Predicting the Distribution of Three Vulnerable Japanese Plants: *Rosa hirtula*, *Kirengeshoma palmata*, and *Salicornia europaea*

Erin Conlisk, Forestry and Forest Products Research Institute, Tanaka Lab

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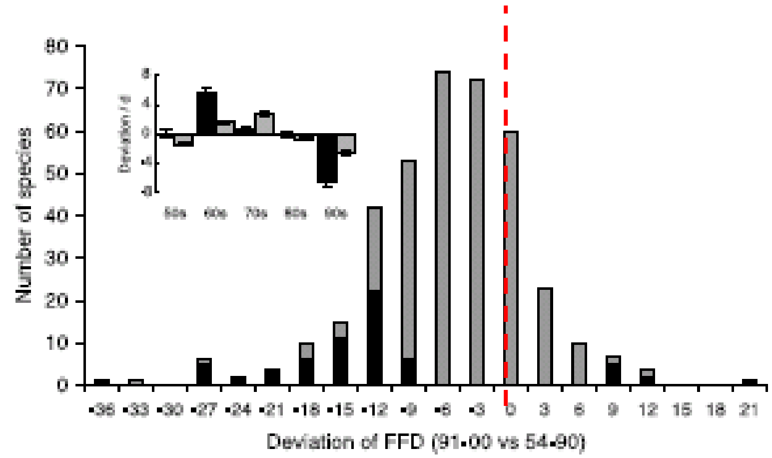
Outline

- Introduce previous work
- Methods
  - Three focal species: *Rosa hirtula*, *Kirengeshoma palmata*, and *Salicornia europaea*
  - Modeling
  - Species locality data
  - Environmental data
  - Difficulties of modeling vulnerable species
- Validation results
- Future shifts with climate change

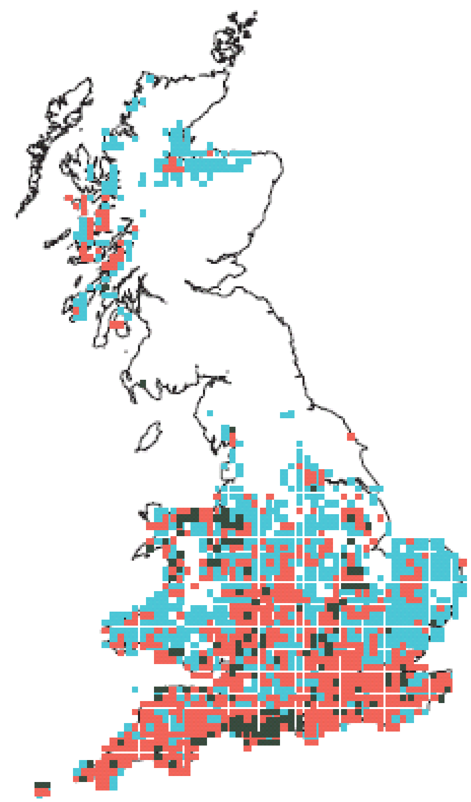
Previous Work

Models and observations suggest:

- Changes in critical behaviors (*e.g.* flowering time, migration time, etc)
- Species are moving polewards, to higher elevations, and often moving to coastal regions
- Natural and human barriers to species migration complicate adaptation
- Considerable retractions and extinctions are likely

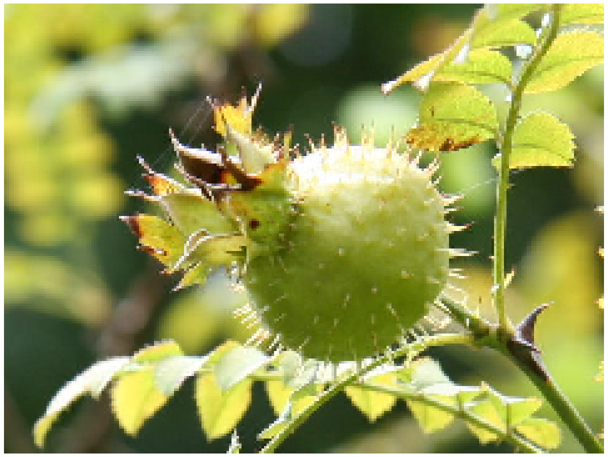


Fitter and Fitter 2002



Parmesan 1999

Vulnerable Species



Rosa hirtula

- Needs direct sunlight, well-drained soils
- Prefers locations where minimum annual temperature is above -20°C
- Grows to 2 meters
- Vulnerable to fungus and aphids
- Spiny fruits are used as a medicated liquor

Vulnerable Species

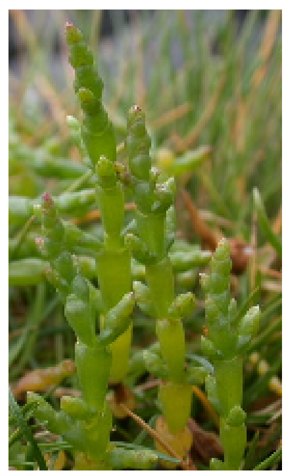
Kirengeshoma palmata

- Hydrangeaceae family
- Prefers typical woodland conditions: moist, humus-rich soil, partial-shade
- Prefers locations where minimum annual temperature is greater than -15°C
- Grows to 2 meters
- Seeds viable for up to 300 days, germinating at temperatures above 12°C

Endangered Species

<u>*Salicornia europaea*</u>

- Amaranthaceae family
- Throughout Northern Hemisphere
- Salt-tolerant, C4 succulent
- Highly edible
- 20-30 cm tall
- Needs water-logged soil and direct sun
- Increased germination with increased temperature up to 32°C



Species Distribution Model

Model:

- Setting: Grid overlaying relevent region; grid cells are possible plant locations
- Goal: Probability(species present) = Function(environmental variables)
- Estimation Method: Maxent
  - For comparison of this and other methods see Elith et al. 2006

Dependent Variable Data:

- Input data: localities where species is present (from presence-only or presence-absence dataset)

Independent Variable Data:

- Climate (precipitation and temperature seasonality and extremes)
- Soil, topography, land use, geology
- No biotic interactions

Model: Maximum Entropy

Software package 3.2.19 (Phillips et al. 2006) from:

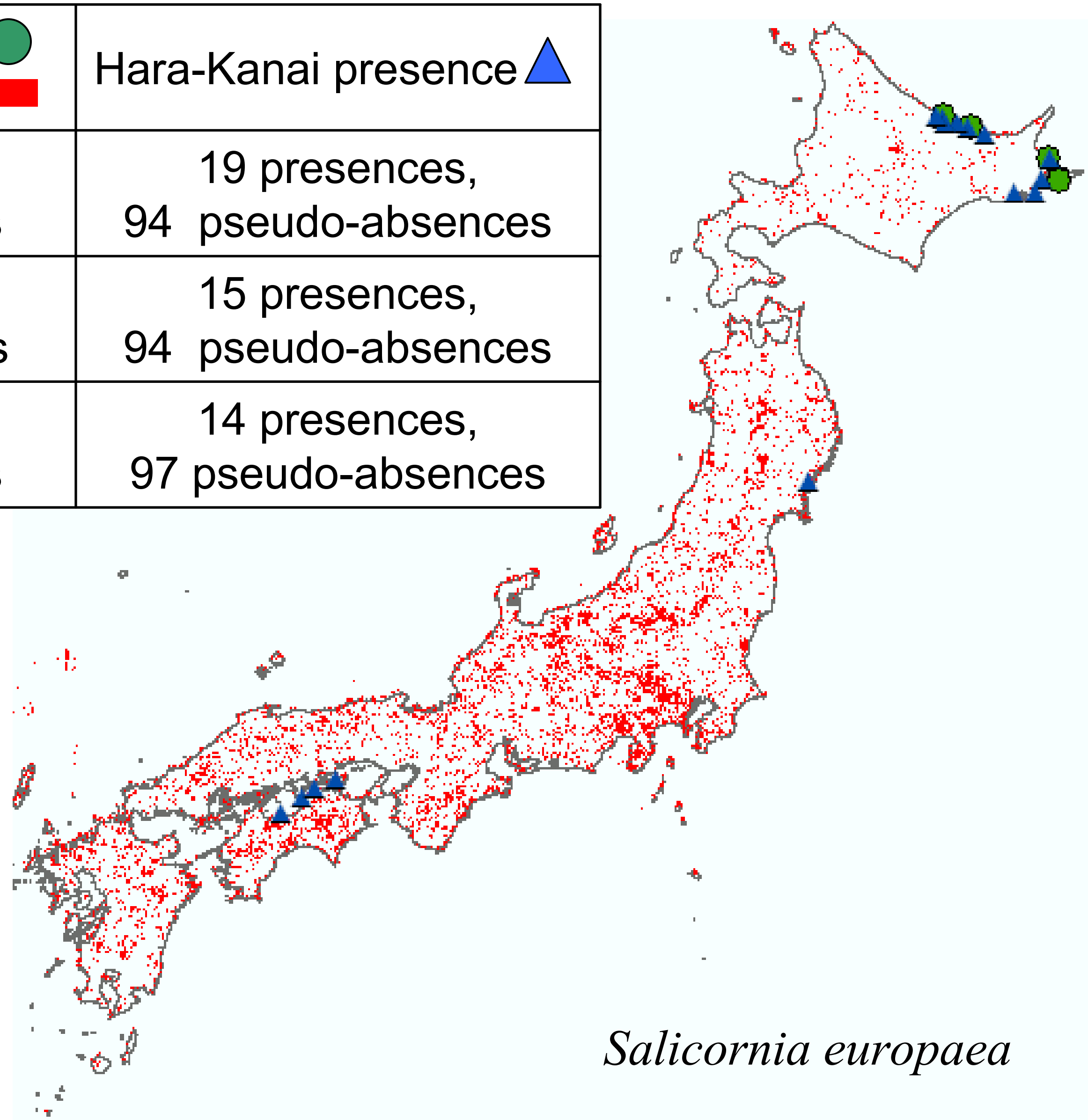
http://www.cs.princeton.edu/~schapire/maxent/

