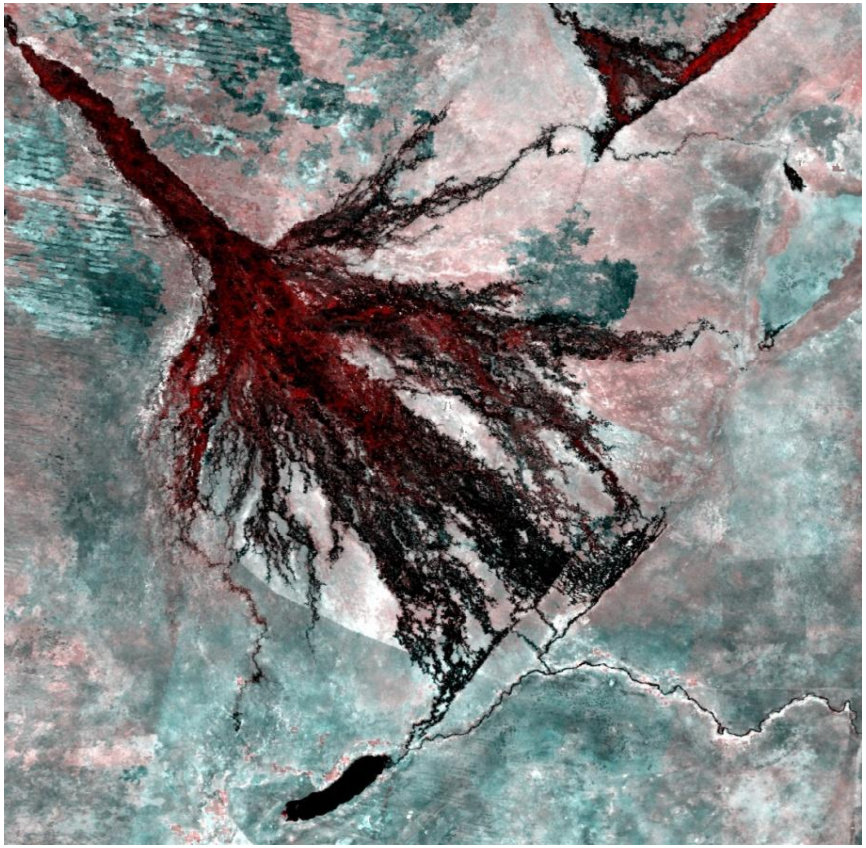
Species distribution models for investigating changes in floodplain vegetation in large flood-pulsed tropical wetlands



Mike Murray-Hudson
Okavango Research Institute, University of Botswana
Piotr Wolski
Climate Systems Analysis Group, University of Cape Town
Mark T Brown
Center for Wetlands, University of Florida
Tom Davidson
Dept Bioscience, Aarhus University

Acknowledgements

Funding for this work was provided by:

•University of Botswana Okavango Research Institute

•University of Botswana Office of Research and Development

•University of Florida NSF AMW3 IGERT Programme

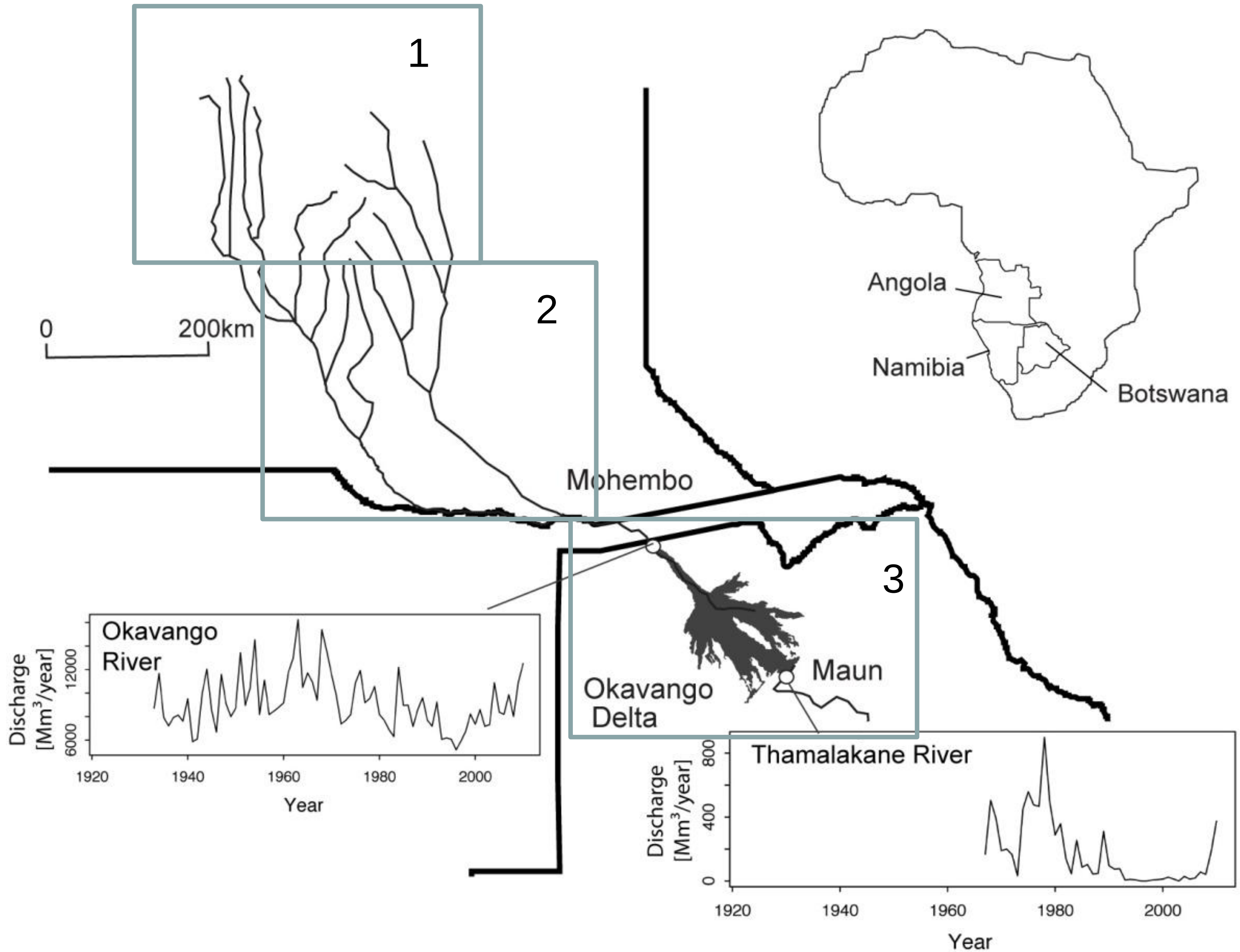
•BiOkavango Project (GEF funded)

