Oecologia
Montana 2003
12, 7 - 11

Defining Yellow-bellied Marmot social groups using association indices

D.D. NANAYAKKARA and D.T. BLUMSTEIN
Department of Ecology and Evolutionary Biology, 621 Charles E. Young Drive South, University of California, Los Angeles, CA 90095-1606, e-mail: marmots@ucla.edu

Abstract. We evaluated the utility of using association indices to define Yellow-bellied Marmot (*Marmota flaviventris*) social groups. We analyzed locational data collected by trapping and regular observations using the program SOCPROG 2.2 (Whitehead 2004); a program traditionally used to study marine mammal associations from observational data. We first focused on simple groups (i.e., those with only a single adult female) to explore various analysis options and then applied them to interpret association patterns in more complex social groups. We suggest that social groups can be defined as groups containing those individuals with a = 0.5 association index. Given our sampling protocols, sufficient data were obtained only when we used the year as the unit of analysis. When applied to more complex social groupings, this criterion meshed with observers' less quantitative estimation of group memberships. In conclusion, calculating association indices using SOCPROG is a novel way to describe marmot association patterns and to define social groups quantitatively.

Key words: social group, association indices

Introduction

The level of association between individuals varies. For example, individuals may associate randomly, showing no preference for particular companions, or pairs or small clusters may have stable bonds nested within larger social aggregations (Cairns and Schwager 1987). To understand social structure, it is essential to describe it. Cairns and Schwager (1987) reviewed types of association indices that are often used in field studies of animal behavior. Each of these indices calculates the relationship between each pair of individuals and estimates their level of association. Here, we evaluate the utility of using association indices to define social groups of Yellow-bellied Marmots (*Marmota flaviventris*).

Unlike highly social marmots that live in very well-defined and physically-isolated social groups, Yellow-bellied Marmot matrilines may be immediately adjacent to each other. Groups typically contain one adult female, optimal matriline size is about 3 females, but some groups may contain many more females (Armitage and Schwartz 2000). Previously, patterns of space use overlap were used as an indirect measure to define foraging and social groupings of yellow-bellied marmots (Frase and Armitage 1984, Armitage 1986). By plotting locality data as three-dimensional block diagrams, with the peak heights representing the frequency of observation, home ranges could be defined by noting the grids in which animals were spotted, and patterns of overlap (in this case, = 50% overlap) defined shared foraging areas and therefore matrilines. The patterns of space use overlap method, however, has some limitations. When the frequency of observations in one grid-square was much higher than the others (such as on a sunning/observation rock), averaging resulted in significant changes in peak heights; this situation may have overestimated or underestimated the association between individuals (Frase and Armitage 1984).

A variety of different association indices can be calculated using the same set of locational data. All have the total number of samples when two specific animals *a* and *b* are located together as a numerator. The denominators, however, differ based on the temporal coincidence of pairs of individuals and different metrics may generate different results (Cairns and Schwager 1987). Hence, the choice of which association index to use requires thinking clearly about how to interpret *a* seen without *b* versus *b* seen without *a*. We used the simple ratio metric because it does not double-count observations when individuals are seen separately (Ginsberg and Young 1992).

The simple ratio is calculated by calculating the ratio of observations of individuals *a* and *b* seen together defined as *x*, over the sum of the observations of them seen together, *x*, plus the time they are both seen separately, y_{ab}, only *a* is seen, y_s, and only *b* is seen, y_b:

$$\text{Sipmle Ratio Index} = \frac{x}{x + y_{ab} + y_a + y_b}$$

Co-occurrence depends on the sampling interval (Cairns and Schwager 1987). If the samples are made too close together, the observations will not be independent. The Simple Ratio Index is least biased when the sample is random.

We analyzed locational data collected by trapping and regular observations of yellow-bellied marmots from a single active season. We focused mostly on burrows: key resources for semi-fossorial marmots. We noted the burrow entrances where individuals were trapped, and, we noted the burrow entrances where we observed individuals. We used a program called SOCPROG 2.2 (Whitehead 2004), which marine mammal biologists use to define social groups based on sighting records, to calculate association indices.