- Uses presence-only data
- Maximizes entropy subject to constraints provided by the data, thereby creating the most "even" distribution of Prob[presence] values consistent with the data
- Let X's denote the environmental variables and λ's denote parameters, the resulting functional form is:

$$\mathrm{Prob}[\mathrm{presence}] = c\exp\left[-(\lambda_1 X_1 + \lambda_2 X_2 + \cdots + \lambda_k X_k)\right].$$

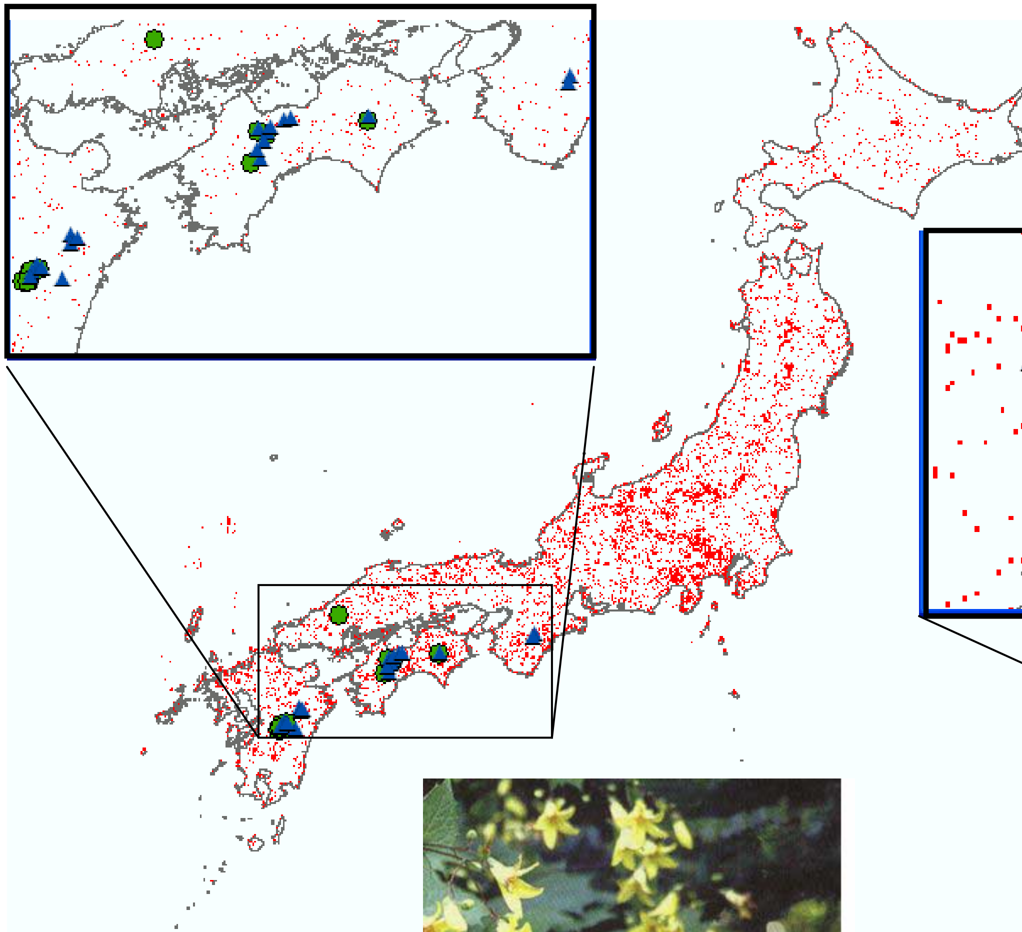
Dependent Variable Data: Species Presence

	PRDB presence ● PRDB absence ■	Hara-Kanai presence ▲
K. palmata	13 presences, 7280 absences	19 presences, 94 pseudo-absences
S. europaea	8 presences, 7475 absences	15 presences, 94 pseudo-absences
R. hirtula	10 presences, 7473 absences	14 presences, 97 pseudo-absences