Assistance with data collection was provided by:

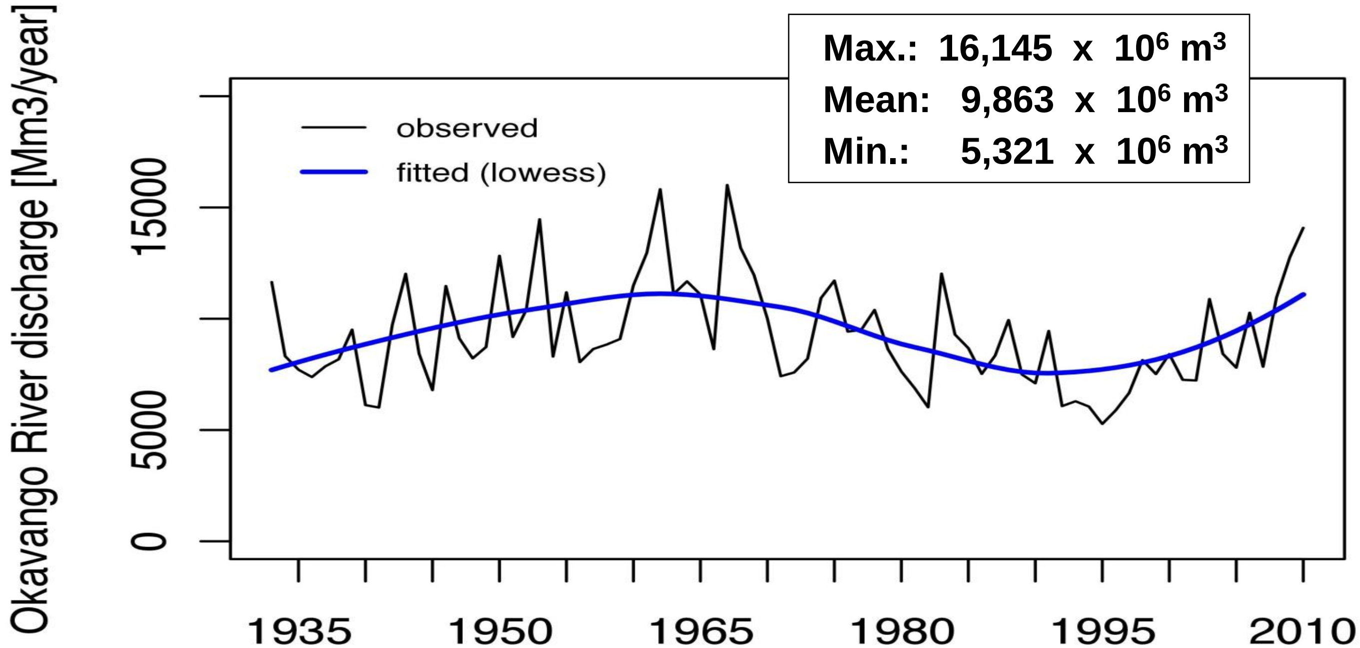
F. Murray-Hudson, W. K. Khaneguba, A. Karumendu, F. Bendsen,

M. Diare and C. Vanderpost.

Study Area: The Okavango Basin



VARIABLE ANNUAL INFLOWS AT MOHEMBO (1933 - 2010)



Problem statement

- In large, open wetland ecosystems, the distribution of floodplain macrophytes has up-trophic effects on whole-system ecology.
- Understanding how distribution may change in response to hydrological change is essential for sustainable management.
- In Botswana, the ability to evaluate such changes is critical for policy formulation and management decision support – the Okavango Delta is a Ramsar Site and potentially a World Heritage Site.

Methods

Sampling

•30 Sample sites, stratified by flooding frequency into 5 groups, 6 from each group.

•At each site, 1 or more transects orthogonal to floodplain long axis

•1m^2 plots at 20m intervals until >30m^2

•Modifed Braun-Blanquet cover scale, all species in each plot.

Analysis

Canonical Correspondence Analysis (CCA)

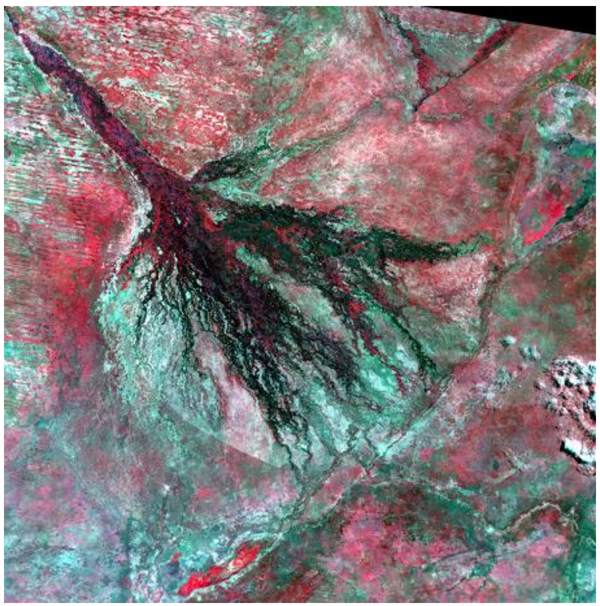
- •Constrains ordination of species-site matrix by regression on variable(s) in the environmental matrix.
- •Used to investigate species and site relationships with specific hydrological variables, and to develop GLMs for spatial model.