Methods

We used SOCPROG to calculate association indices in marmot data collected in 2004 from the set of all trappings and observations. Focal group observations were made where the location of individuals was noted with respect to specific burrows because burrows are important resources for marmots. During a given observation session (early morning and late afternoon), the identity and location of all marmots were noted. Whenever a marmot moved from one burrow location to another, its new location was recorded. These data were not formal scan samples (Martin and Bateson 1986); vegetation and habitat features prevented us from identifying all subjects without bias in all locations of their home ranges throughout the season. We combined observational data with the set of all locations where marmots were trapped, and then used SOCPROG to calculate associations between pairs of individuals.

We analyzed associations between non-pup females using day, month, and year as the sampling

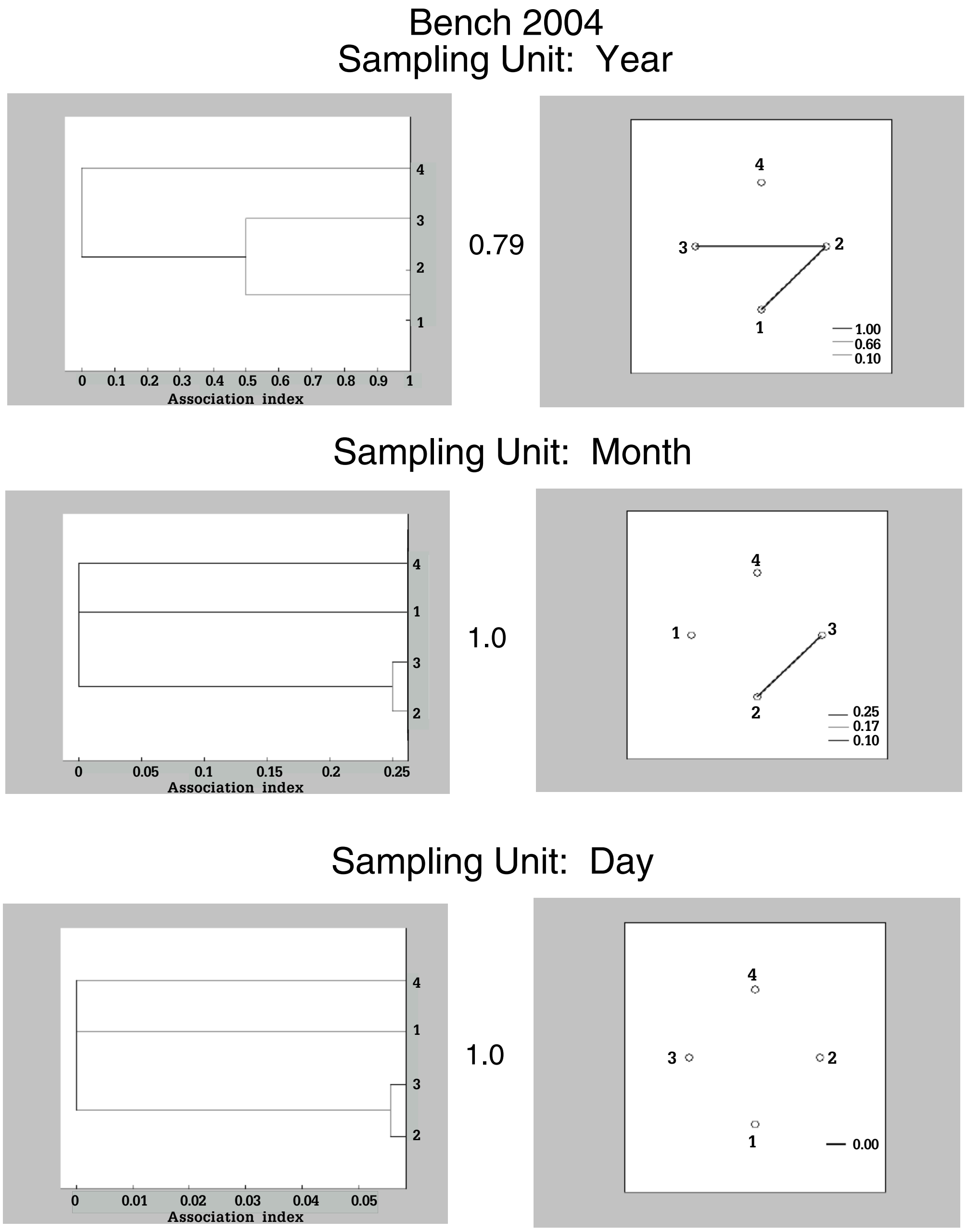

Fig. 1. Dendrograms, cophenetic correlation coefficients, and sociograms illustrating the association patterns of the Bench site's non-pup females quantified using different sampling units. Note the declining association indices as sampling unit shrinks from year to day.

period. Because these different sampling periods contained different amounts of data, we aimed to determine which was the least-biased estimate of associations, and one of our main goals was to determine the appropriate sampling period that would best estimate the overall social groupings. Moreover, the number of individuals in a colony site varied considerably: there were only 4 non-pup females (only a single adult female) in the Bench colony site while there were 19 non-pup females in the Picnic colony site and a total of 118 animals of all ages and sexes. We chose the 'Simple Ratio' association index because it provides an exact answer to the question of how often a pair is associated.

