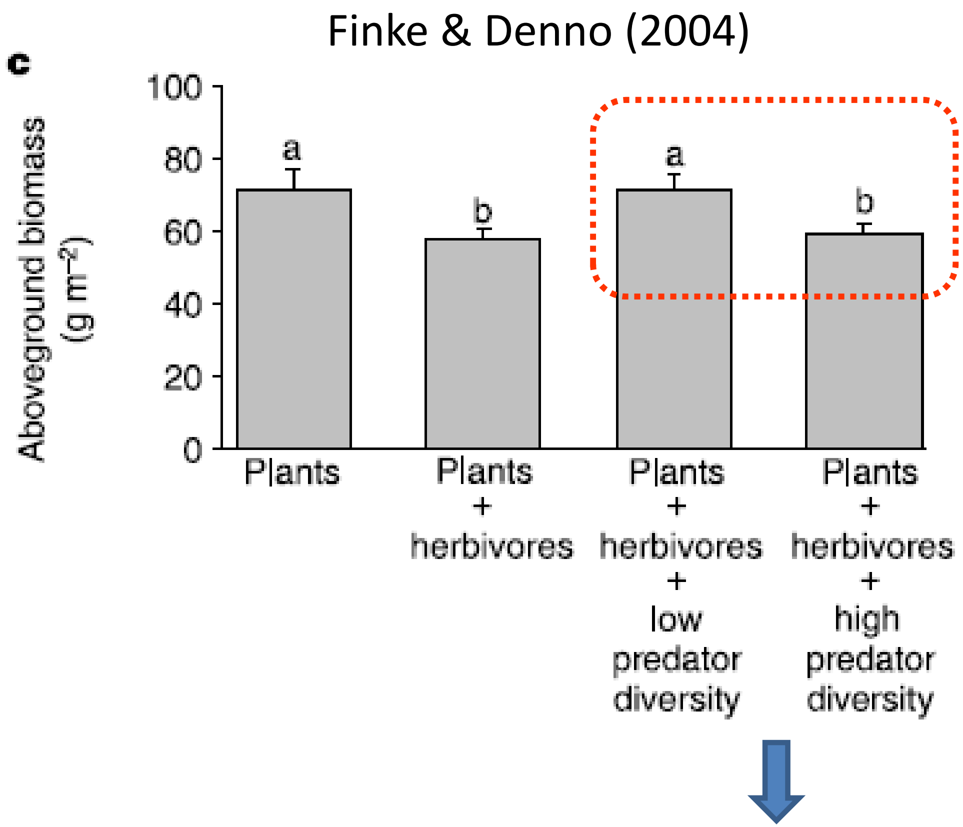
--- predation is not so efficient to suppress pests

--- bottom-up effect associated with landscapes is stronger

--- pesticide use is landscape dependent

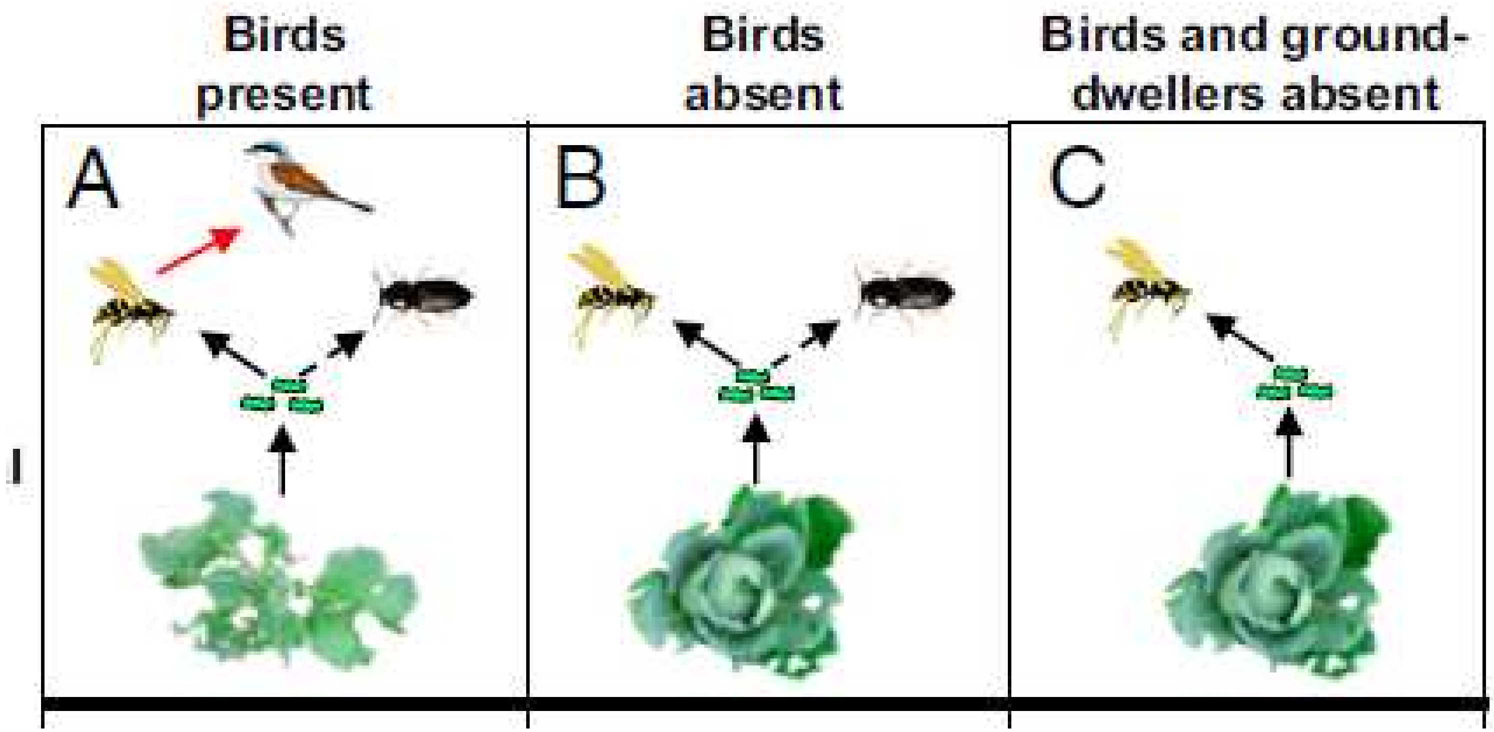
Species richness of natural enemies decreases pest control services --- due to intraguild predation