Non-metric multi-dimensional scaling (NMS)

- •No assumption of linear relationships among variables
- •Used to investigate species inter-relationships to aid in interpretation of cluster analysis

Methods continued – establishing hydroperiod parameters: Annual Flood Frequency

A sequence of Landsat TM & ETM imagery from period of max flood extent 1989-2006.
Resolution 28.5m



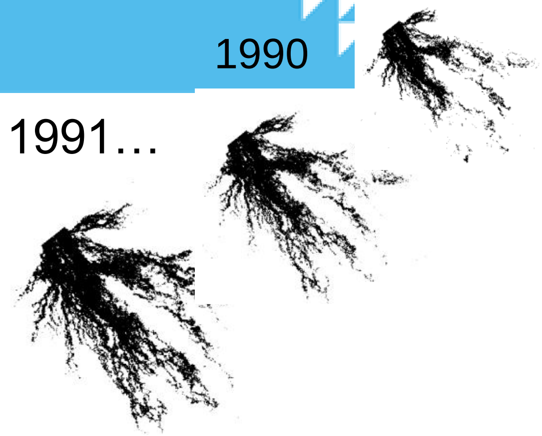
2 major gaps in the record: 2003, and 2004.
Filled with MODIS

1989

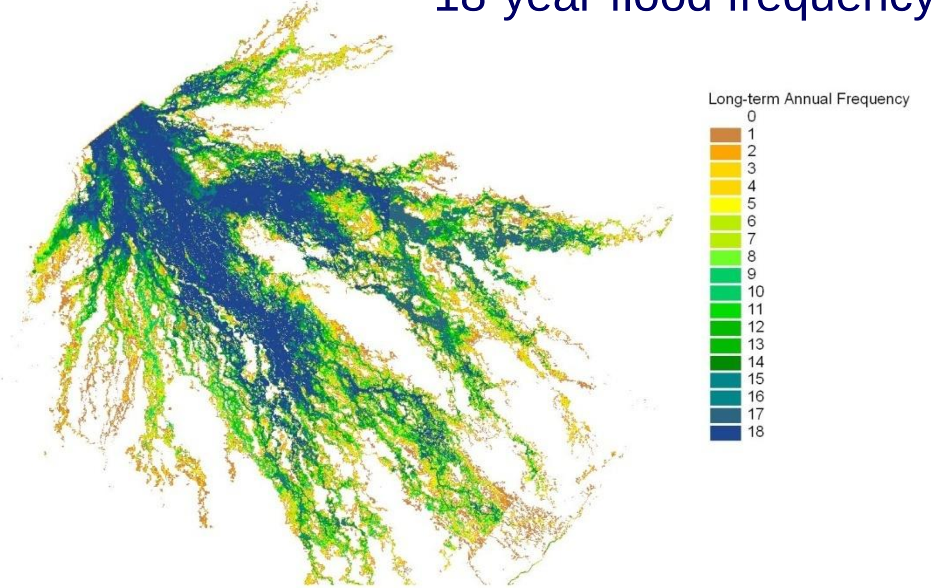
1990

1991…

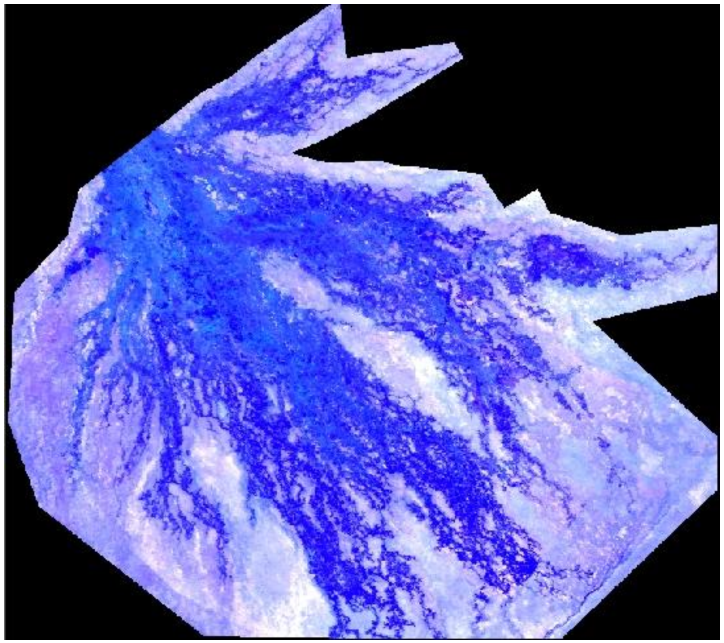
…2006

