

# Analysis of cowbird social networks with graph theory metrics.

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## ABSTRACT

Animal social behavior research has recently moved from focusing on a dyad [2] to consider how other members of a social group are influenced by those dyadic interactions in a complex network [5]. With this shift in emphasis, analytical tools and metrics from graph theory have begun to appear in the animal behavior literature. Croft et al. analyzed social networks in guppies. Although current studies [1, 4] take a first step towards developing parameters and hypothesis tests, neither considers how those parameters might be influenced by changes in community features. In this study, I explore the effects of changes in community features over BC values and ask whether the presence of juvenile females influences the social dynamics of cowbird (*Molothrus ater*) social networks.

## Keywords

Brown-headed cowbirds, social network, Betweenness centrality, average degree, weight distribution.

## 1. INTRODUCTION

Graph theory promises to be particularly helpful to the study of animal social behavior in describing three main aspects of network structure: individual characterization, cohesiveness, and modularity. **Individual characterization** describes the role of individuals within a network/population. Some individuals might serve as gate-keepers. **Cohesiveness** in social networks is the property of the graph to remain closely connected. **Modularity** refers to the subdivision of a network or social group into smaller sub-communities.

The presence or absence of individuals influences the dynamics of social of complex social groups. Female cowbirds in flocks with adult males spend more time interacting with males than they do when in flocks with only juvenile males [6]. Previous studies suggest that juvenile females are more likely than adult females to be “male-interactive”, participating in dyadic encounters with males [6]. Adult females, on the other hand, exhibit a more restricted pattern of interactions, interacting mainly with other females. I focus on three hypotheses about the effect of juvenile females

1. Cohesiveness: I expect adult females to form

tighter-knit bonds with other females in the groups than do juvenile females which are more likely to interact with males [6]. Groups containing juvenile females and males should exhibit lower  $BC_{network}$  values.

2. Individual characterization: I hypothesize that the presence of juvenile females in a mixed age group will decrease the tendency of adult females to serve as gatekeepers. To test this hypothesis, I compare estimates of  $BC_{individual}$  for adult females housed with and without juvenile females.

3. Modularity: Finally, even when adult females do not interact much with males, a temporary mixing with less-discriminating juvenile females [3] might have a lasting effect on the behavior of adult females. I test whether the social network shows a long term effect after mixing with juvenile females, by comparing  $BC_{individual}$  before and after mixing has occurred

Furthermore, the experimental groups used in the cowbird study differed in a number of important ways that were behaviorally interesting, important and highly common in the animal behavior field. I focused on three potentially important factors: number of gatekeepers, total number of dyadic interactions recorded and group size. I explored the response of BC values to changes in the above community features using computer simulations.

## 2. RESULTS

### 2.1 Juvenile female influence

Hypothesis 1: Adult aviaries exhibited a higher average  $BC_{network}$  (mean = 0.06, S.E. = 0.031) than did juvenile aviaries (mean = 0.01, S.E. = 0.005) in the first round of the experiment.

Hypothesis 2: Individual BC values for adult females were somewhat higher before the introduction of juvenile females than during the mixing period ( $t = 1.6$ ,  $df = 21$ ,  $p < 0.06$ ).

Hypothesis 3: West & King’s data suggest that there is not a long-term effect from the introduction of juvenile females to adult female’s aviaries. Individual BC values for adult females at the beginning of the experiment were not significantly different ( $t = 1.0$ ,  $df = 21$ ,  $p > 0.15$ ) from individual BC values for the same individuals after the removal of juvenile females.

### 2.2 Computer simulations results

#### 2.2.1 Group size

BC estimates were strongly influenced by the number of individuals present in a network (Fig. 1). In smaller communities, individuals have more opportunity to interact with each of the other individuals, such that no individual is truly central to the community.

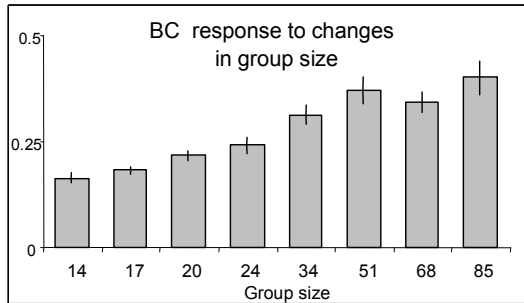


Figure 1. Response of BC estimates to variance in group. Ratio was kept constant at 2.4 female/male.

### 2.2.2 Number of gatekeepers

The number of gatekeepers is inversely associated with BC estimates (Figure 2). In a community where all individuals act as “gatekeepers” by having a high interaction across sub-groups, these individuals lose their importance in terms of information flow.

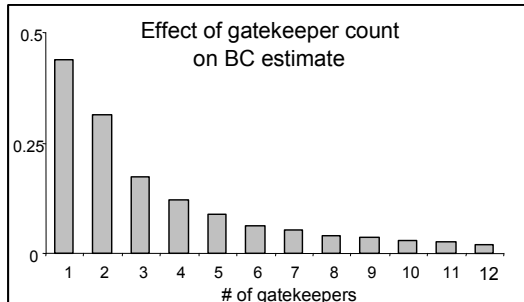


Figure 2. Response of BC estimates to the number of gatekeepers.

### 2.2.3 Sample size (data collected)

The amount of data collected also has a strong effect on BC estimates. The number of interactions recorded has an inverse relationship with the BC estimate (Fig. 6). As the number of interactions within a community increases, the probability that any pair of individuals have an interaction increases as well.

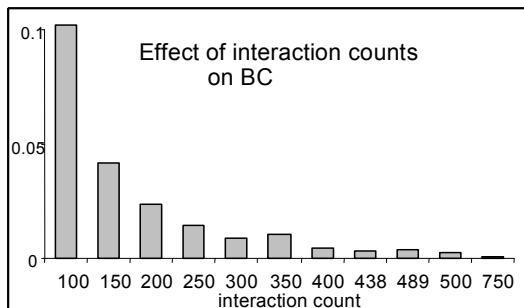


Figure 3. Response of BC networks estimate to number of interactions recorded.

## 3. CONCLUSIONS

Even when there were differences in the number of near neighbor points collected for adults and juvenile females as well as for BC values, there is still no certainty about how significant these results are.

Results suggest that BC is strongly influenced by data collection details as well as community features. In fact, many of the observed differences can be explained by subtle differences in experimental design and data collection.

These preliminary results motivate the development of a randomization framework to test hypotheses comparing different communities, as well as further exploration of the response of other parameters to the changes in data composition observed here.

## 4. ACKNOWLEDGMENTS

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