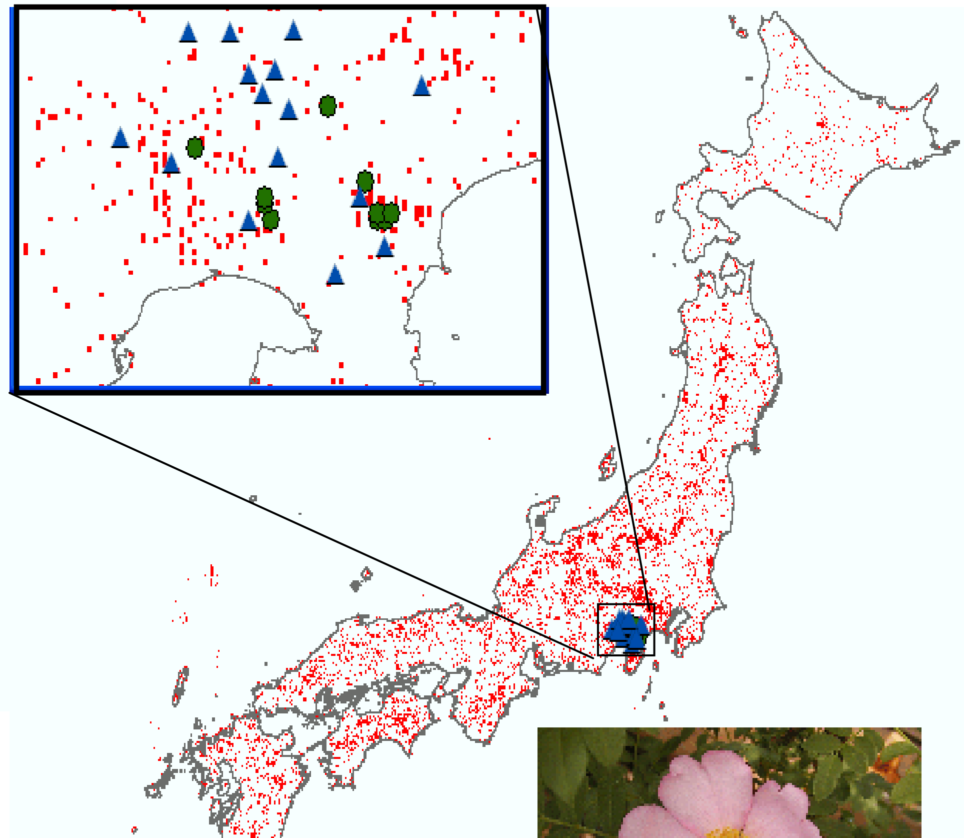


Salicornia europaea

Dependent Variable Data: Species Presence



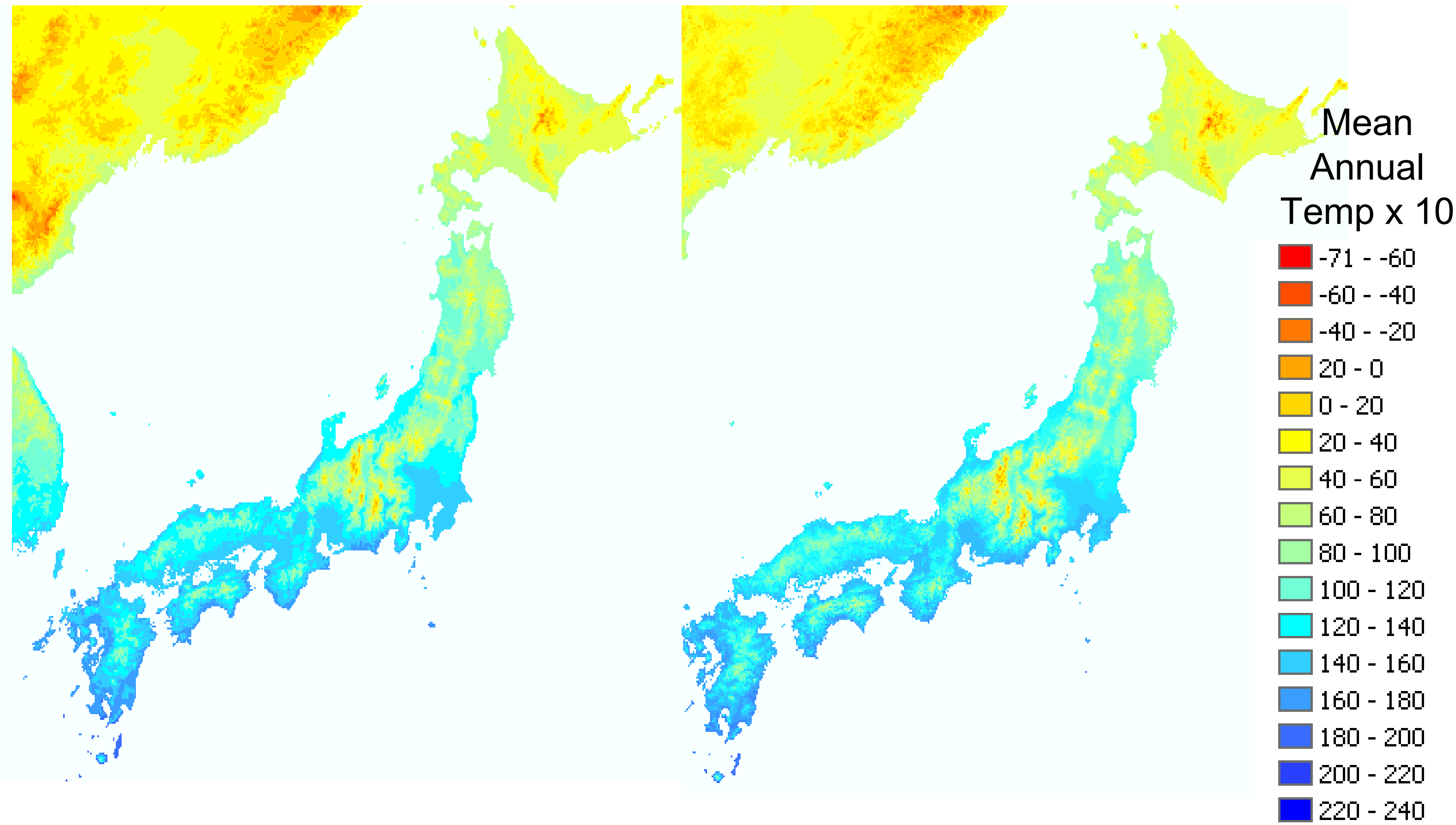
Kirengeshoma palmata



Rosa hirtula

Independent Variable Data: Mean Temperature

Current | Future



Independent Variables: Worldclim + Nonclimate Variables

Bioclim 1	**Mean Annual Temperature**
Bioclim 2	**Mean Diurnal Temperature Range**
Bioclim 3	**Isothermality**
Bioclim 4	**Temperature Seasonality**
Bioclim 5	**Maximum Temperature**
Bioclim 6	**Minimum Temperature**
Bioclim 7	**Temperature Range**
Bioclim 8	**Mean Temperature of Wettest Quarter**
Bioclim 9	**Mean Temperature of Driest Quarter**
Bioclim 10	**Mean Temperature of Warmest Quarter**
Bioclim 11	**Mean Temperature of Coldest Quarter**
Bioclim 12	**Annual Precipitation**
Bioclim 13	**Precipitation of Wettest Month**
Bioclim 14	**Precipitation of Driest Month**
Bioclim 15	**Precipitation Seasonality**
Bioclim 16	**Precipitation of Wettest Quarter**
Bioclim 17	**Precipitation of Driest Quarter**
Bioclim 18	**Precipitation of Warmest Quarter**
Bioclim 19	**Precipitation of Coldest Quarter**

USGS Geology
Japanese Ministry of the Environment Geology
FAO Soil Type
Japanese Ministry of the Environment Soil Type
Topography (Higa, personal communication)
University of Maryland Land Use

Worldclim variables from:
http://www.worldclim.org/

Validation of Models in Current Climate

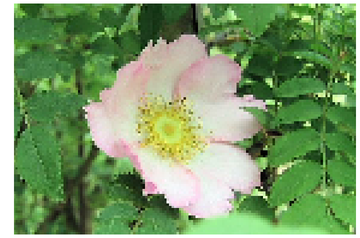
Goodness of Fit: How well does the model fit the data?

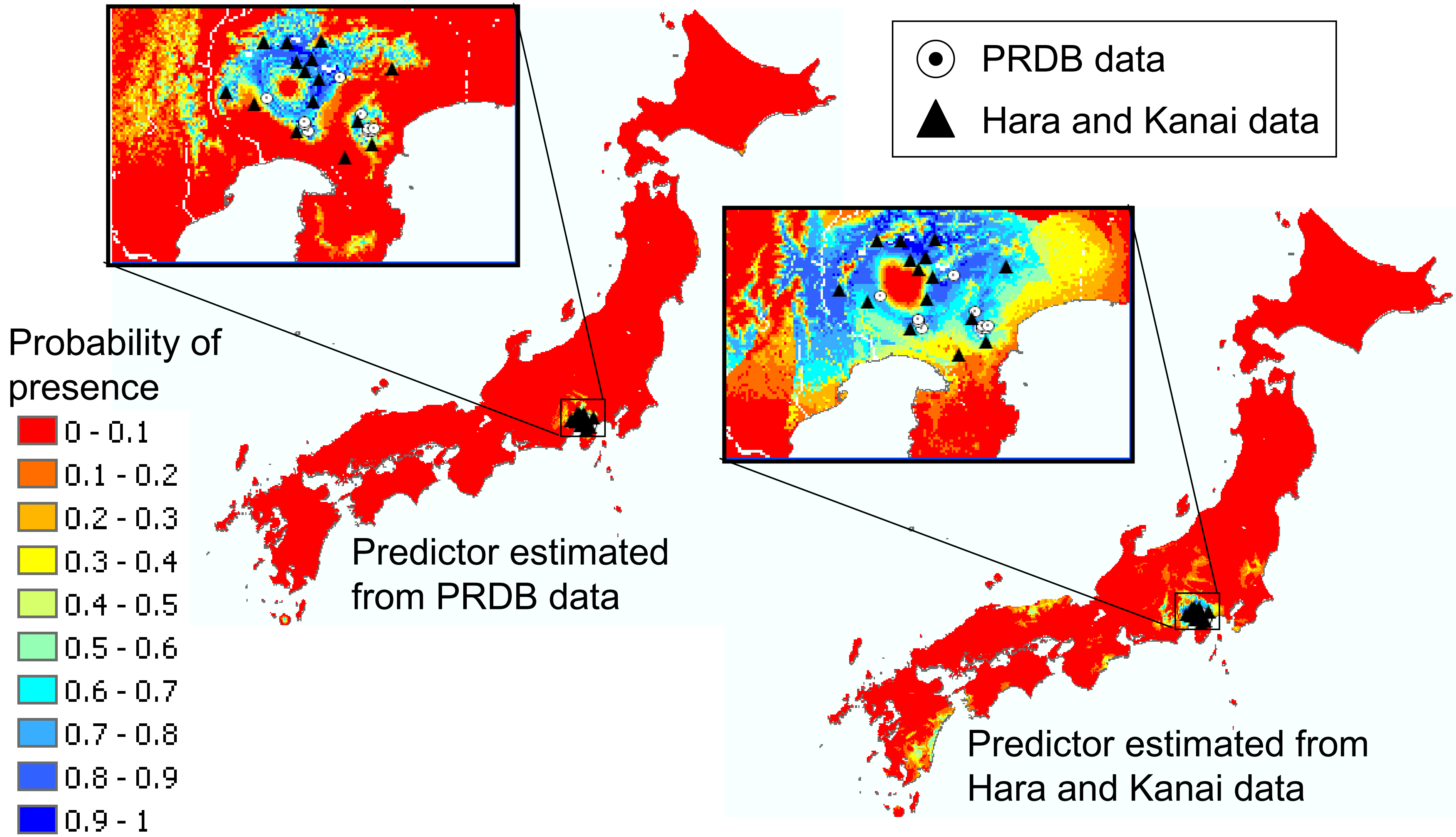
- Random: AUC = 0.5. Perfect: AUC = 1
- ~~Reserve a fraction of the data for model validation~~
- Use each dataset to validate the other's estimated model