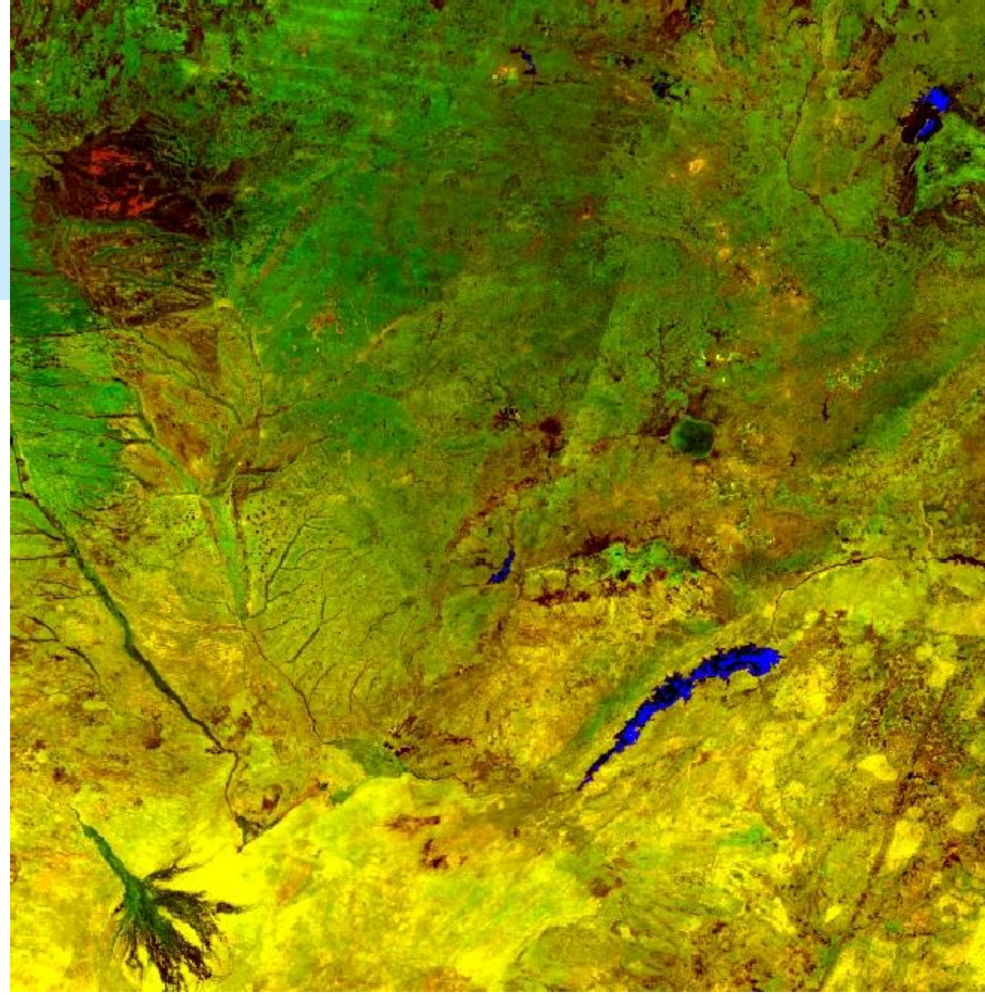


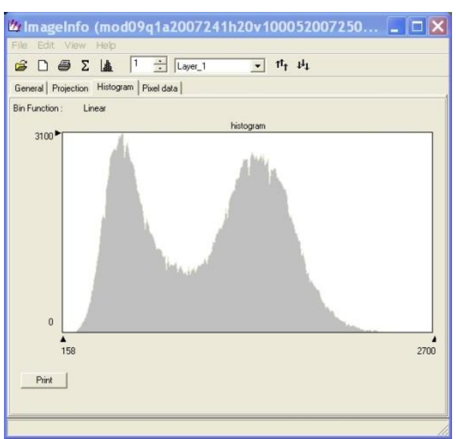
18-year flood frequency

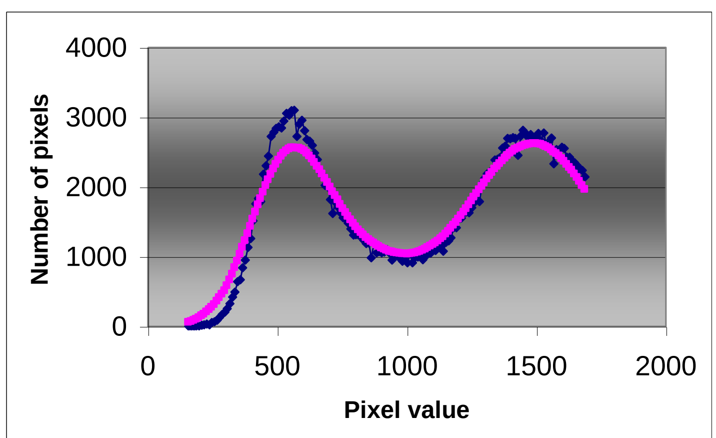


Monthly Duration:
MODIS 250m
Red & Infrared
SR 8-day composite



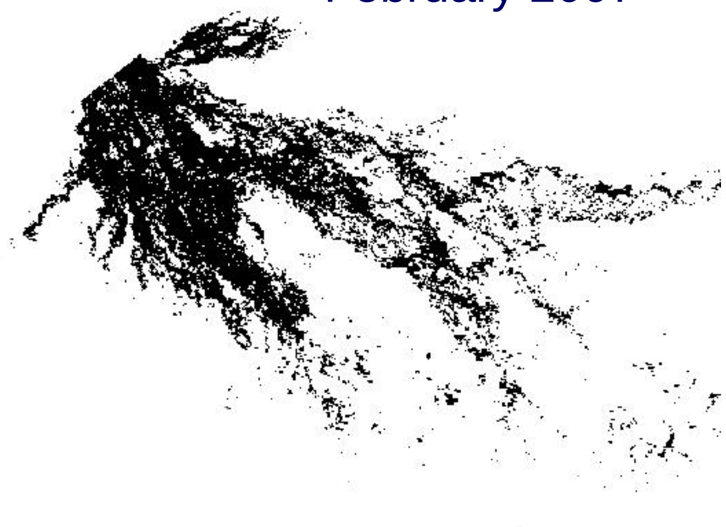




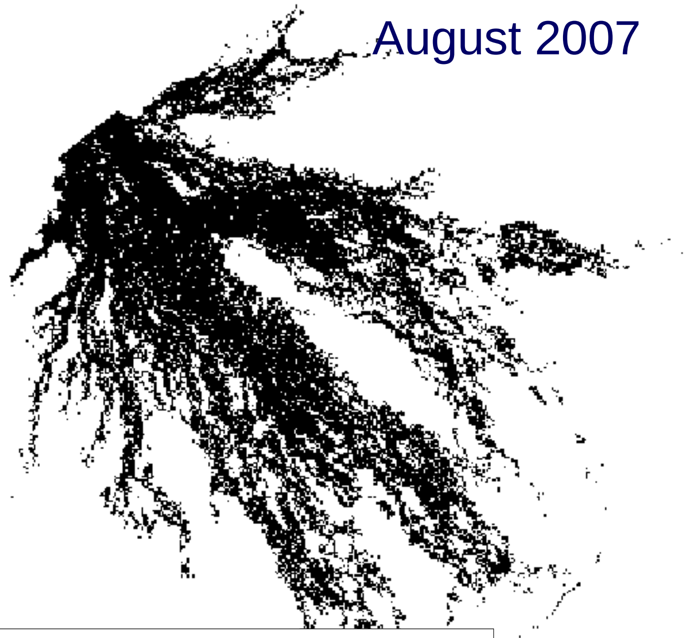


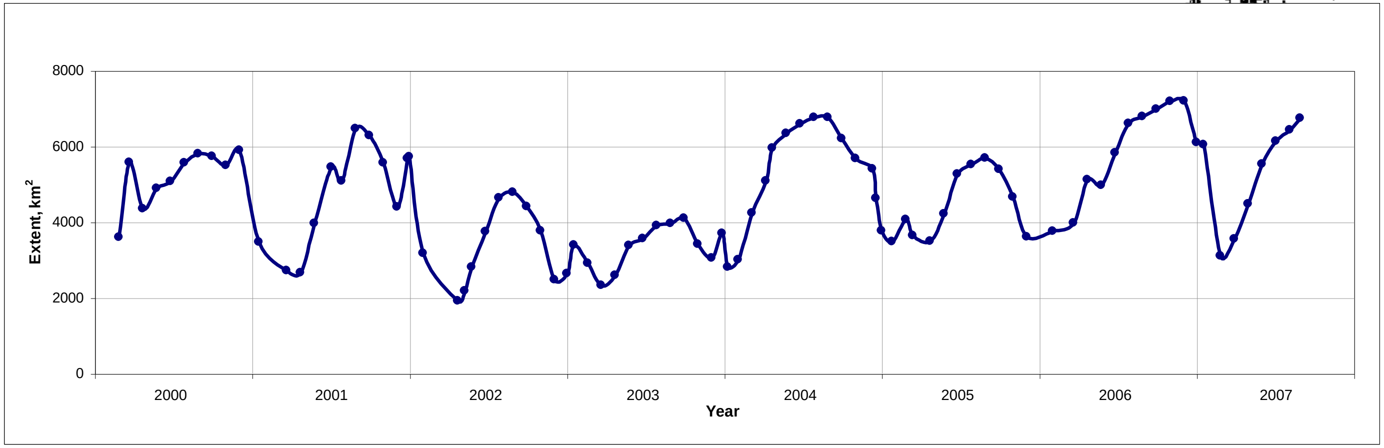
Monthly Flood Extent Maps for 2000-2007

February 2007



August 2007





Relationships between habitat and hydrology

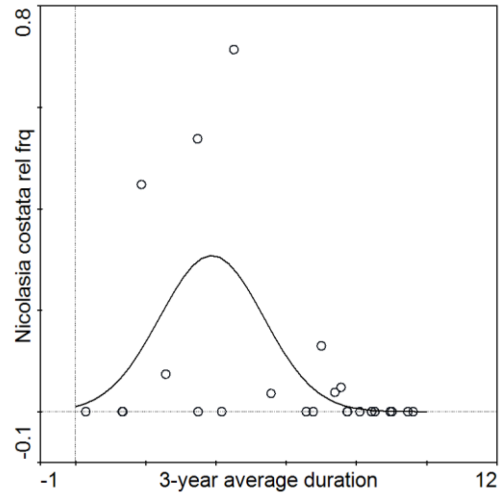
Correlations of hydrology with NMDS axis 1 of floodplain plant species (Pearson's r):

