

Evaluation of Manatee Feeding Preferences from Partial Ranks

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ABSTRACT

A series of trials was conducted to measure the feeding preferences of captive manatees at Homosassa Springs State Park, Florida. During each trial, one manatee was allowed to browse through a completely randomized grid of five plant foods with four replications of each food. Responses consisted of arbitrary numbers of ranks which indicated the order in which the foods were eaten. A method of describing food preferences based on partial ranks was developed by obtaining Mann-Whitney preference counts for each pair of foods, then fitting Bradley-Terry models to the corresponding contingency tables.

INTRODUCTION

In 1994, researchers in the Department of Wildlife Ecology and Conservation at the University of Florida conducted a series of trials to evaluate feeding preferences of the West Indian manatee. The goal of the study was to foster the recovery of injured captive manatees by providing them with favorite foods having adequate nutritive value.

STUDY DESIGN

The feeding trials were conducted at Homosassa Springs State Park, Florida. A large 5X4 grid was constructed from plastic tubing. During each trial, a diver placed food in each of the 20 cells of the grid as it floated on the surface of the water. Then, one manatee would be allowed to swim under the grid and eat the foods at will. The trial was concluded when the manatee swam away from the grid.

Four manatees participated in the study, and each manatee participated in ten or more trials. Nine species of plants were examined in the study. During each trial, five species were selected for use, and each of the selected species was replicated four times within the grid. An example is shown in Figure 1.

Figure 1. Layout of foods within one trial.

E	A	D	A	C
B	B	A	C	C
A	D	B	B	C
D	E	E	D	E

The trials were initiated without statistical consultation, and there were numerous flaws in the experimental design. For example, no design was used to select five foods for each trial from the nine foods of interest. Instead, the choices were based on seasonal availability and convenience. As a result, some manatees never had the opportunity to eat some foods, and some foods were not paired equally often with other foods. Since pairwise comparisons of all foods were of interest, the researchers should have used a balanced incomplete block design to select foods for each trial. The researchers could also have used a 3X3 grid with no replication of

the nine foods. Another option would have been to limit the study to only five foods which would always be available.

After the foods for a trial were selected, the replicates were completely randomized within the grid. Thus, feeding preferences were confounded with grid location effects. If a manatee followed the current or simply preferred to remain in the same area while feeding, this would lead to incorrect conclusions about preferences. A Youden square design would have offered more control over location effects than the completely randomized design that was used.

The manatees provided more problems with the design, but these were unavoidable. The sample size of four is small in a statistical context; however, it is a sizeable portion of the 2600 West Indian manatees in existence. Also, the subjects did not constitute a random sample from the manatee population. All of them lived in captivity in the same location, all were female, and all were related. The subjects included an older manatee and her three calves (Save the Manatee Club Inc., 1997).

There were several other confounding factors in the study. For example, there were days in which one manatee participated in several trials. Since feeding is cumulative, each trial could plausibly affect the results of successive trials. Also, preferences could be affected by weather and water conditions, but the manatees did not participate in the trials on the same days.

METHODOLOGY FOR PARTIAL RANKS

The design of the study was faulty, and analysis of the data posed another problem. Instead of collecting data on a continuous measurement, such as the time spent in each cell or the amount of food eaten, the researchers recorded only the sequence or ranking of grid cells in which food was eaten by a manatee. Only the first visit to any cell was recorded. Ideally, 20 ranks would be assigned, with each of the five foods receiving four ranks. However, in every trial, the manatee stopped eating and swam away before completing the grid. Thus, each trial resulted in a series of partially-ranked data, with arbitrary numbers of ranks assigned.

A traditional analysis of rank data involves comparisons of the average ranks assigned to each food in a trial with a Kruskal-Wallis test. The uneaten replicates could be regarded as tied with the highest ranks. Then, by convention, the average of the tied ranks is assigned to each uneaten replicate, and an approximate test with modifications for ties is appropriate (Hollander and Wolfe, 1973). Another option would be to conduct the same test using the exact null distribution of the tied ranks. In this study, so many replicates were left untouched that the Kruskal-Wallis test had little power to detect differences among foods.

Since the uneaten foods should logically receive ranks at least as large as the number of replicates eaten, another option would be to conduct the Wilcoxon or log-rank tests for Type I censored data (Kalbfleisch and Prentice, 1980). These tests also provided little power to detect differences among foods. In addition, these tests were developed for lifetime data in which an event must occur but may not be observed. In this study, there was no requirement for the manatee to visit all 20 replicates, so the assumption that each of the replicates would eventually receive a ranking is false. Inferences from these tests would be defined by permutations of ranks, rather than distributions of observed and unobserved lifetimes. If the manatees could have been forced to select a fixed

number of replicates of each food in each trial, procedures for a Type II censoring mechanism would have been appropriate.

Tate (1961) considered the problem of partial ranks. The problem was stated in terms of measuring the support for a hypothesized ordering of events, when those events occur once in a sequence. Some ordering among events is known, but the ranks of some events are known only to be within certain limits. Tate developed an analogue of the Jonckheere-Terpstra test for the alternative hypothesis of a given ordering among treatments in a one-way design. In his approach, events are grouped into ranked sets. Then, comparisons are made between members of different ranked sets, but no comparisons are made within a set. This approach would have been directly applicable to the manatee data if the foods had not been replicated in each trial.

Critchlow (1985) considered ordinary measures of distance between two vectors of fully-ranked data, such as Kendall's tau and Spearman's rho. He described analogues of these measures for partial ranks and evaluated their distributions in terms of the permutations of ranks which are possible when the known ranks are held fixed. The results apply when a fixed number of ranks is known in advance, as when a judge chooses the top three competitors in a contest. In the manatee trials, the number of ranks assigned varied from trial to trial.