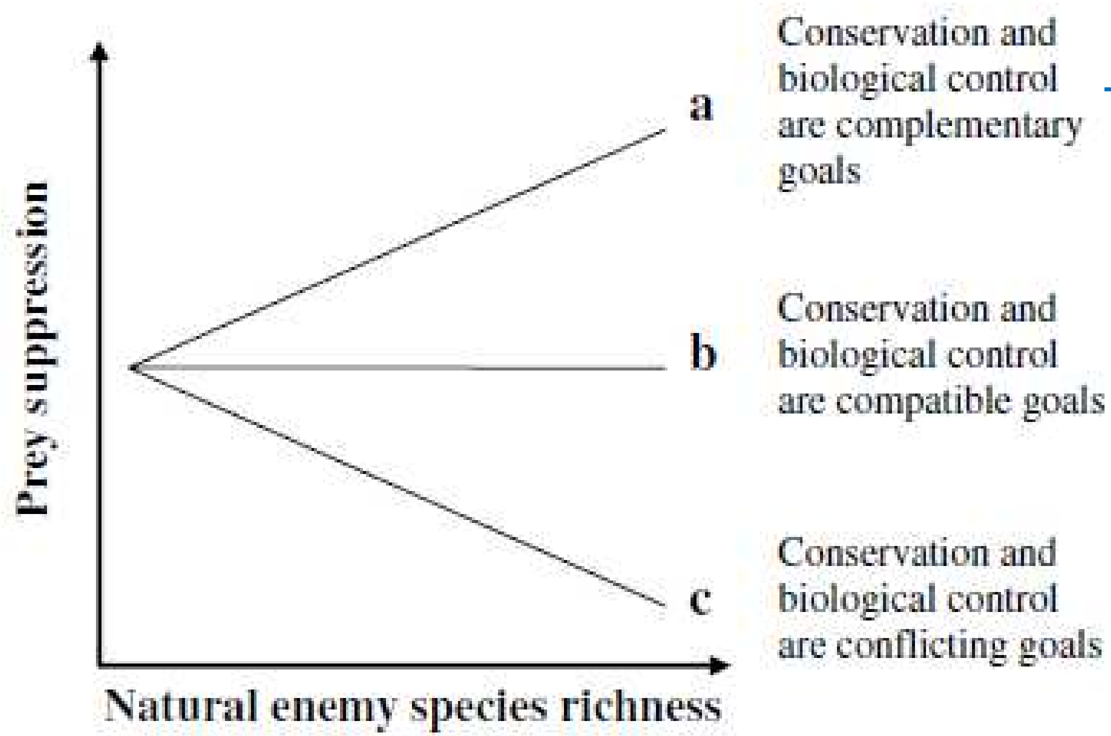
Positive effect of predator diversity on pests
Negative effect of predator diversity on plants

Species richness of natural enemies decreases pest control services --- due to intraguild predation