- Flood Frequency over 18 years: 0.934
- Flood Duration for preceding 3 years: 0.859
- Time since last flood: 0.767
- Mean depth of wet quadrats: 0.678

Okavango - flood frequency, duration and depth co-vary:
Coefficients (r)

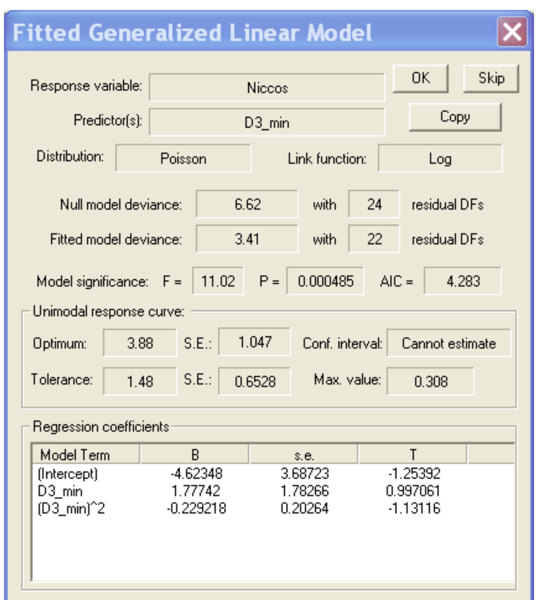
Variable	Average frequency	Average Duration	Years since last flood	Average depth
Average frequency	1			
Average Duration	0.909	1		
Years since last flood	-0.617	-0.706	1	
Average depth	0.727	0.609	-0.335	1

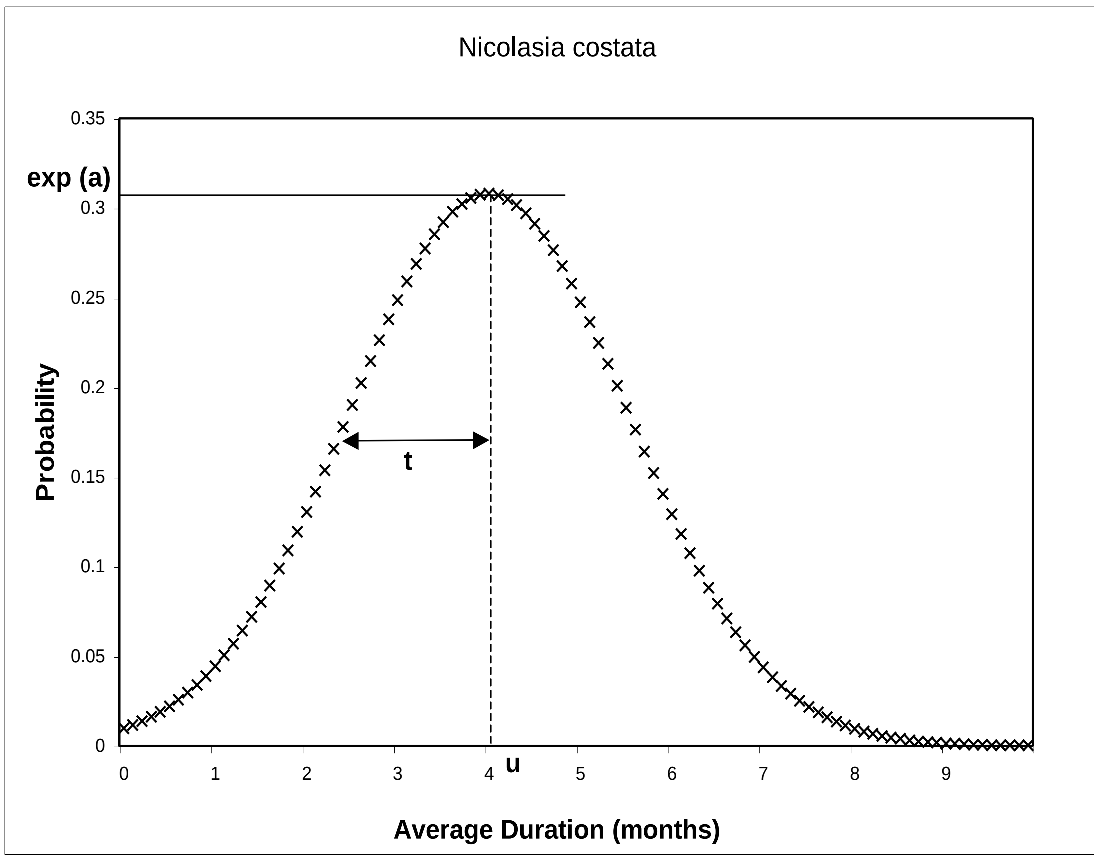
How do we link species distribution with hydrology? Generalized linear species distribution models.



