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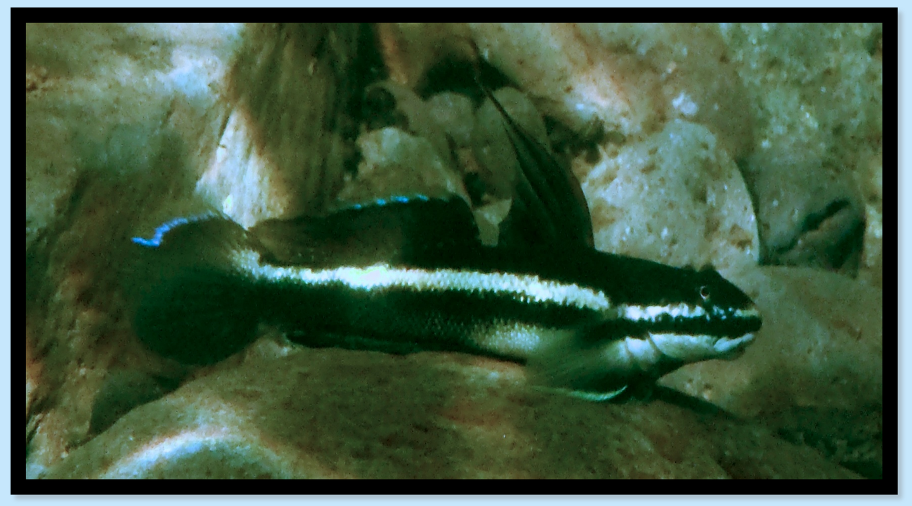

Modeling population structure and adaptation in a Hawaiian stream goby: *Sicyopterus stimpsoni*

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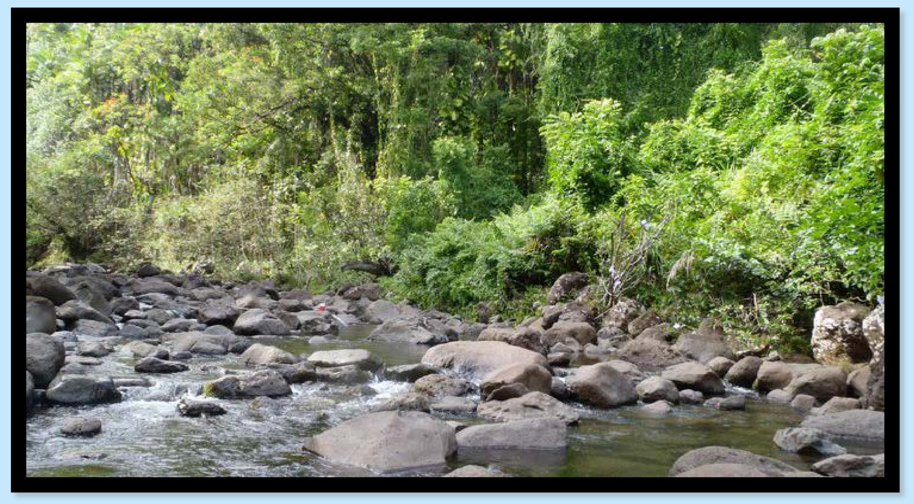

Introduction

Climate change is an environmental problem that is expected to drastically affect ecosystems all over the world. In the Hawaiian Islands, the total amount of rainfall is expected to decrease, but the variability and severity of downpours is expected to increase[1]. These changes could cause variation in stream discharge and threaten the endemic amphidromous fishes that live there[2]. Hawaiian gobies face two distinct challenges. To get beyond the non-climbing predators in the lower portions of the streams, gobies must use their ventral suckers to climb waterfalls, sometimes thousands of body lengths in height[3]. Drought conditions and an increase in variability could potentially impact the morphological structure of goby populations, with the effects differing across the archipelago. Individuals with a streamline body shape and large suckers are favored by selection for waterfall climbing performance in Hawai'i, where waterfalls are tall and close to shore; whereas individuals with a taller, wider body are favored by selection for predator evasion on Kaua'i, where predation is high due to long flat streams with waterfalls far inland[3].

