



# GEOGRAPHIC VARIATION AMONG MONARCH BUTTERFLY POPULATIONS: MIGRATORY BEHAVIOR AND THE EVOLUTION OF WING MORPHOLOGY



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## Abstract

Three populations of monarch butterflies in North America display different migration strategies (long distance, shorter distance and nonmigratory). We obtained wild and lab reared monarchs from each population and used digital image analysis to compare forewing morphology (size and shape) across populations. We found significant variation among populations in both wing size and shape. Monarchs from eastern N. America (that migrate the farthest distance) had the largest and most angular forewings. Western N. American monarchs (that migrate a shorter distance) had large but less narrow forewings. Monarchs from South Florida (nonmigratory) had the smallest wings but were similar in shape to eastern monarchs. Differences were similar among most groups of wild and captive reared monarchs, and we observed significant within family variation in each sample tested. These results suggest that populations within N. America have diverged in wing characteristics, and that long distance migration might be important to the evolution of monarch butterfly wing shape and size.

## Background

- Among birds, long distance migration is associated with larger, narrower wings relative to non-migratory



- Long, narrow wing shapes in birds are associated with increased aerodynamic efficiency while large wings increase the surface area for soaring flight, which reduces energy expenditure

- Monarch butterflies in N. America are divided into 3 populations that differ in their migration strategies and therefore may show similar trends in wing morphology

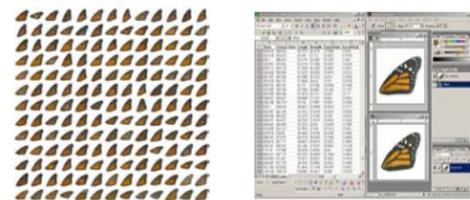
## Questions

We compared forewing shapes and sizes across monarch populations to examine geographic variation in wing morphology relative to migratory strategy. We asked:

- Does the size or shape of forewings differ among North American monarch butterfly populations?
- Do monarchs from long distance migratory populations have larger or more angular forewings than short distance migrants and resident monarchs?
- Does forewing size and shape vary consistently between males and females?
- Is variation within populations significantly related to family level effects (i.e., similarity among relatives)?

## Methods

- Wild monarchs were collected in S. Florida, eastern N. America (MN, WI, GA, MO) and western N. America (CA, UT, NV, OR, WA, CO) during the summers of 1996, 1997, and 2003
- Lab-raised monarchs from wild-collected females were reared at low density in plastic-screened containers during the summers of 1996, 1997, and 2003
- Right forewings from over 1500 individuals were scanned using an HP flatbed scanner



- Principal components analysis used to create
  - one shape variable from aspect ratio and area/perimeter (PCA-shape)



- one size variable from length, width and area (PCA-size)



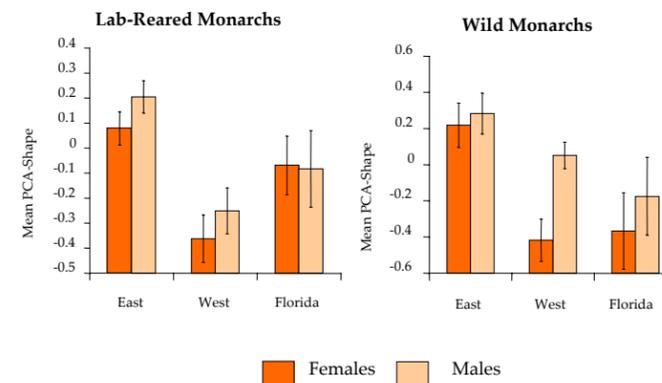
## Sample Sizes

Group	Rearing	Year	East	Florida	West
1	Wild	All years	100	43	260
2	Lab	1996	166	91	-
3	Lab	1997	119	-	113
4	Lab	2003	158	32	53
5	Incubator	2003	140	52	56
<b>Total</b>			<b>683</b>	<b>218</b>	<b>482</b>

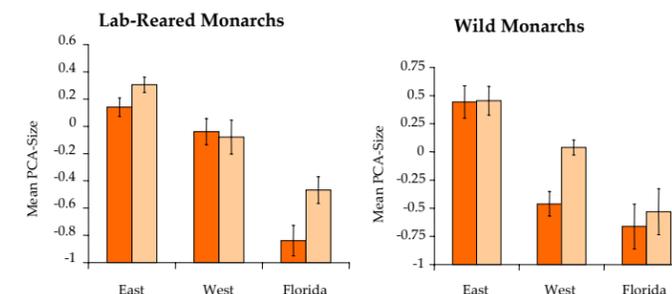
Total sample size = **1383 forewings**

## Results

### Shape means for population and sex



### Size means for population and sex



## Conclusions

- Differences in wing morphology among monarch butterfly populations may reflect a combination of different migratory strategies, sexual selection, and genetic drift or gene flow
- Forewings from longest distance migrants (eastern) were largest and most angular, and this may be associated with migratory ability
- Resident S. Florida monarchs had smallest forewings, possibly owing to relaxed selection, drift, or inbreeding
- Western monarchs had least angular forewings
- Differences were similar across wild vs. lab reared monarchs, and among experimental groups from different years
- Significant family level effects indicate variability within populations and potential genetic basis for observed differences
- Further experimental work should address associations between flight parameters, mating success, and wing morphology within populations
- Additional comparative work will examine variation in wing color patterns within and among populations, and will include Hawaiian monarchs as a second resident population

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