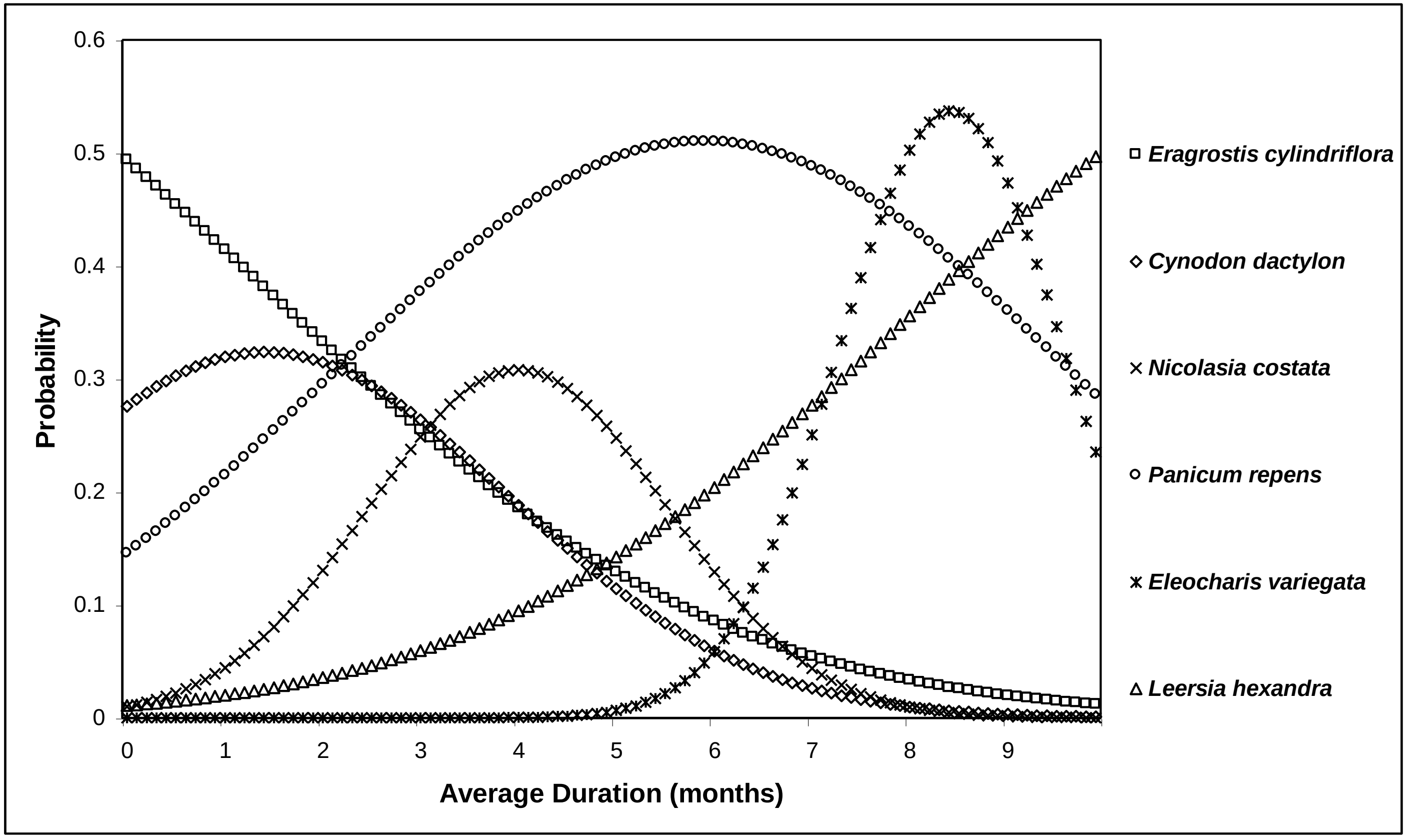
Gaussian logistic regression, with log link function and Poisson error distribution

$$\log\left(\frac{p(x)}{1-p(x)}\right) = b_0 + b_1 x + b_2 x^2 = a - \frac{(x-u)^2}{2t^2}, \text{ (ter Braak and Prentice 1988)},$$



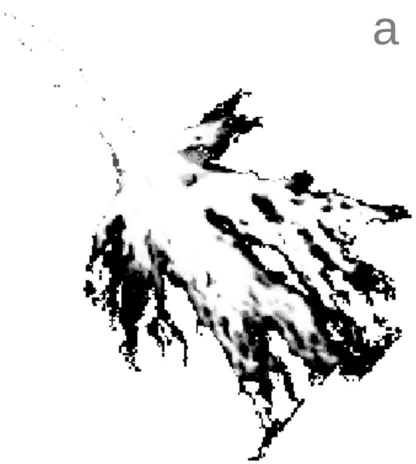


Examples of GLSDM curves

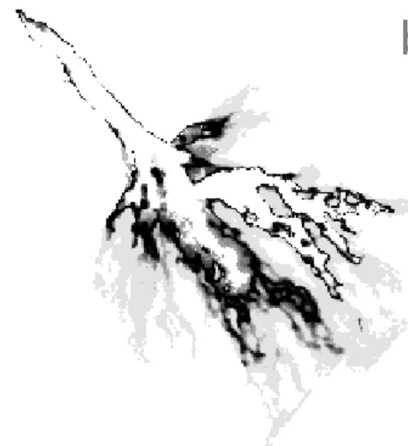


Modeled distribution curves for selected species representing low (*Eragrostis cylindriflora, Cynodon dactylon*), intermediate (*Nicolasia costata, Panicum repens*), and high (*Eleocharis variegata*, *Leersia hexandra*) flood duration communities

GLSDM outputs

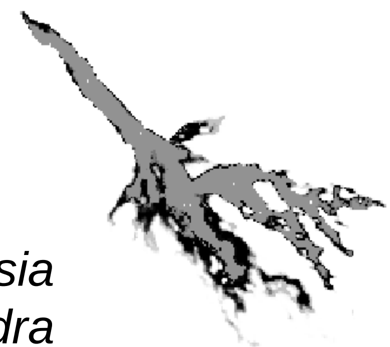


a *Eragrostis cylindriflora*



b *Cyperus sphaerospermus*

c *Eleocharis variegata*



d *Leersia hexandra*

Simulated 2007 distributions of species typical of DFG (a), SFG (b), SFS (c) and SAC (d). Darker shades indicate higher probability of occurrence.