In SOCPROG, we used several tools to identify associations between individuals. The 'List Association Matrix' function displays the association matrix of the sampling population. The 'Hierarchical Cluster Analysis,' helped us visualize relationships by plotting a dendrogram. This is an easy way to visualize any social groupings that may be present and identify an objective cutoff point. The degree to which the dendrogram agrees with the matrix of association indices can be summarized by the cophenetic correlation coefficient, which ranges from 0 to 1. If the cophenetic correlation coefficient is > 0.8, the dendrogram accurately portrays the patterns of association (Whitehead 2004). The 'Sociogram' function makes a sociogram of the association matrix. Points representing the individuals are arranged around a circle and the thickness of lines between points indicates the strength of their association.

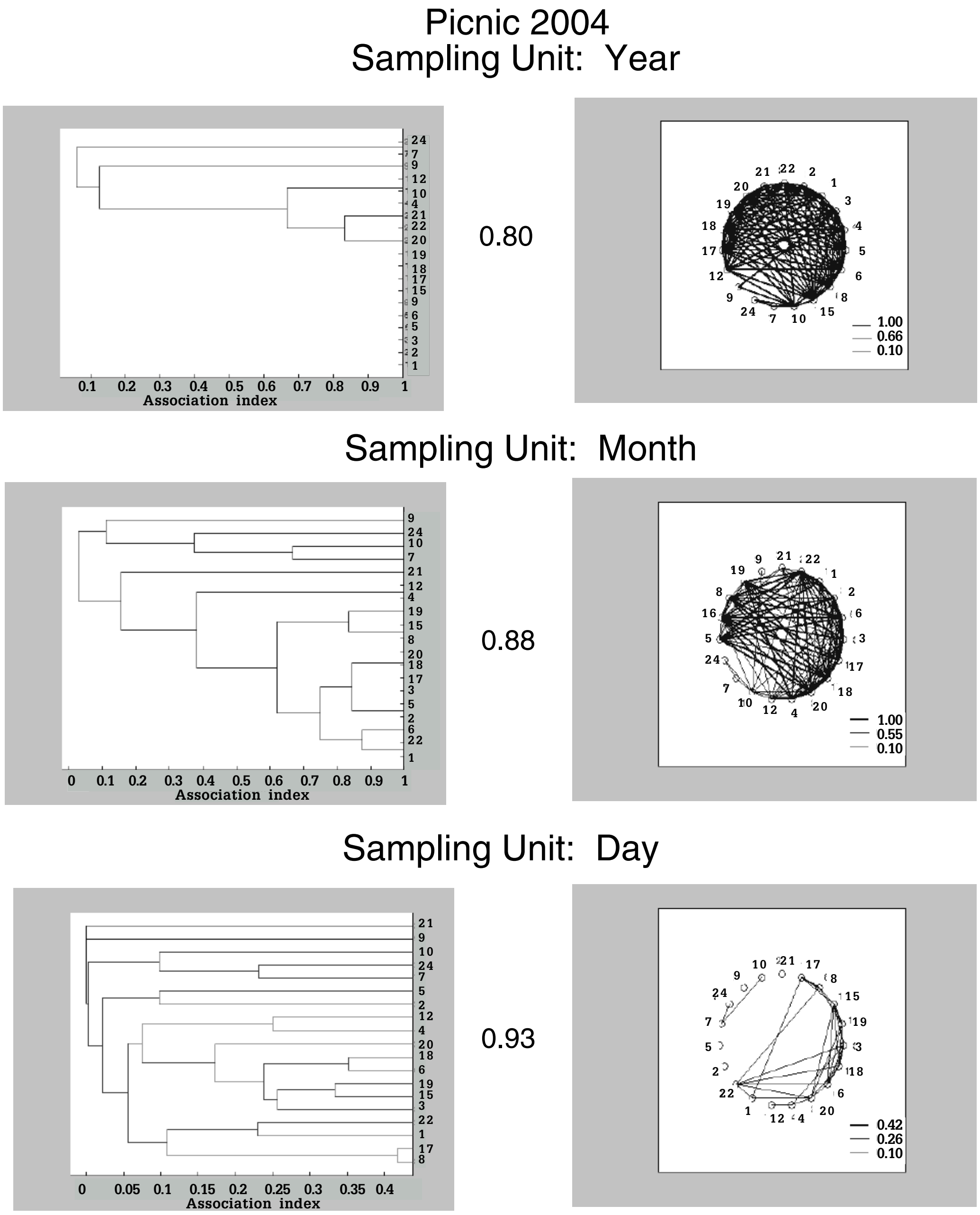

Fig. 2. Dendrograms, cophenetic correlation coefficients, and sociograms illustrating the association patterns of the Bench site's non-pup females quantified using different sampling units. Note the declining association indices as sampling unit shrinks from year to day.

Results

We found that using the year as the sampling period gave us high levels of association that appeared robust. When we sampled using smaller time intervals in the Bench group, we found that association indices declined substantially (Fig. 1). We attribute this to insufficient data in smaller time intervals creating a bias. Using the entire year as the sampling interval, we defined social groups as clusters with = 0.5 association index. This made it relatively easy to identify from the dendrogram (i.e., individuals that were clustered = 0.5 were defined as being in the same social group). When we used the entire year as the sampling period for Picnic, three social groups emerged which matched our intuitive estimation of what happened in Picnic in 2004 (Fig. 2). Based on the preceding results, we decided that the year is the best sampling unit, and that the simple ratio provides a reasonable measure of association. We then analyzed association patterns between marmots in the Gothic Townsite, Marmot Meadow, River, and Stonefield with these parameters (Fig. 3).

Discussion

We believe that association indices based on burrow sharing is an appropriate way to identify marmot social groups. Based on our empirical results from a relatively simple social group, we suggest that groups be defined as those individuals with a = 0.5 association index. Given our sampling protocols (groups were typically observed 10 – 20 h/week and trapped bi-weekly), sufficient data were obtained when we used the year as the unit of analysis. When we used either