Stability: Do predictions change when dataset is altered?

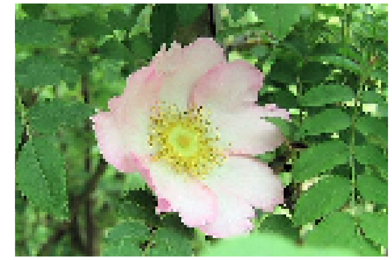
- Bootstrap subsamples, compute AUC for each
- Compute AUC standard deviation over subsamples

Predicted distributions for *Rosa hirtula* under the current climate





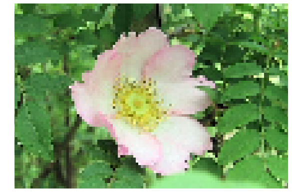
Model validation for *Rosa hirtula*



AUC values and bootstrapped standard deviations

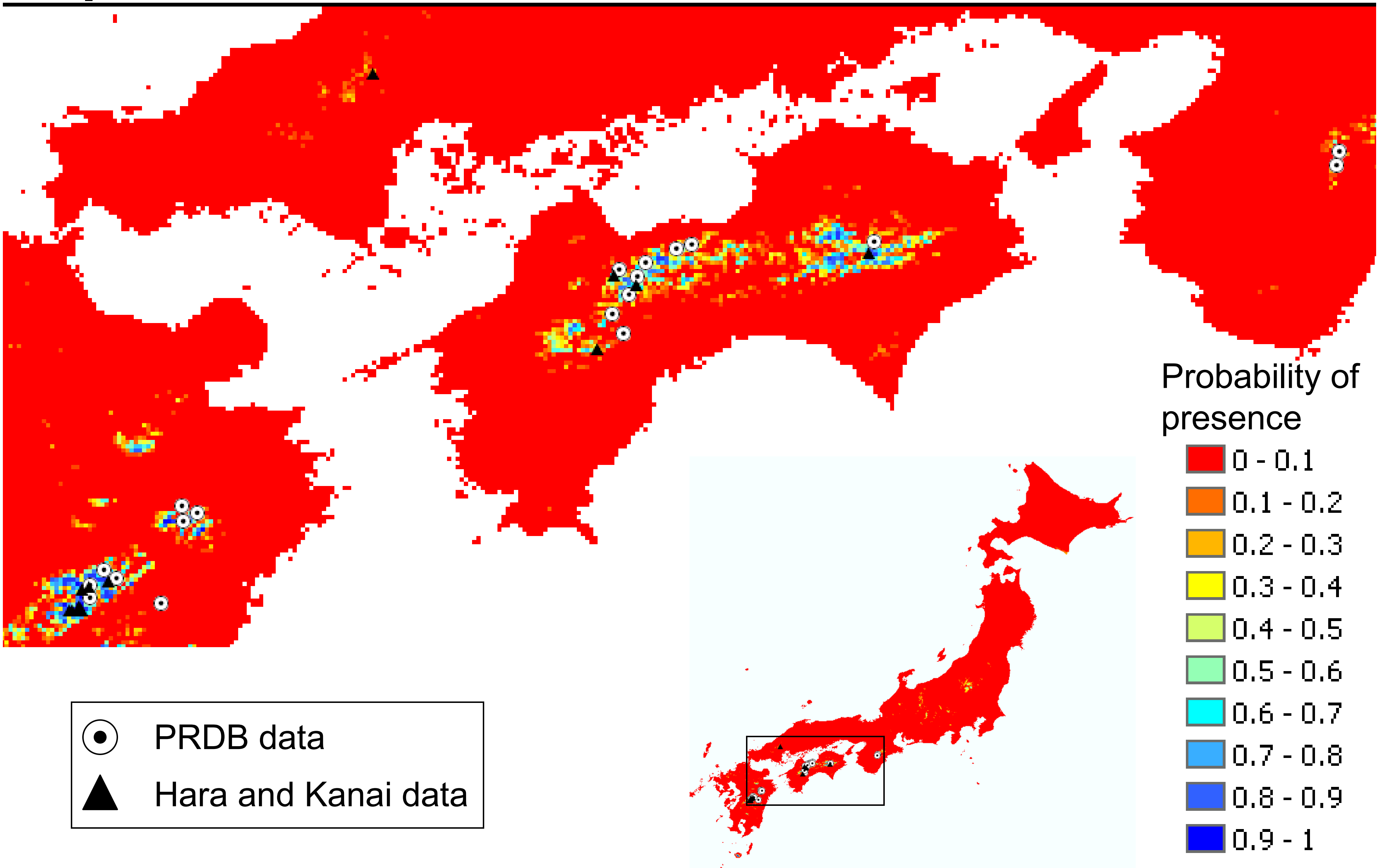
	PRDB data used for validation	Hara-Kanai data used for validation
Using predictor estimated from PRDB data	0.9917 (0.0003)	0.9293 (0.0026)
Using predictor estimated from Hara-Kanai data	0.9789 (0.0012)	0.9870 (0.0009)