Species distribution models performance

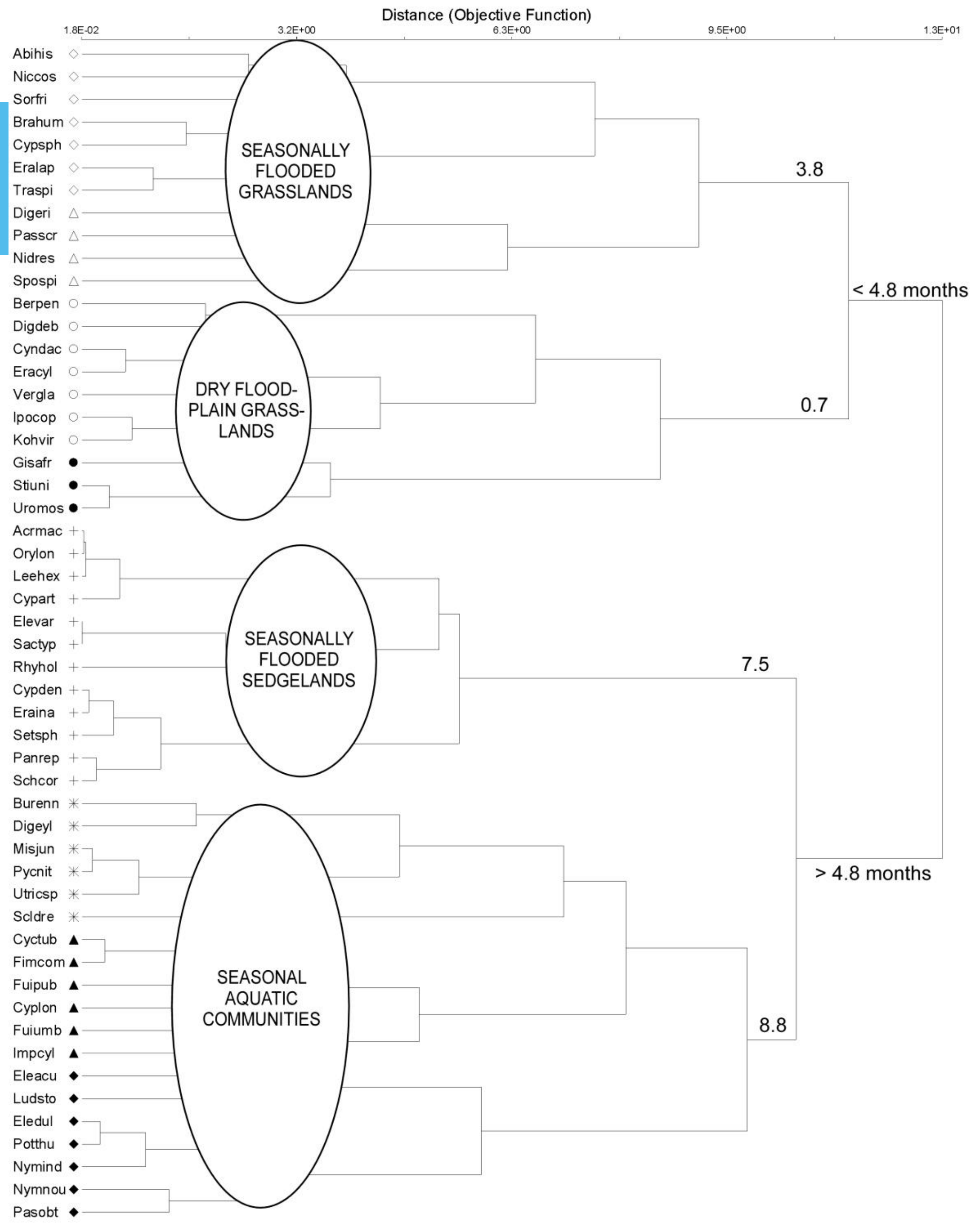
Site	MOC		TSW		KIR		KOA		XHA	
Species	Obs	Pred	Obs	Pred	Obs	Pred	Obs	Pred	Obs	Pred
Chloris virgata	0	0	0	0	0	0	0.53	0.01	0	0.01
Cynodon dactylon	0	0	0	0.13	0.22	0.24	0.73	0.22	1	0.22
Cyperus denudatus	0.09	0.26	0.5	0.23	0.61	0.09	0	0.03	0	0.03
Cyperus longus	0	0	0.82	0.08	0.11	0.04	0	0	0.48	0.01
Cyperus sphaerospermus	0	0	0.5	0.17	0.28	0	0	0	0.04	0
……..										
Leersia hexandra	0.73	0.43	0.09	0.04	0	0	0	0	0	0
……..										
Urochloa mosambicensis	0	0	0	0	0	0.13	0.27	0.53	0.3	0.53
Present	12	18	16	20	9	12	6	10	8	11
Correctly predicted presence	**100%**		**88%**		**89%**		**83%**		**75%**	
Correctly predicted absence	**60%**		**54%**		**79%**		**77%**		**76%**	

Floodplain Classes

Flood Duration Optima

Dendrogram of species assemblages based on species occurring in more than 5 sites (n=53).

Mean duration optima (months) characterize 4 distinct assemblages.

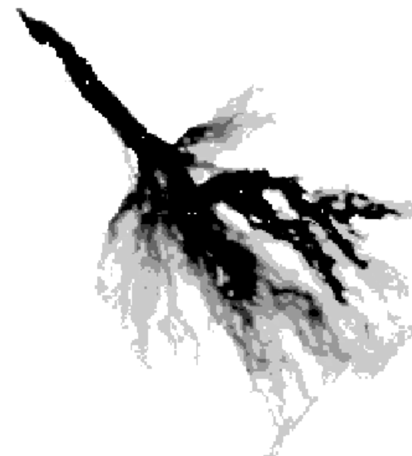



Dry
Wet

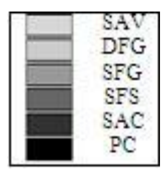
Simulated 2050 Floodplain Community Distributions under different Global Circulation Models of climate change

Reference Situation

GFDL (USA)



Key



CCCma GCM2

HadCM3

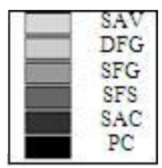
UNIVERSITY OF BOTSWANA

Simulated 2025 Floodplain Community Distributions under Basin Development Scenarios