To study the impact of these projected changes in climate, we constructed spatially-explicit individual-based population models for a waterfall climbing goby, *Sicyopterus stimpsoni*. We simulated four levels of drought conditions and three levels of increased flow variability for three islands with different topographies (Hawai'i, O'ahu and Kaua'i). Our results showed that population density increased with intermediate drought conditions and decreased with increases in flow variability. Island topography also influenced the magnitude of change in precipitation and morphological distribution. The gobies ability to adjust to changing stream conditions due to future climate change will depend primarily on the interaction between the timing and variability of precipitation on each individual island.

Predictions

Abundance

- Abundance will decrease with increasing island age
- Abundance will decrease with increasing drought conditions
- Abundance will decrease with increasing flow variability

Demographic Distribution

- Juveniles will decrease with increasing island age
- Juveniles will decrease with increasing drought conditions
- Juveniles will decrease with increasing flow variability

Morphological Distribution

- Climbers will decrease with increasing island age
- Climbers will decrease with increasing drought conditions
- Climbers will decrease with increasing flow variability

Methods / Results

- Used an individually based and spatially explicit population model (NetLogo) to track population size, demographic and morphological structure on three islands: Hawai'i, O'ahu, and Kaua'i (Figure 2).
- Drought conditions were defined as normal, moderate, severe, and extreme.
- Flow amplitude was increased at low, medium, and high levels.
- The variables were manipulated in order to analyze their effects on abundance, demographic distribution, and morphological distribution.
- Five replicates were used for each run and population structure was analyzed for a simulated ten-year period.
- A sensitivity analysis was done using ANOVA to determine the significance of each variable (Table 1).