Martin et al. (2013)

Context dependent associations between species richness of natural enemies and pest control



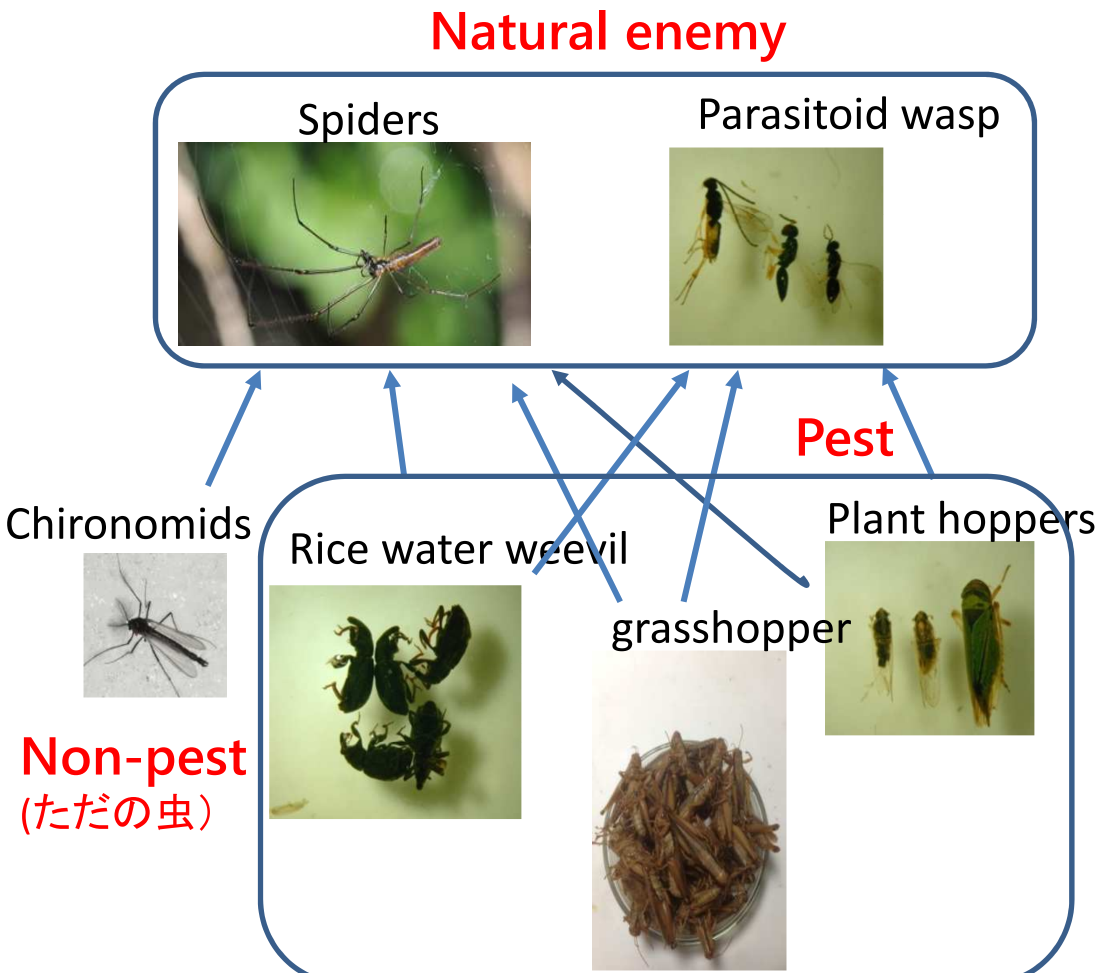