Reference Situation

All potential dams constructed

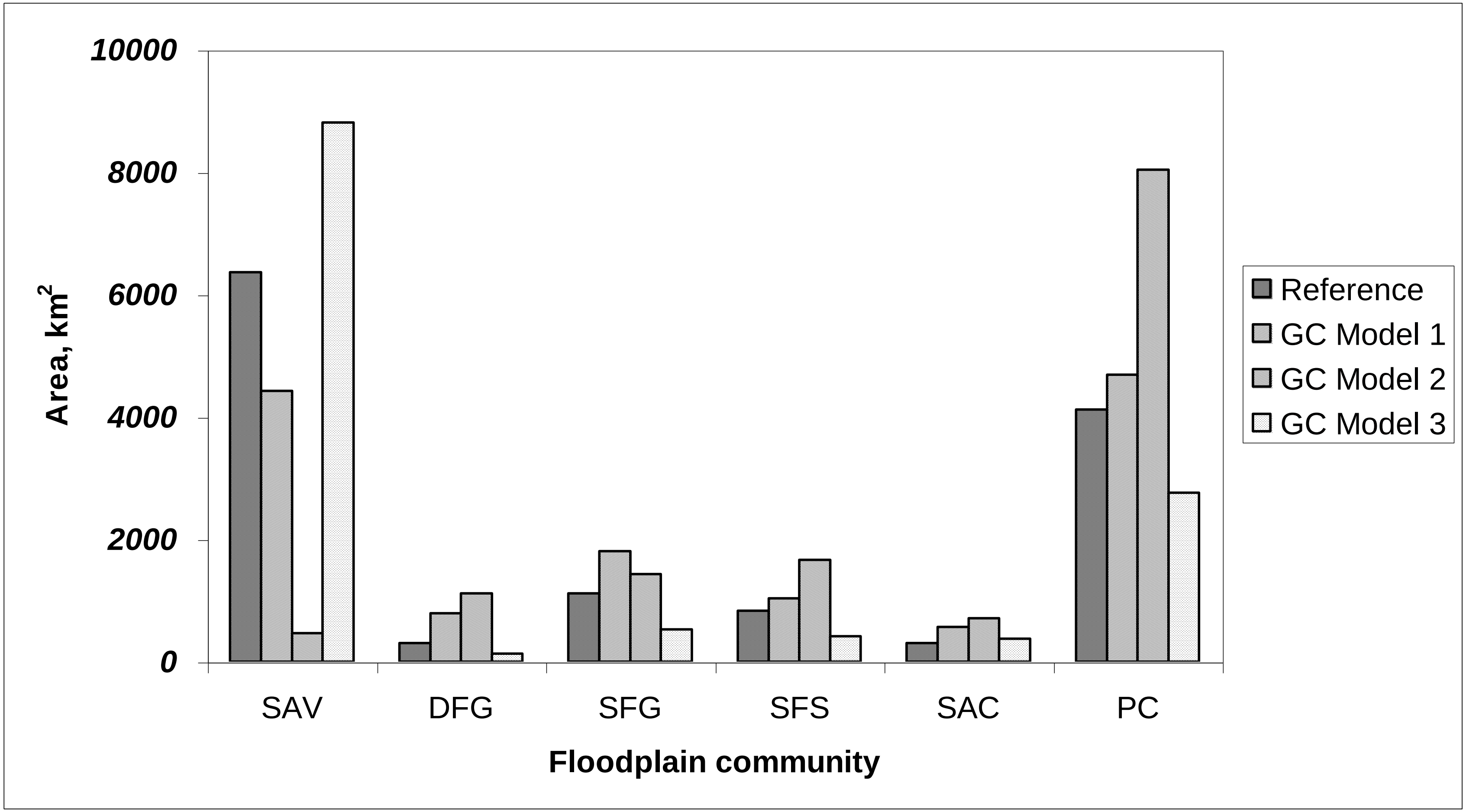
Key



Maximum development of potential irrigation

Combination of all dams, maximum irrigation and other withdrawals

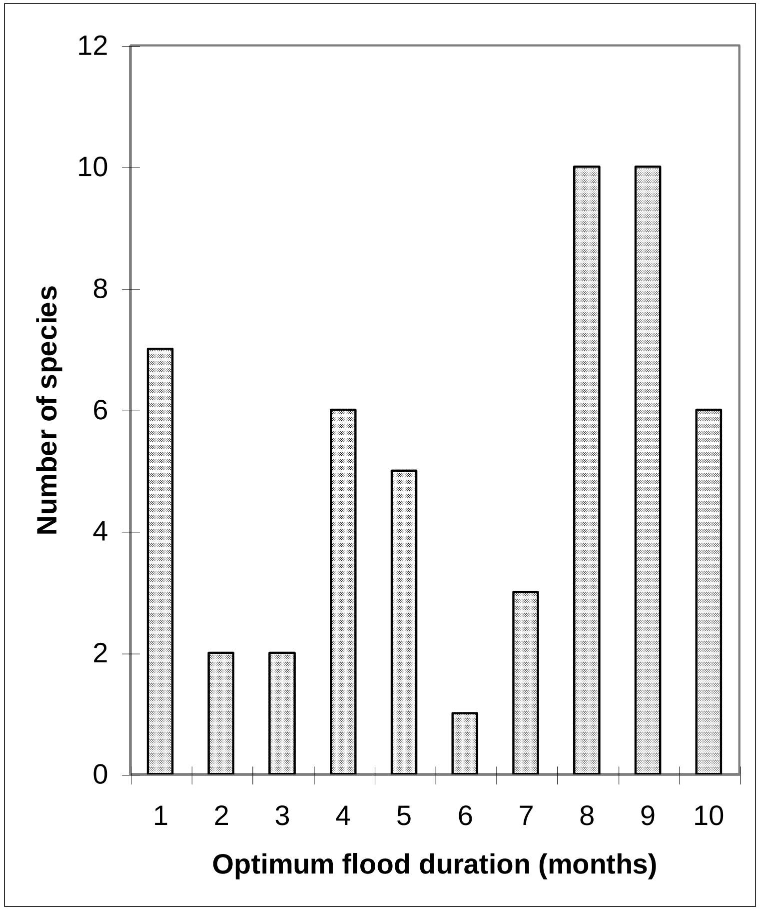
Changes in extent of floodplain communities from simulations of different climate change scenarios for 2020-2050



GC Model 1 – GFDL, GC Model 2 – CCCma GCM2; GC Model 3 – HadCM3.


Thank you

Some generalisations about flooding tolerances



- Based on Gaussian logistic regression modelling from CCA against mean monthly duration

- Most species are either flood intolerant, tolerant of a few months inundation, or primarily aquatic.

- Few species fall in the 6-7 month optima range