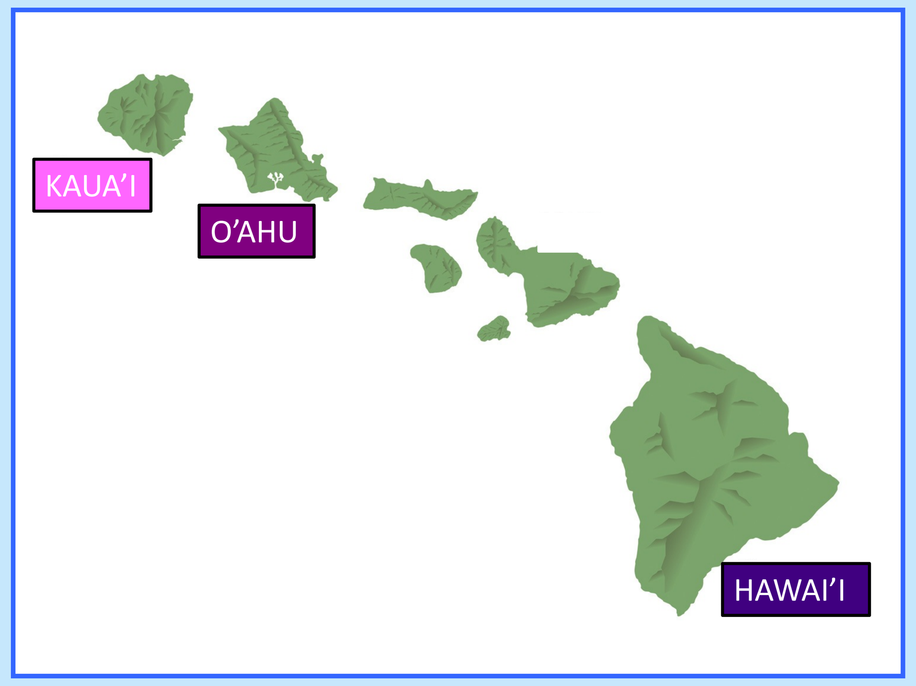

Figure 1: Hawaiian Islands Archipelago

Table 1. Model Sensitivity Analysis using ANOVA

Measure	Source	df	F	p	Significance
Abundance	Island (I)	2	341.7	< 0.0001	***
	Drought (D)	3	444.7	< 0.0001	***
	Flow variability (F)	2	25.6	< 0.0001	***
	I X D	6	60.1	< 0.0001	***
	I X F	4	3.1	0.0183	*
	D X F	6	4.6	0.0003	**
	I X F X D	12	1.7	0.0818	
Demographic Distribution (average stage)	Island (I)	2	10.2	< 0.0001	***
	Drought (D)	3	13.5	< 0.0001	***
	Flow variability (F)	2	1.6	0.2088	
	I X D	6	10.3	< 0.0001	***
	I X F	4	1.2	0.2936	
	D X F	6	0.8	0.5448	
	I X F X D	12	1.1	0.3473	
Morphological Distribution (average morphotype)	Island (I)	2	20.0	< 0.0001	***
	Drought (D)	3	12.3	< 0.0001	***
	Flow variability (F)	2	2.4	0.0906	
	I X D	6	1.9	0.0870	
	I X F	4	0.5	0.7086	
	D X F	6	0.3	0.9559	
	I X F X D	12	1.2	0.2697	

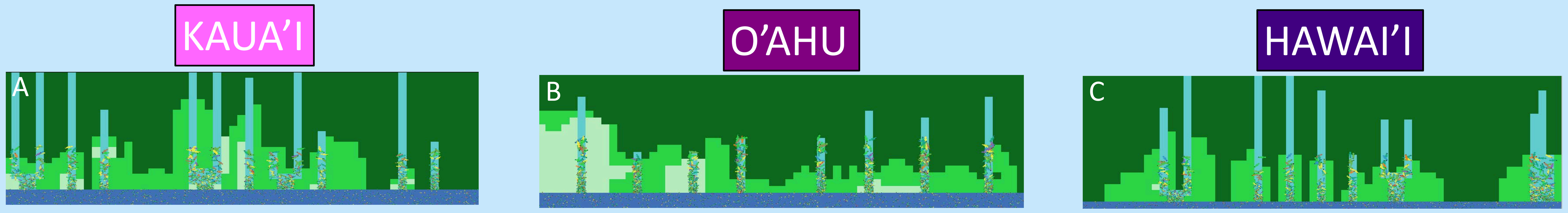

Figure 2: Model interface display with dark blue representing the ocean, light blue representing streams, and different shades of green representing land use for each of the islands: (A) Kaua'i, (B) O'ahu, (C) Hawai'i. Fish color represents body shape (morphotype) from red (good climbers) to purple (predator evaders).

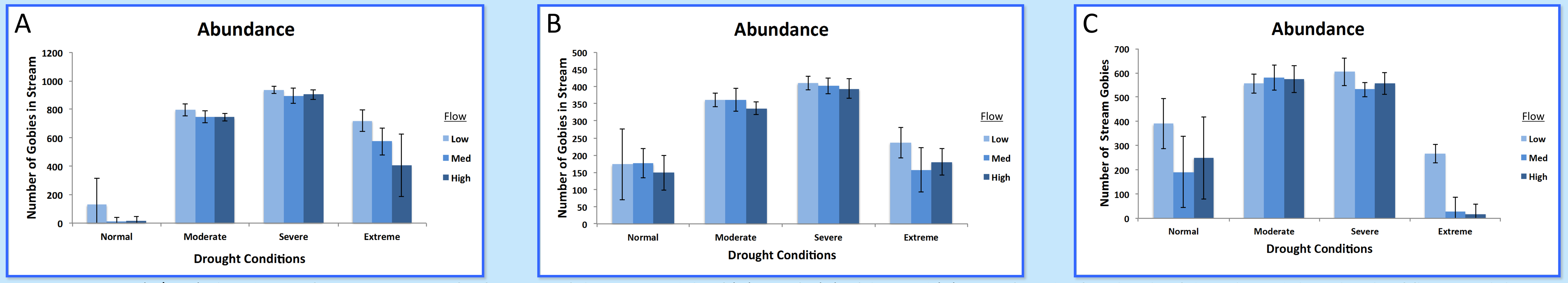

Figure 3: Mean (+/- SD) abundance after a 10 year run for five runs of the IBM models of (A) Kaua'i, (B) O'ahu, and (C) Hawai'i under four levels of drought and three levels of flow variability.