Important Variables for *Rosa hirtula*

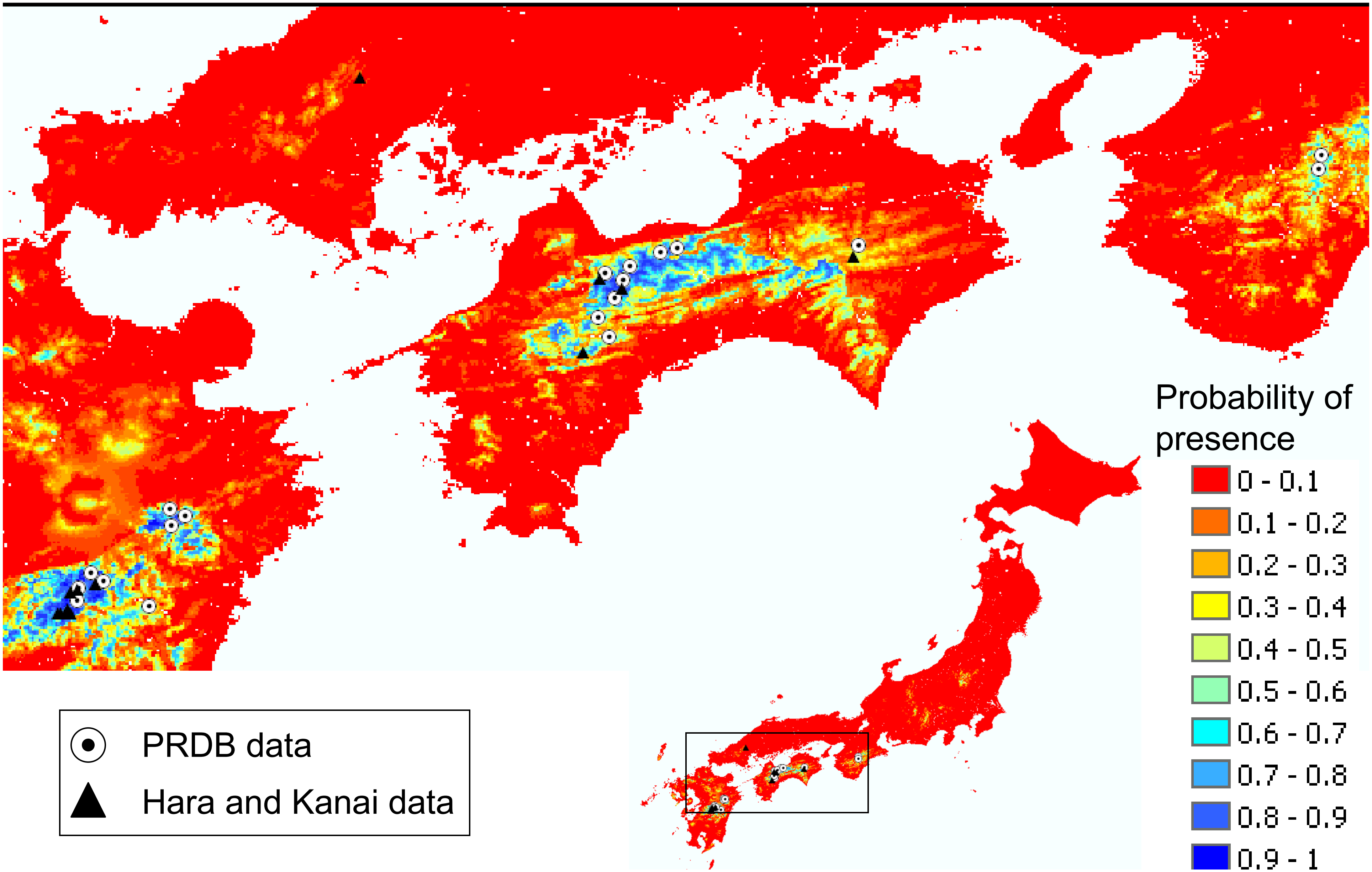


	PRDB Estimate			Hara and Kanai Estimate		
Variable	**Ave Import**	**Std Dev Import**	**Ave Rank**	**Ave Import**	**Std Dev Import**	**Ave Rank**
Isothermality (Bioclim 3)	47.72	3.47	1	53.7	3.04	1
Mean Temp of Warmest Quarter (Bioclim 10)	24.76	3.23	2	0	0	8
Temperature Seasonality (Bioclim 4)	10.42	0.61	3.4	4.3	0.53	5.9
USGS Geology	6.72	3.38	4.4	15.86	0.93	2
Precipitation Seasonality (Bioclim 15)	5.82	1.39	4.6	5.84	1.36	4.5
Topography	3.48	4.95	6	6.46	1.42	4.5
Annual Precipitation (Bioclim 12)	1.06	0.83	6.6	2.26	0.81	7
Mean Diurnal Range (Bioclim 2)	0	0	8	11.6	2.67	3.1

PRDB Predictions for *Kirengeshoma palmata* under the current climate



Hara and Kanai Predictions for *Kirengeshoma palmata* under the current climate

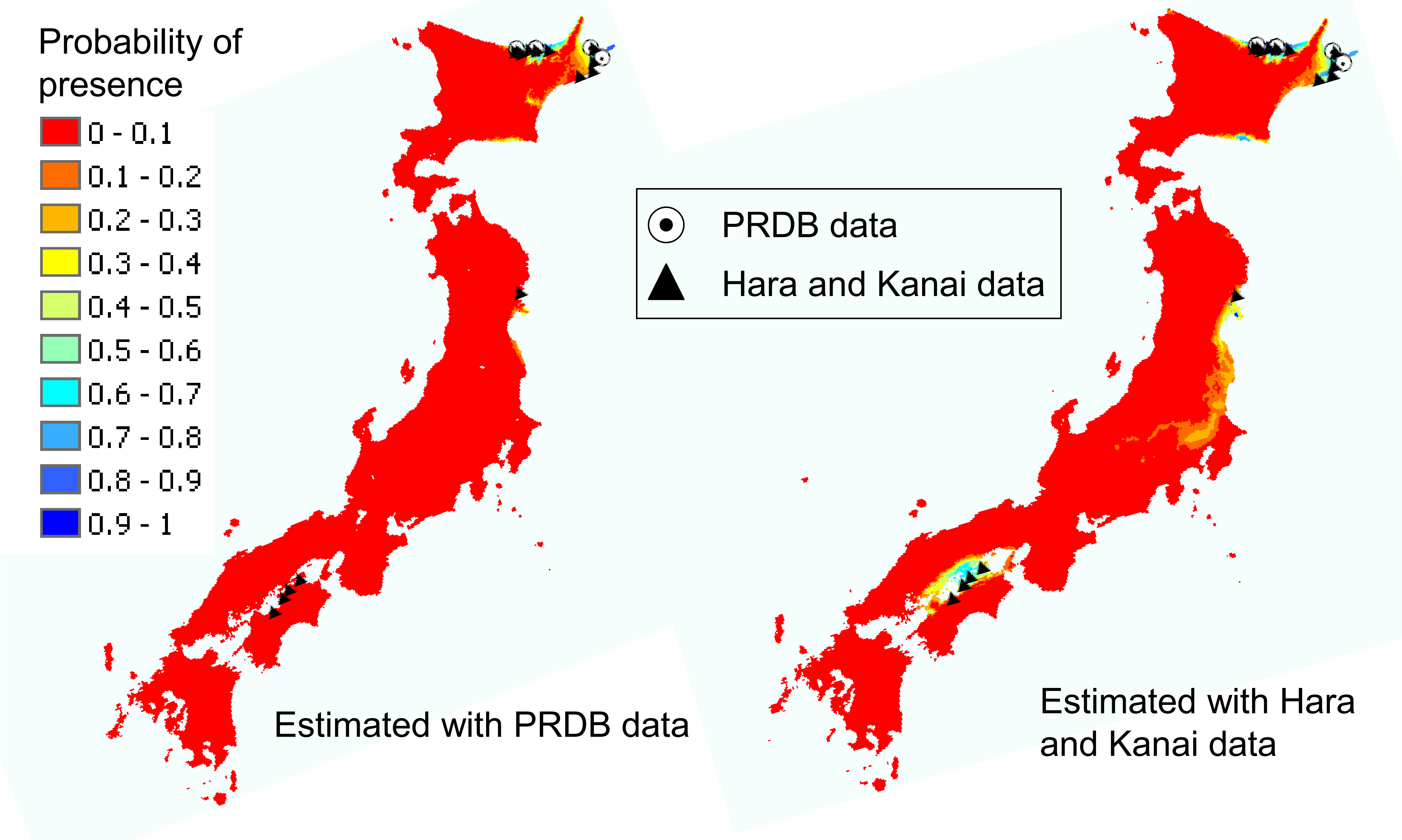


Model validation for *Kirengeshoma palmata*

AUC values and bootstrapped standard deviations

	PRDB data used for validation	Hara-Kanai data used for validation
Using predictor estimated from PRDB data	0.9901 (0.0002)	0.8873 (0.0007)
Using predictor estimated from Hara-Kanai data	0.9769 (0.0034)	0.9793 (0.014)