→ Niche complementarity

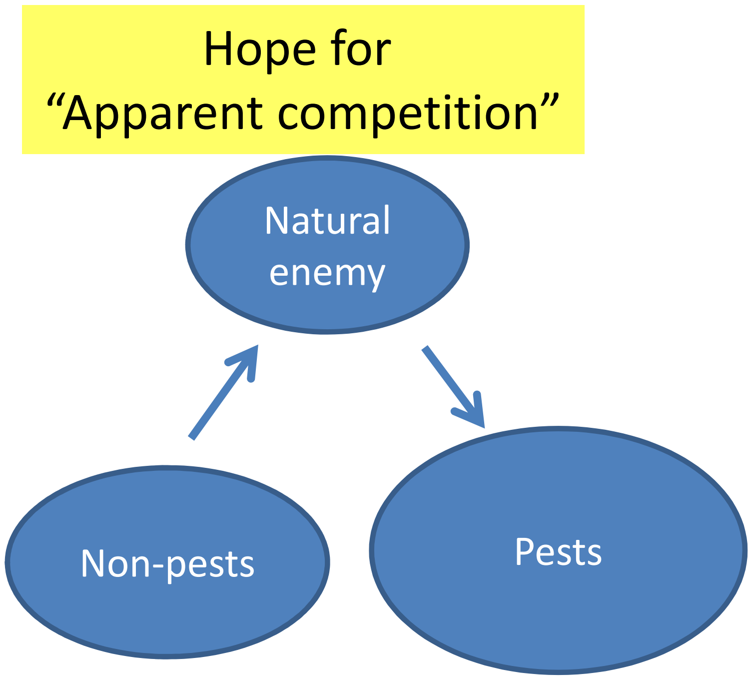
→ Functional redundancy

→ Intraguild predation

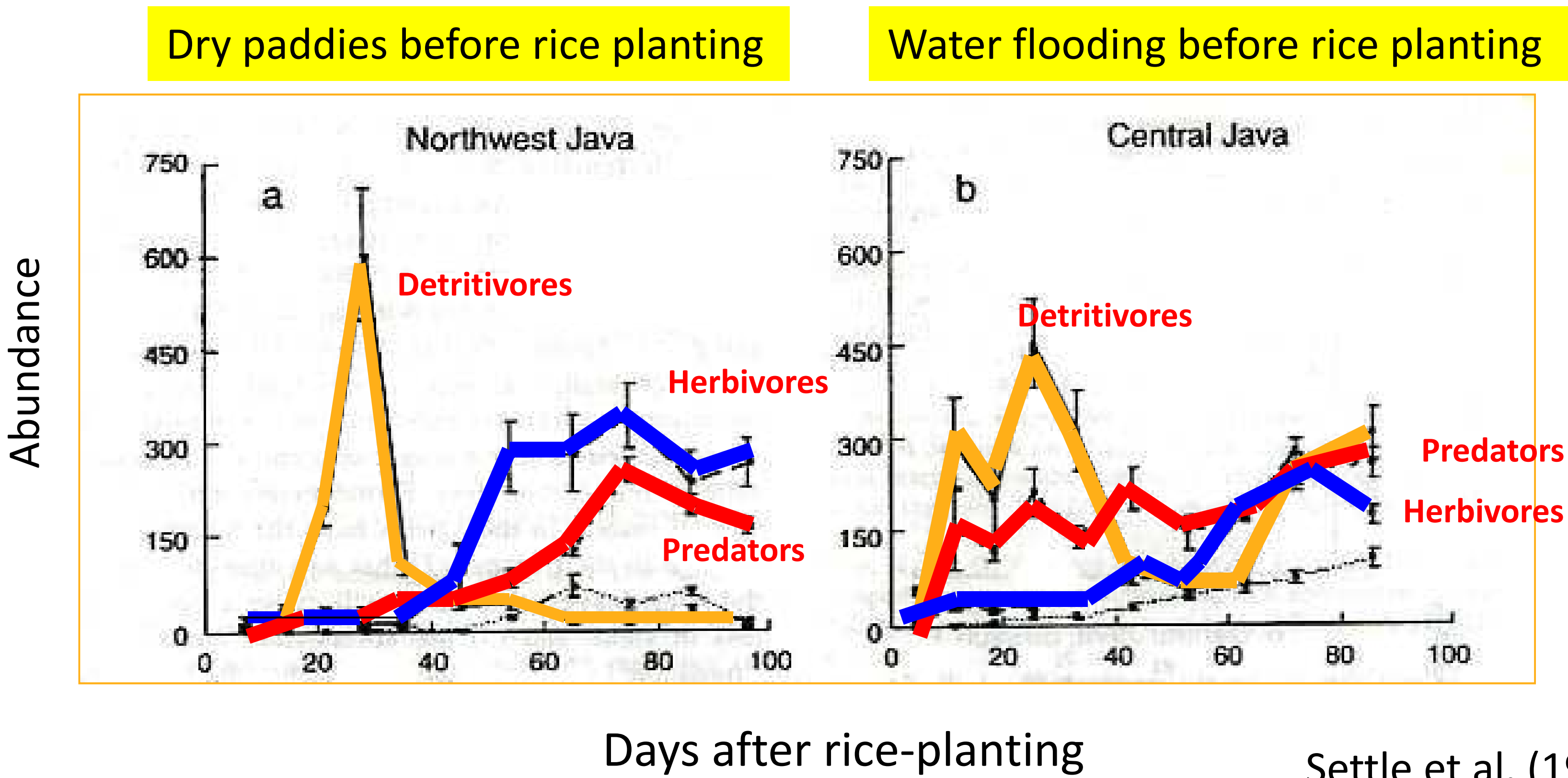
Straub et al. (2008)