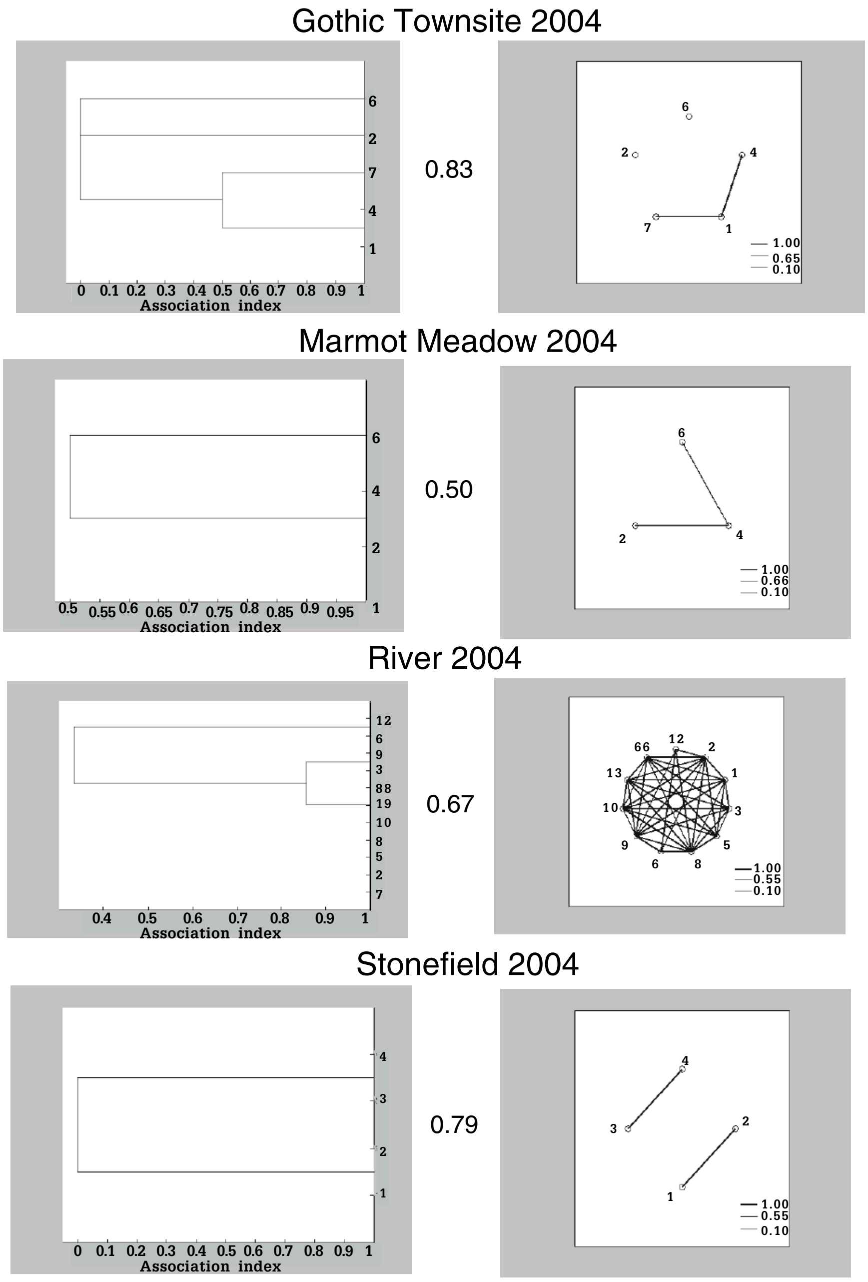

Fig. 3. Dendrograms, cophenetic correlation coefficients, and sociograms illustrating the association patterns in RMBL, Marmot Meadow, River, and Stonefield, non-pup females quantified using all observations from the 2004 active season as the sampling unit.

the day or the month as the unit of analysis, association indices were lower. However, it is also possible that by using the month as the unit of analysis, we can identify seasonal differences in association, such as those found with Olympic Marmots (*M. olympus*) (Barash 1989).

Different groups illustrate different sorts of social integration. River and Picnic are well-integrated 'small worlds' (Milgram 1967, Lusseau 2003) where individuals have considerable spatial overlap. Other groups are less cohesive and future analyses will focus on the relationship between social integration and subsequent dispersal. Future studies will also have to test the relationship between genealogical matrilines and social groups as defined here.

In conclusion, using SOCPROG to calculate association indices provided a novel way to define social groups quantitatively. These techniques may also be useful when studying seasonal variation in association patterns in Olympic marmots and other highly social species, help identify the notoriously difficult social system of Vancouver Island Marmots (*M. vancouverensis*), and help make better sense of groundhog association patterns.

Acknowledgements