PRDB Predictions for *Salicornia europaea* under the current climate

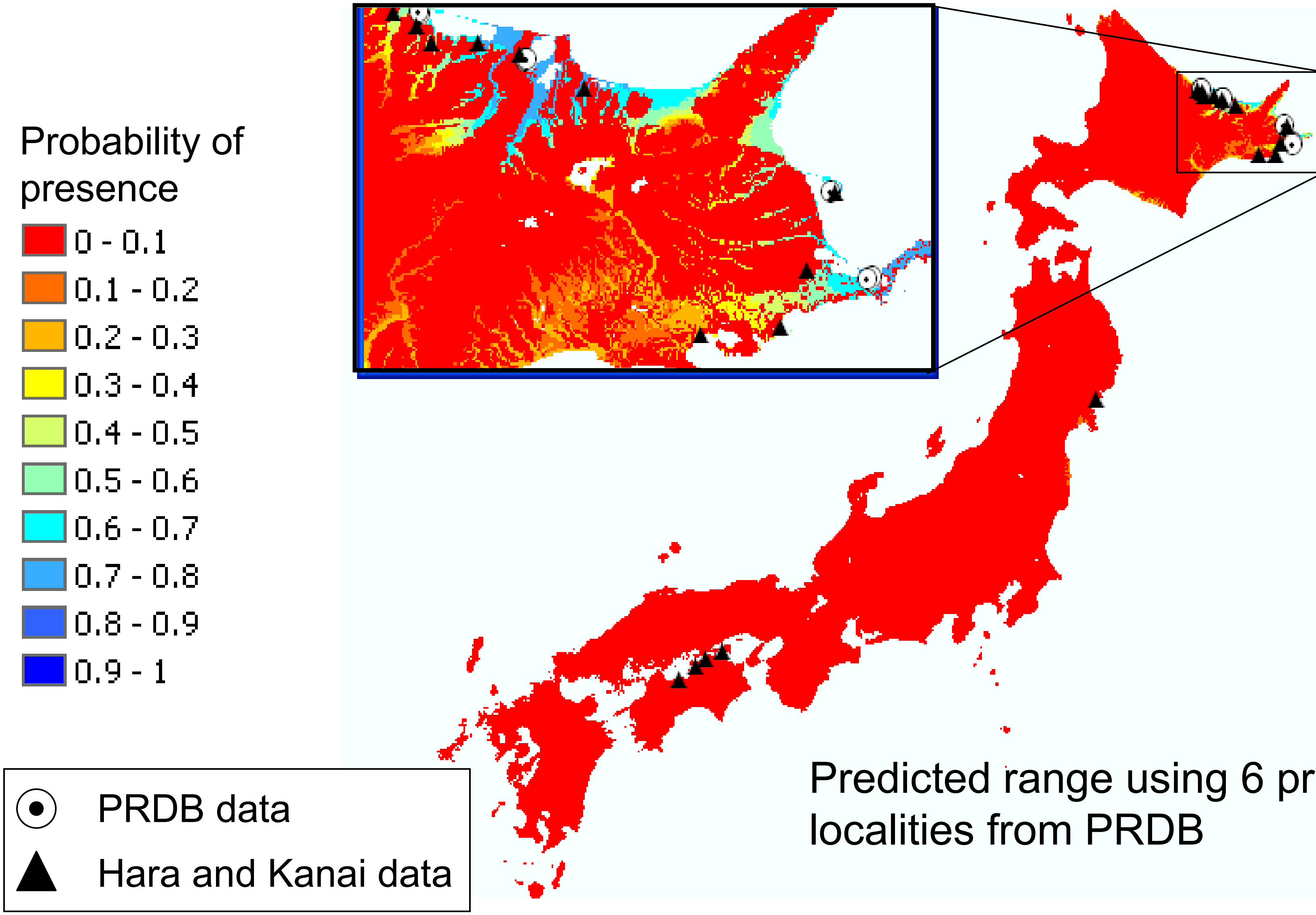


Model validation for *Salicornia europaea*

AUC values and bootstrapped standard deviations

	PRDB data used for validation	Hara-Kanai data used for validation
Using predictor estimated from PRDB data	0.9666 (0.0622)	0.7092 (0.2547)
Using predictor estimated from Hara-Kanai data	0.9974 (0.0003)	0.9802 (0.0015)

Too few localities for *Salicornia europaea*

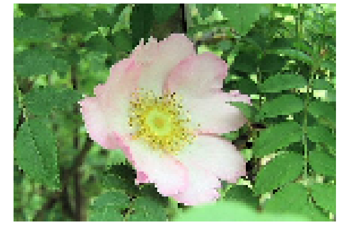


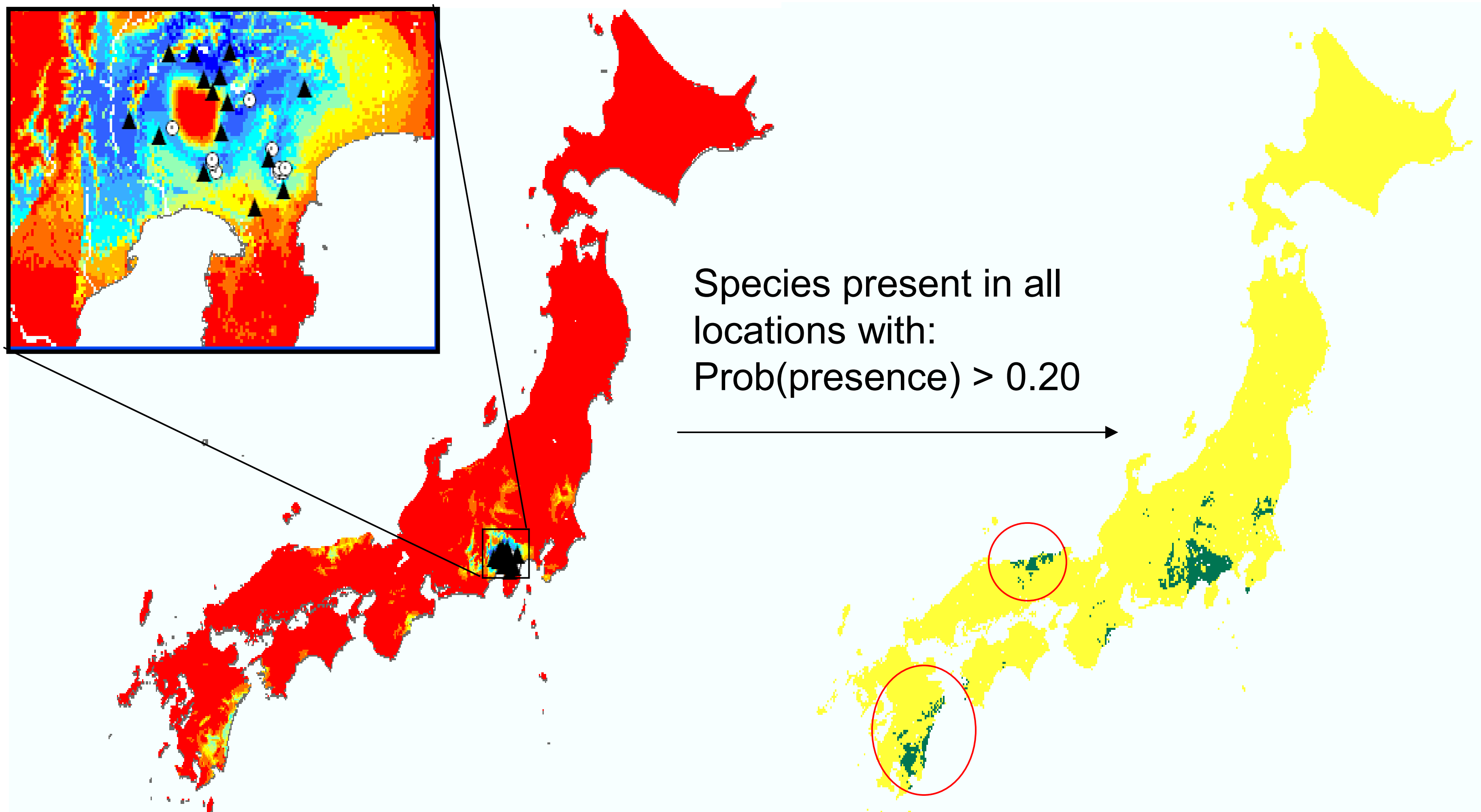
Predicted range using 6 presence localities from PRDB

Summary of model validation

- High AUCs for rare species
  - Initial sensitivity tests suggest that this is not a spurious effect
  - More sensitivity analyses are needed
- Estimates from Hara and Kanai data predicted true PRDB localities better than estimates from PRDB data predicted Hara and Kanai localities
  - Hara and Kanai had approximately 5 more localities per species, suggesting the importance of large datasets
  - More sensitivity analyses with larger datasets are needed
- At least when there are few presence observations, older distribution maps appear to make reasonable predictions
  - More sensitivity analyses are needed
- Important variables identified
  - More comparisons to literature needed

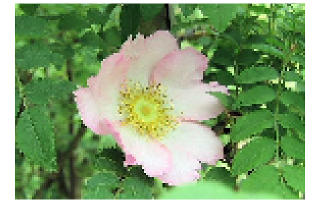
Rosa hirtula – Continuous to discrete presence probability