Another approach for partially-ranked data involves statistical models. One approach would be to regard each trial as a stochastic process, with five states corresponding to the foods and a sixth state to represent entering or exiting the grid. Then, probabilities of transferring among states could be modeled. Marden (1995) described various models for ranked responses, including the Bradley-Terry model for paired comparisons.

DATA ANALYSIS

A combination of some of the techniques listed above was used to analyze food preferences. First, the preference counts for each pairwise comparison of foods in each trial were compiled. Tate's convention was used to compare replicates of Foods A and B in the same trial. Food A was preferred to Food B if both A and B were ranked, with A receiving the lower rank, or if A was tasted and B was not tasted. No comparisons were made among uneaten plants. Each pair of foods received two Mann-Whitney scores to indicate the preferences of each food over the other. An example is shown in Figure 2.

Figure 2. Example of assignment of preference counts.

Eaten plants:	1	2	3	4	5	6	7
	A	B	A	D	E	B	C
Uneaten plants:	A	A	B	B	C	C	D
	D	D	E	E	E	E	E

7 preferences of A over B, 5 preferences of B over A

Within each trial, the preference scores were arranged in a matrix with empty cells along the diagonal. Next, the preference matrices for each manatee were added together to form four pooled preference matrices. Variability from other sources, such as grid position, was ignored. Subsequently, interpretations about food preferences were made in terms of the numbers in the matrices formed in this manner. The preference matrix for one manatee is shown in Figure 3.

Since the manatees were not selected at random, analyses were conducted separately for each manatee. No attempts were made to pool their results or compare their preferences. The sizes of the matrices varied among manatees, since each manatee was exposed to a different subset of foods during its trials. To be included in a pooled preference matrix, a food must have been

Figure 3. Pooled preference matrix for one manatee. Each entry indicates the number of times the column food was preferred over the row food.

	A	B	C	D	E
A		86	47	64	43
B	25		20	52	17
C	62	122		86	45
D	15	59	26		12
E	21	46	17	20	

paired with each other food in the matrix in at least one trial for each manatee. There were five foods which were included in each of the four pooled preference matrices.

Next, the Bradley-Terry model was fitted to each of the four pooled preference matrices. The model can be expressed as $\ln(\Pi_{ab} + \Pi_{ba}) = \Phi_a - \Phi_b$, where Π_{ab} represents the proportion of times that Food a was preferred over Food b when a preference between the two was exhibited. This model is described by Marden (1995) and Agresti (1996). An important assumption of the Bradley-Terry model is transitivity of preferences. If A is preferred to B and B is preferred to C, then A must necessarily be preferred to C.

The Bradley-Terry model offered several advantages. Most importantly, the researchers were able to interpret the results; each food was assigned a number, with larger numbers indicating higher preferences. The partial ranks and imbalanced numbers of pairwise comparisons were reflected in the standard errors of parameter estimates. Foods which were eaten more often had estimates with lower standard errors. Also, the transitivity assumption allowed information other than direct comparisons to be used; for example, the comparison of Foods A and B was influenced by their individual comparisons with Food C. Finally, the estimates of Φ for each food were useful in subsequent analyses involving correlations of preference with nutritional variables, such as protein and carbohydrate content.

Estimates for the coefficients in the model were obtained with the GENMOD procedure (SAS Institute, Inc., 1996). The program in Figure 4 was used to analyze the data presented in Figure 3. The variable PREF represents counts above the diagonal of the preference matrix, and TOTAL represents the sum of a cell and its reflection across the diagonal.

Goodness of fit for each of the four models was evaluated with tests produced automatically by PROC GENMOD. In a Bradley-Terry model for a $k \times k$ table, there are $(k-1)(k-2)/2$ degrees of freedom for the model. For the data in the example, there was no significant lack of fit of the model (Pearson $\chi^2 = 4.07$, $df = 6$, $p > .6$).

The estimates of Φ and their standard errors for the foods in the example were: A, $-.64 \pm .17$; B, $.78 \pm .17$; C, $-.88 \pm .17$; D, $.58 \pm .18$; and the effect of E was constrained to be zero. These indicated that the food preferences, ordered from highest to lowest, were B, D, E, A, and C. Predicted values and residuals for each observation were printed with the OBSTATS option, which also provided 95% confidence intervals for each proportion. Whether two foods differed significantly in preference could be examined at a comparisonwise Type I error rate of .05 by checking if the corresponding confidence interval included .5. In the example, preferences for B and D were not significantly different; neither were preferences for A and C. All other comparisons indicated significant differences between foods.

Figure 4. Obtaining Bradley-Terry estimates with PROC GENMOD.

```
data manatee;
input pref total a b c d e;
datalines;
86 111 -1 1 0 0 0
47 109 -1 0 1 0 0
64 79 -1 0 0 1 0
43 64 -1 0 0 0 1
20 142 0 -1 1 0 0
52 111 0 -1 0 1 0
17 63 0 -1 0 0 1
86 112 0 0 -1 1 0
45 62 0 0 -1 0 1
12 32 0 0 0 -1 1
;
proc genmod data=manatee;
model pref/total = a b c d e/
dist=bin link=logit noint obstats;
run;
```

CONCLUSION

The flawed design of the study and the collection of partially ranked data made the evaluation of manatee feeding preferences difficult. The approach described above provided a reasonable way to obtain some worthwhile information from the data.

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