We thank Hal Whitehead for all his support with SOCPROG, Janice Daniel for help managing the marmot data base, and Louise Cooley, Louise Lochhead, Amanda Nicodemus, Lucretia Olson, Arpat Ozgul, David Pelletier, Tricia Stark, and Tyler Van Fleet for help collecting data in 2004.

References

Armitage, K.B. and Schwartz, O.A. 2000: Social enhancement of fitness in yellow-bellied marmots. *Proc. Nat. Acad. Sci. USA*, **97**: 12149-12152.

Armitage, K.B. 1986: Marmot polygyny revisited: determinants of male and female reproductive strategies. In *Ecological aspects of social evolution* (eds. D.I. Rubenstein and R.W. Wrangham), pp. 303-331. Princeton University Press, Princeton.

Barash, D.P. 1989: Marmots: social behavior and ecology Stanford University Press, Stanford.

Cairns, S.J. and Schwager, S.J. 1987: A comparison of association indices. *Anim. Behav.*, **35**: 1454-1469.

Frase, B.A. and Armitage, K.B. 1984: Foraging patterns of Yellow-bellied Marmots: role of kinship and individual variability. *Behav. Ecol. Sociobiol.*, **16**: 1-10.

Ginsberg, J.R. and Young, T.P. 1992: Measuring association between individuals or groups in behavioral studies. *Anim. Behav.*, **44**: 377-379.

Lusseau, D. 2003: The emergent properties of a dolphin social network. *Biol. Lett.*, **270**: S186-S188.

Martin, P. and Bateson, P. 1986: Measuring behaviour Cambridge University Press, Cambridge.

Milgram, S. 1967: The small-world problem. *Psych. Today*, **2**: 60-67.

Whitehead, H. 2004: Programs for analyzing social structure. 24 Sep. 2004 <http://myweb.dal.ca/hwhitehe/social.htm>.