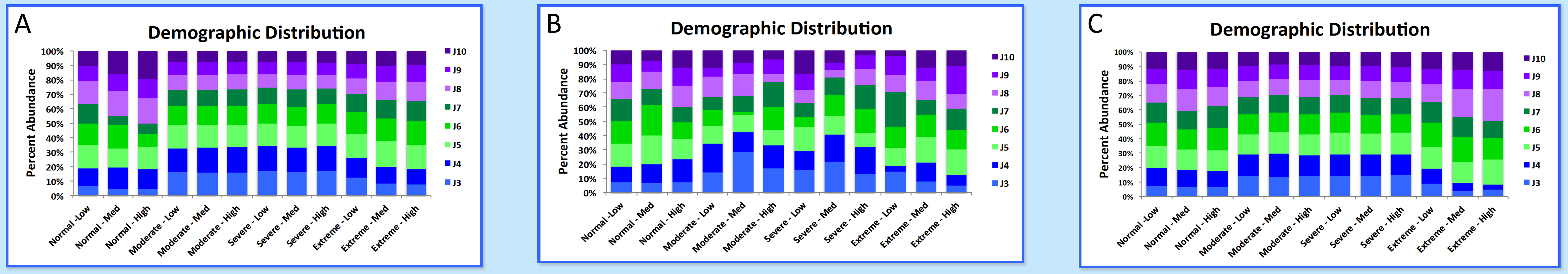

Figure 4: Colors represent the distribution of body size (cm SL) from J3 (3cm) to J10 (10cm). Demographic distribution after a 10 year run for five runs of the IBM model of (A) Kaua'i, (B) O'ahu, and (C) Hawai'i under four levels of drought and three levels of flow.

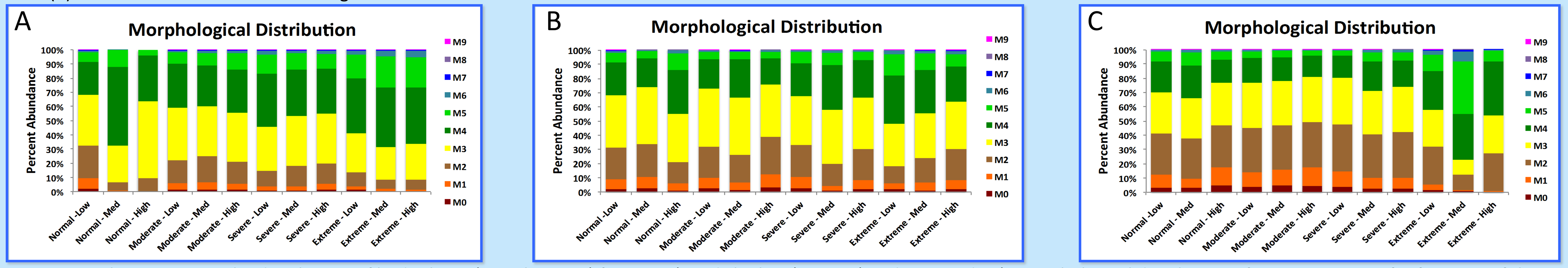

Figure 5: Colors represent the distribution of body shape (morphotypes) from M0 (good climbers) to M9 (predator evaders). Morphological distribution after a 10 year run for five runs of the IBM model of (A) Kaua'i, (B) O'ahu, and (C) Hawai'i under four levels of drought and three levels of flow.

Conclusions

Our results show that abundance was affected by all three variables: drought conditions, flow variability, and island age. Moderate and severe drought conditions increased abundance on every island with extreme drought causing a decrease in abundance. As we predicted, increased variability caused a decrease in abundance. While island age had a significant effect on abundance, there was not a linear correlation between abundance and age of the islands. For both demographic and morphological distributions, island age and drought conditions had significant effects, while flow variability had an insignificant influence. Extreme drought conditions on each island significantly decreased demographic and morphological distribution.

Overall, our conclusions show that predicted climate change would not have negative effects on goby populations across the three islands, except when those variables reached extreme values.

References

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