Focusing on another aspect of species richness
--- the need to consider alternative prey for predators





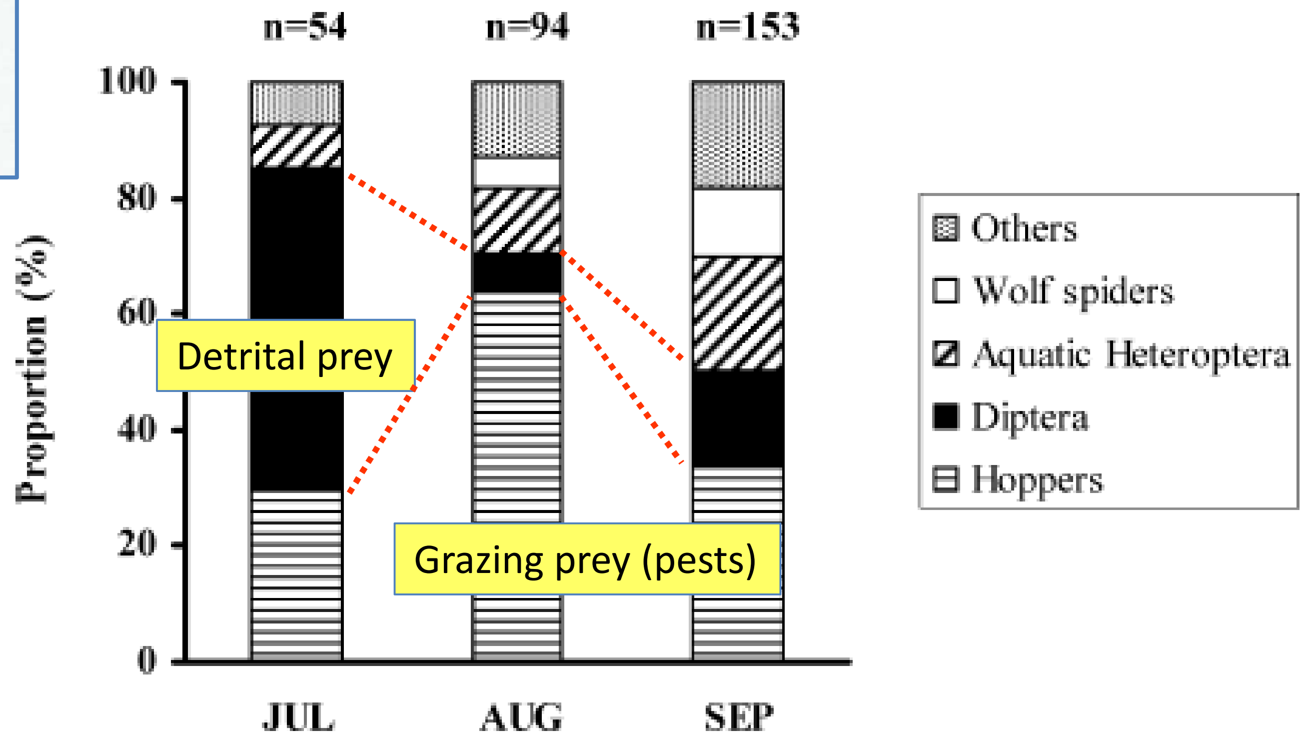
Circumstantial evidence for "apparent competition" between detritivores and herbivores mediated by generalist predators
--- Seasonal population dynamics of arthropods in paddy fields in Java



Settle et al. (1996)

Evidence for predation by predators on detritvores

--- Seasonal change in diet composition of a wolf spider (*Pardosa pseudoannulata*) found in paddy fields



Ishijima et al. (2006)

Our ongoing project:

How do spiders maintain their populations in paddy ecosystems?

--- in relation to dipteran prey

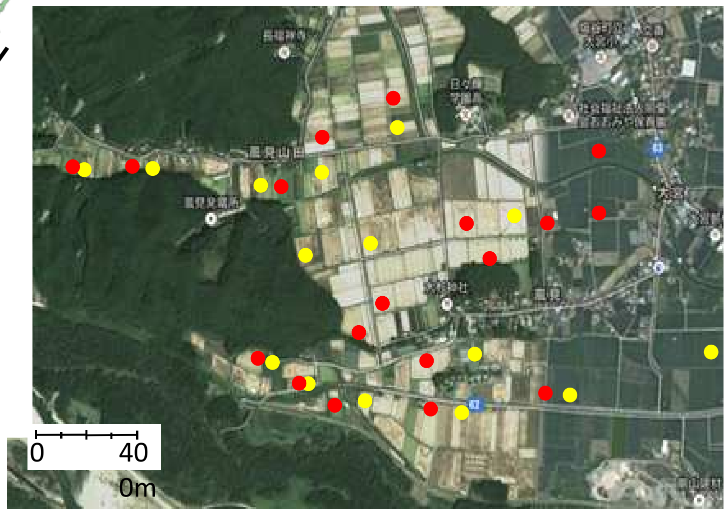
***Tetragnatha* spiders** --- wetland-dependent, highly abundant web spiders