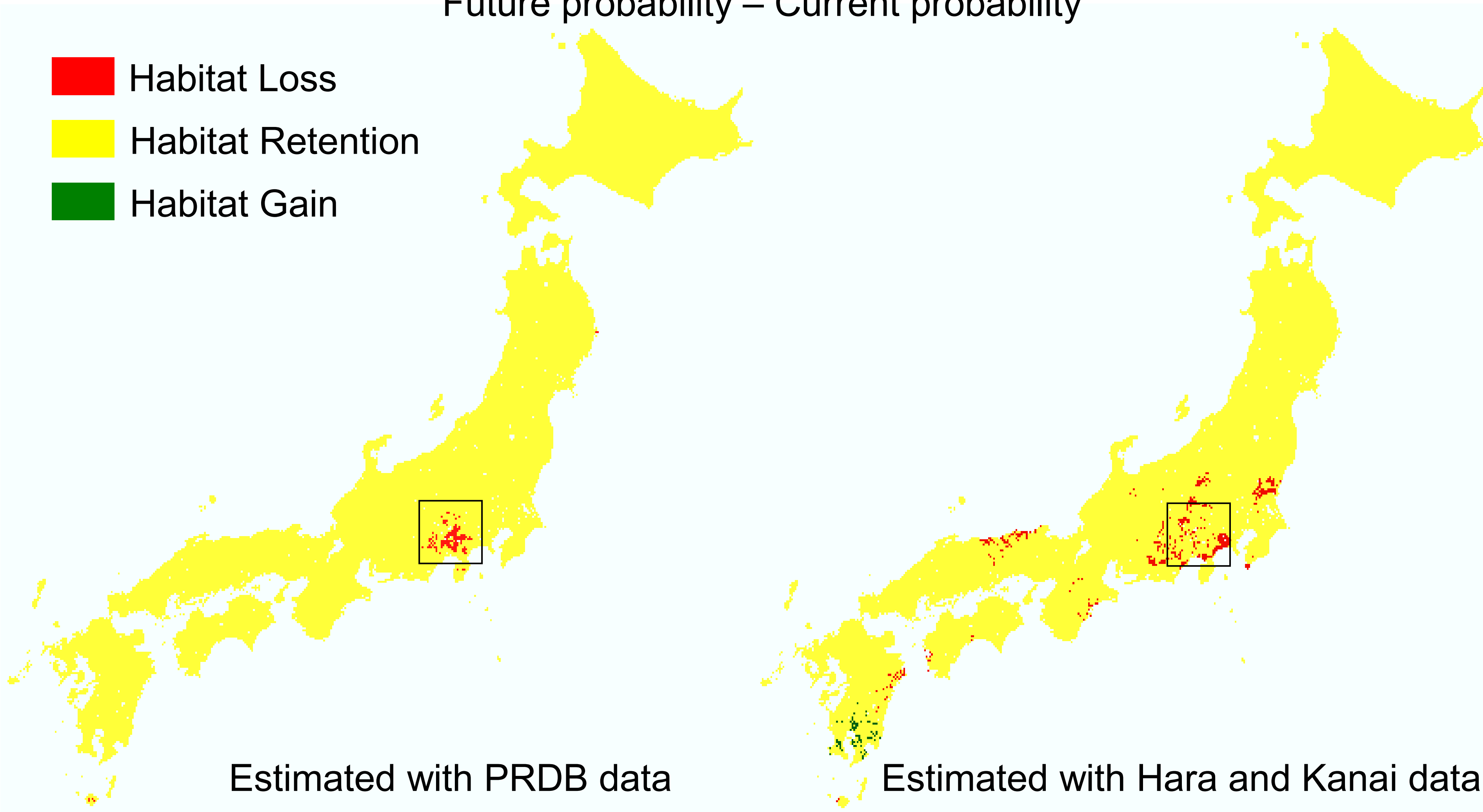


Current distribution estimated with Hara and Kanai data.