T. extensa

T. maxillosa

T. caudicula

Tochigi Pref.
Shioya town



- ● Conventional: 15 sites
- ● Environmentally friendly: 18 sites

EF farming in this area

- ✓ no insecticide
- ✓ herbicide < 50%
- ✓ chemical fertilizer <50%

Nematocerans captured by web of *Tetragnatha* spiders

Mostly Chironomids that emerged from water in paddy fields

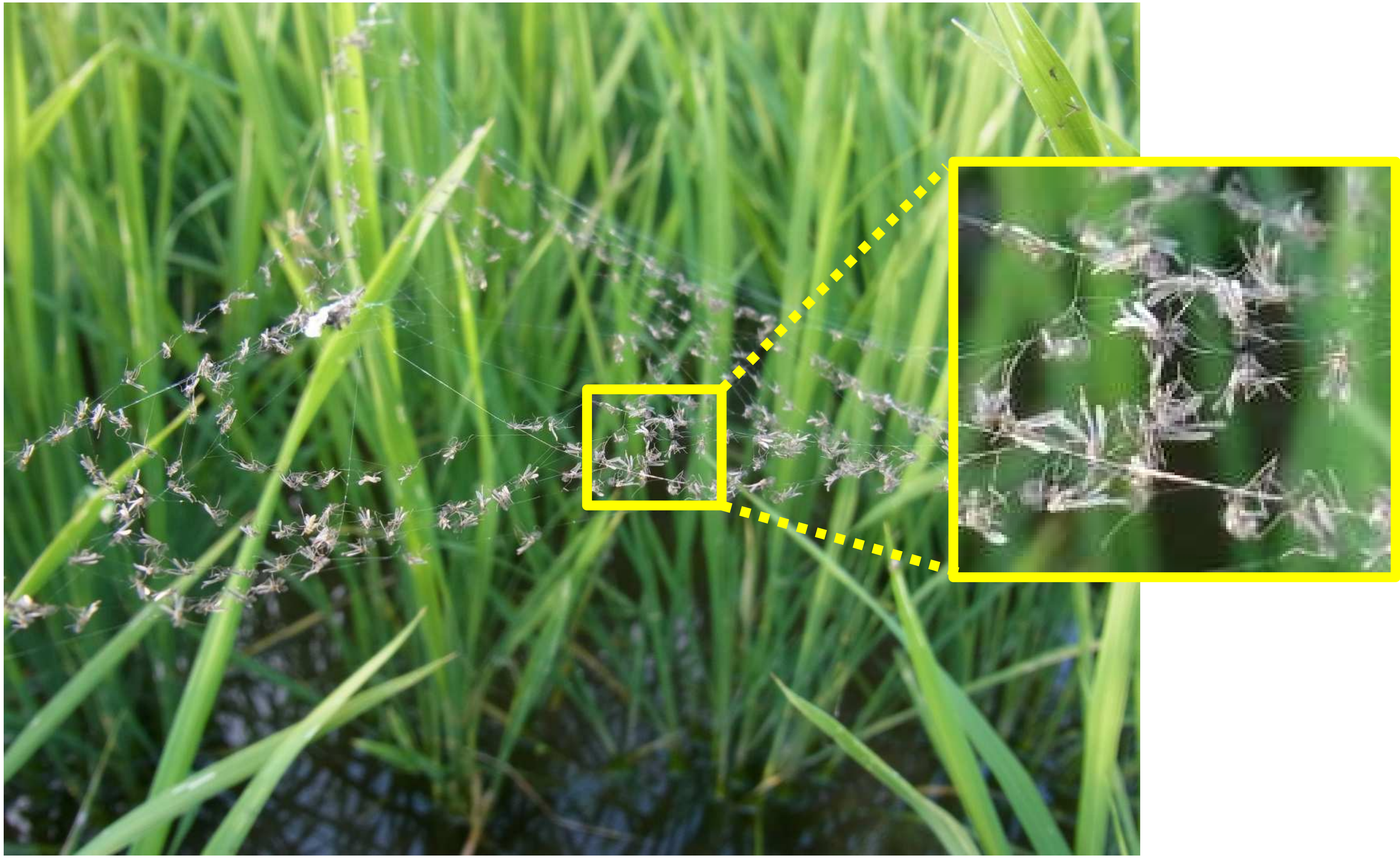
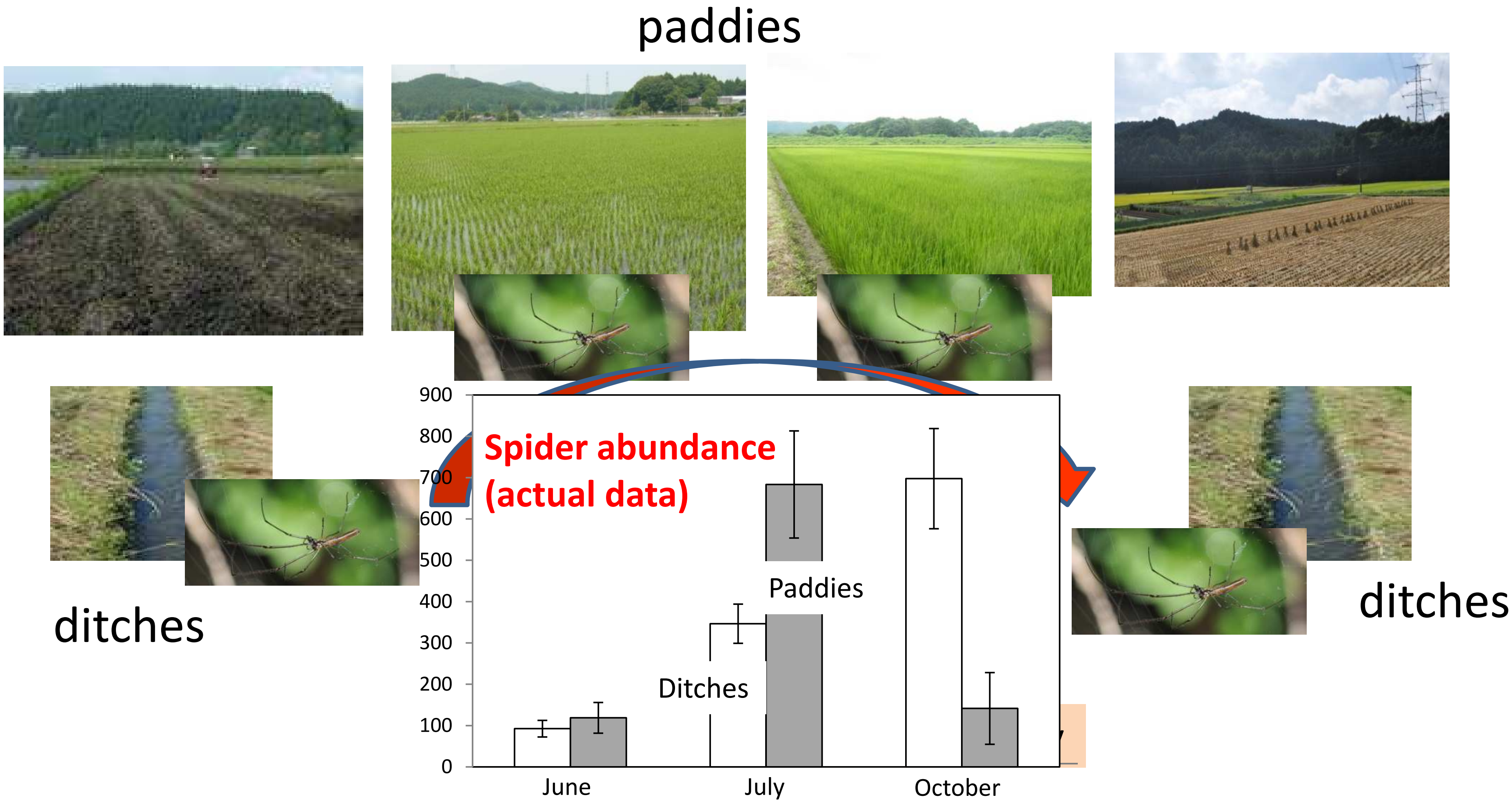


Photo: M H Tsutsui

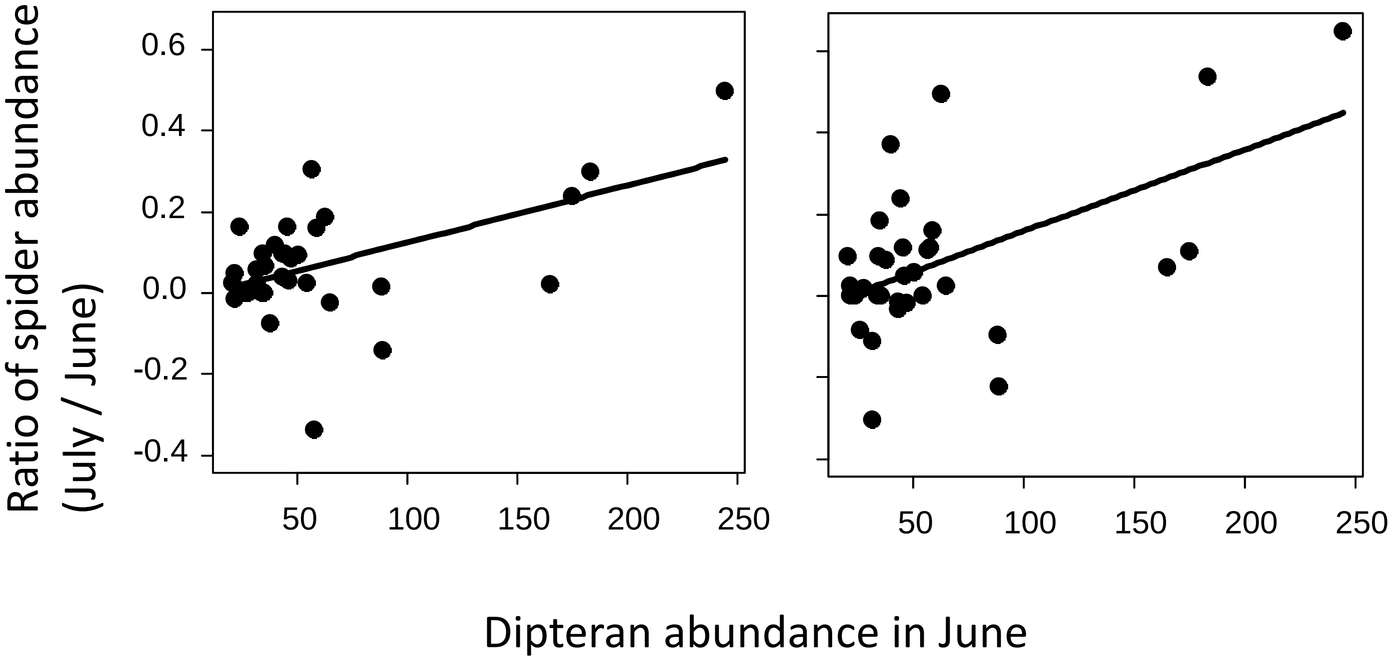
Hypothetical life cycle of *Tetragnatha* spiders in and around paddies

April	May	June	July	August	September



Population growth rate of *Tetragnatha* spiders (from June to July) as a function of dipteran abundance

p = 0.002, t(31)=-3.430 p = 0.001, t(31)=3.545



Bottom-up effect by dipterans on spiders was supported

Diversity of Dipteran species in paddy fields

----- temporal species turnover stabilizes total biomass?

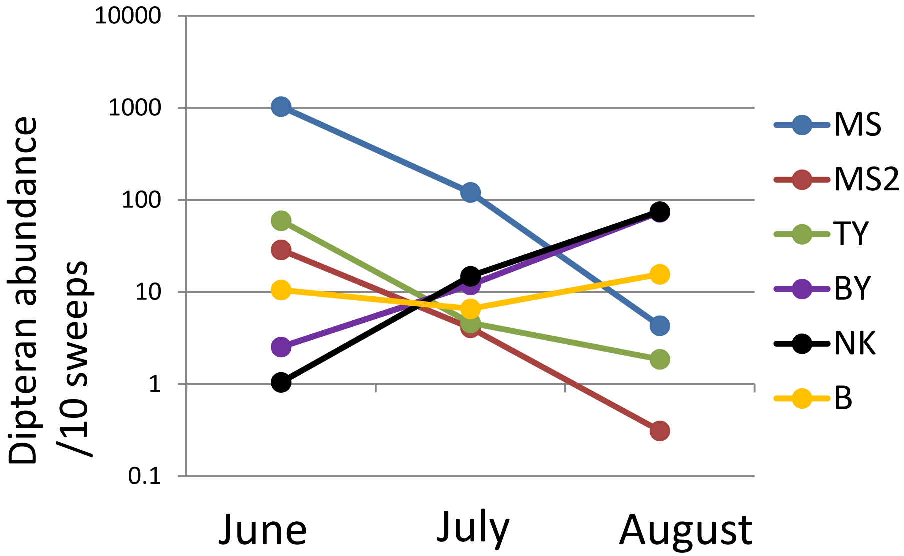
MS

MS2

TY

BY

BYD



Tsutsui et al. (unpubished)

Diversity of alternative prey would be the key for sustaining natural enemies

Future perspective:

The need to consider diversity of non-target insects, in addition to the diversity of natural enemies

--- “diversity-diversity interaction” has rarely been addressed