Range contraction for *Rosa hirtula*

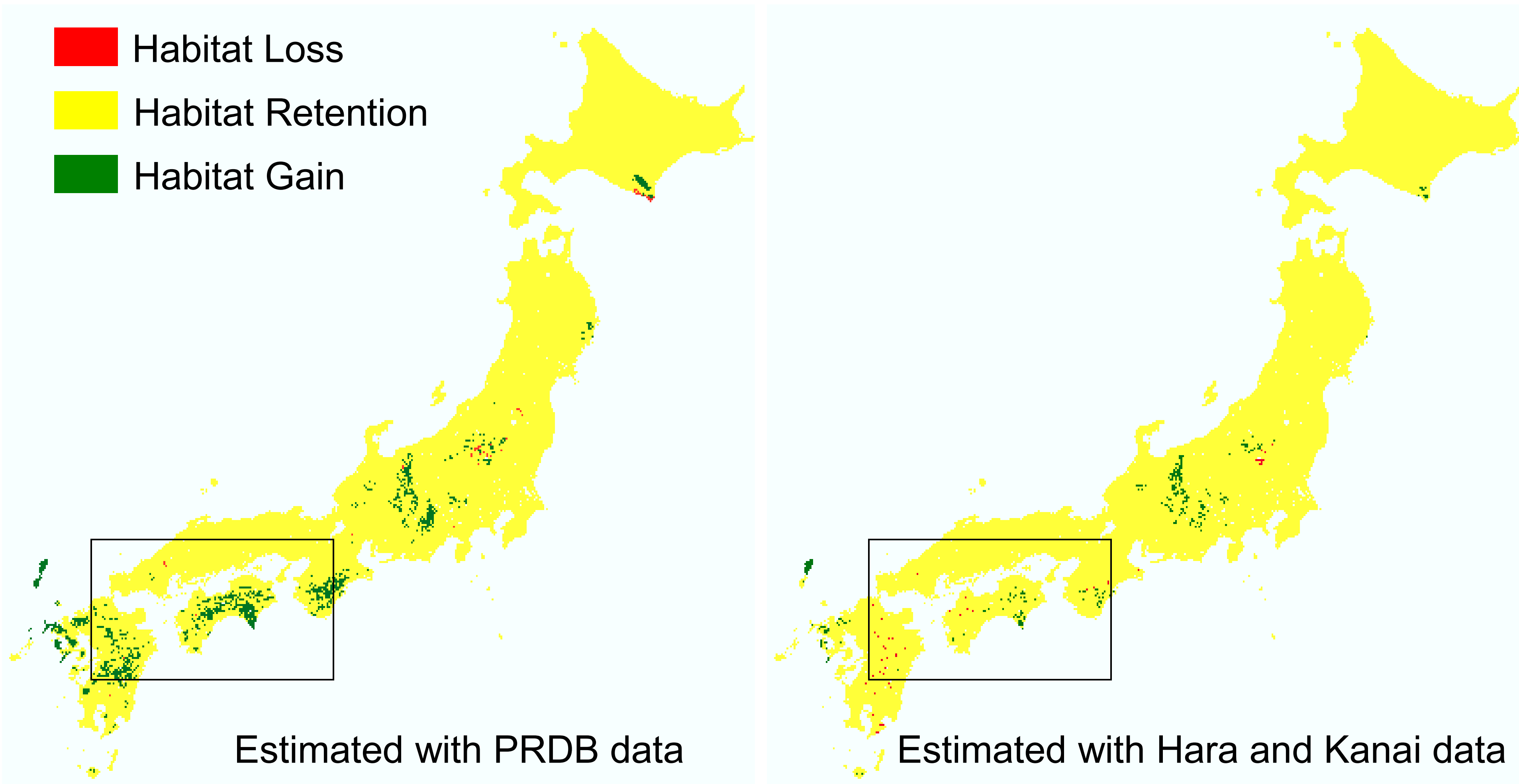


Future probability – Current probability



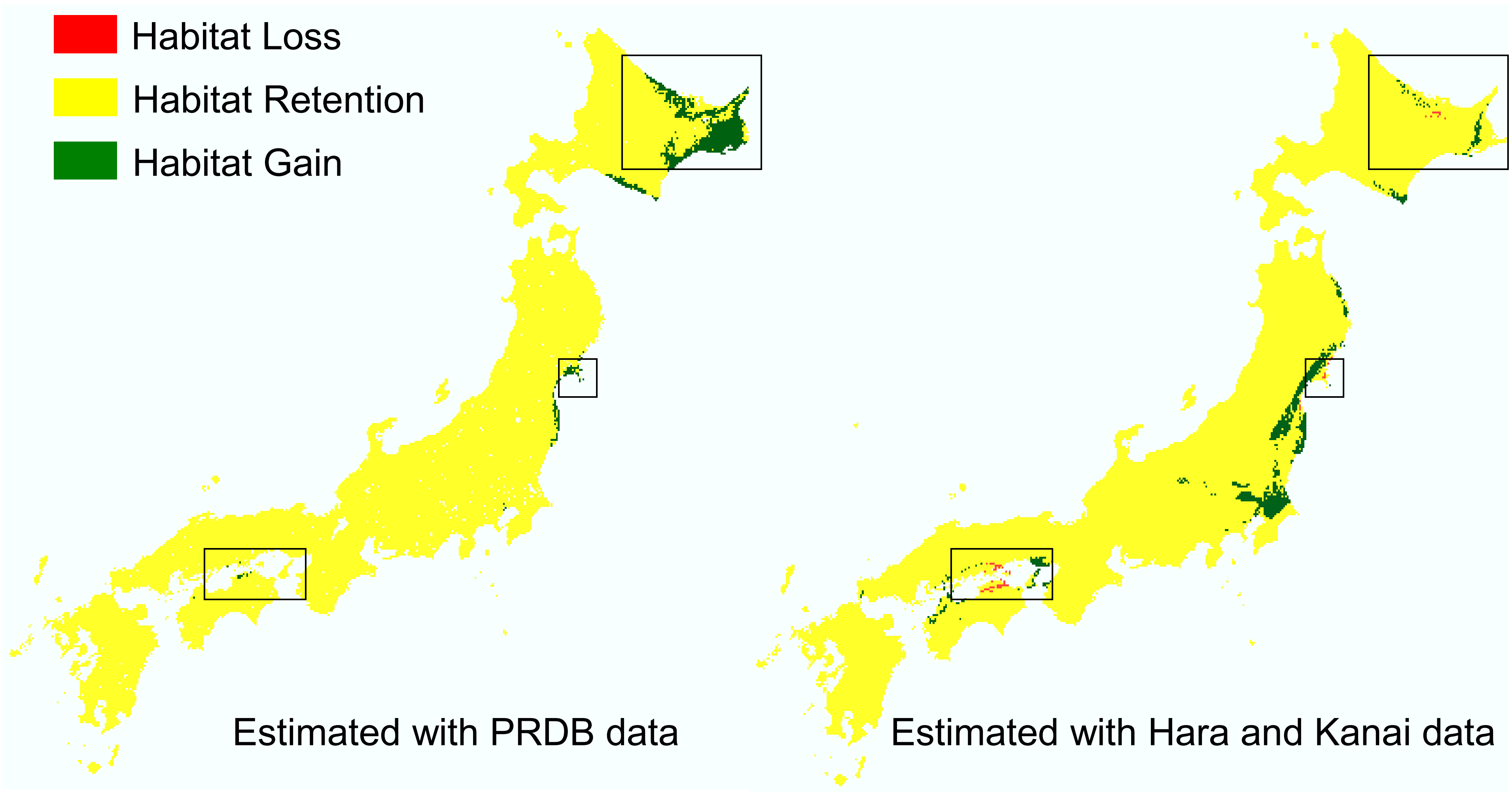
Range changes for *Kirengeshoma palmata*

Future probability – Current probability



Range expansion for *Salicornia europaea*

Future probability – Current probability



Warnings about *Salicornia europaea*

- Model validation suggests that results be viewed with skepticism
  - Possibly due to shortage of presence data
- Much of the range expansion is predicted away from the coast (or other waterway); this is highly unlikely
- Introduced in Shikoku
  - Models predicted the suitability of the introduction
  - What are the conservation implications
- Experimental study points to the importance of species interactions
  - Gedan and Bertness 2009’s warming experiment showed *Salicornia europaea* and *bigelovii* were outcompeted by *Spartina* due to soil drying

Summary of Species Distribution Predictions for a Warmer Climate

Rosa hirtula

- Predictions based on either dataset show range contractions

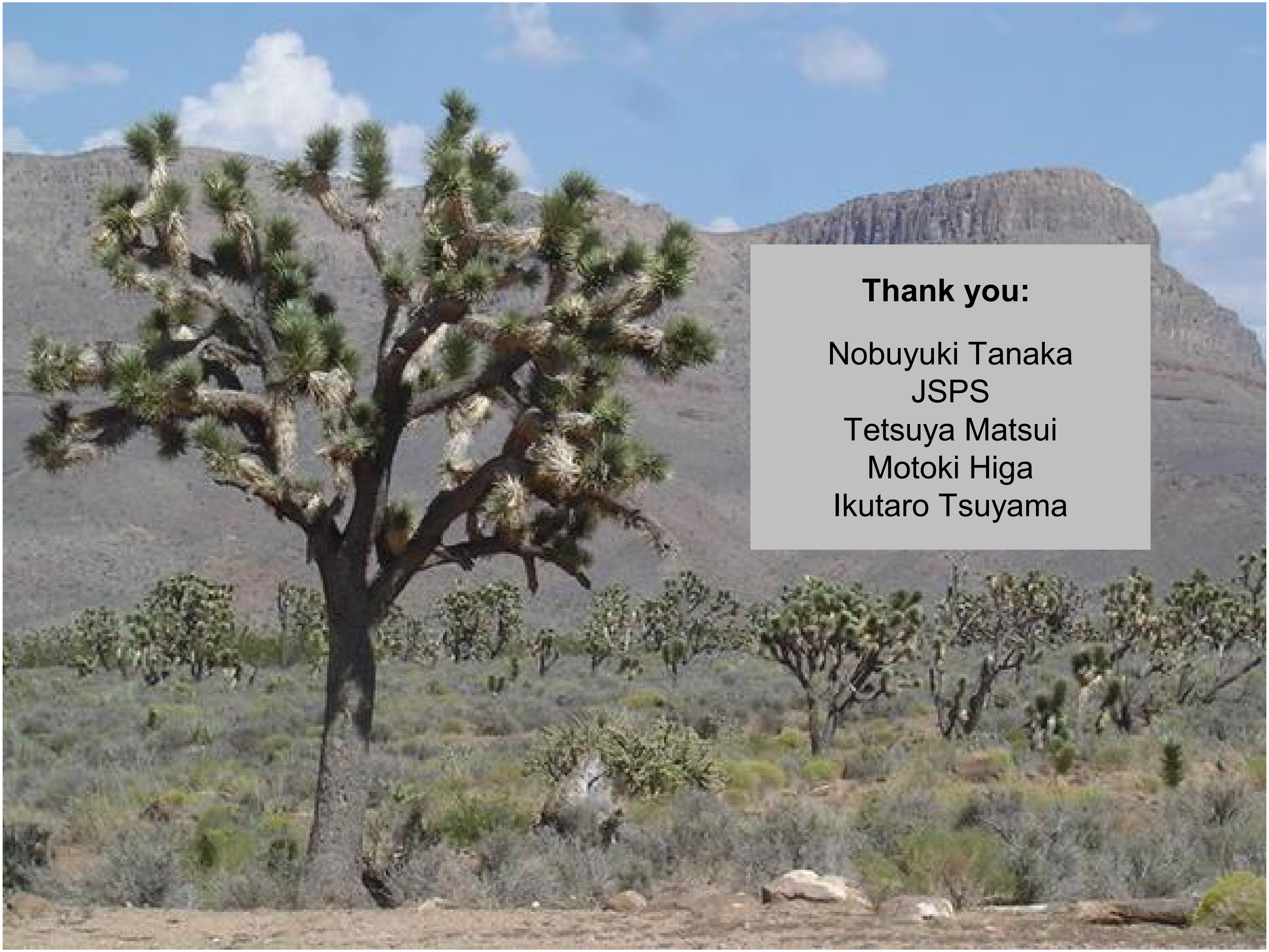
Kirengeshoma palmata

- Mostly range expansions with models estimated using PRDB data
- Roughly equal levels of expansion and contraction for models estimated with Hara and Kanai data

Salicornia europaea

- Predictions based on PRDB show mostly expansions
- Predictions based on Hara and Kanai data show retractions

Differences between datasets are magnified when future climate scenarios are used, suggesting the need for more data and more sensitivity analyses.



Thank you:

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