A SURVEY AND ANALYSIS OF MANAGEMENT PRACTICES IN THE NORTH AMERICAN RED PANDA SSP

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The goal of this paper is to present an analytical method that allows a diverse, intercorrelated and seemingly uninterpretable array of management practices to be quantified and rendered comprehensible enough to suggest solutions to specific management problems. I will state from the outset that the results described here are preliminary and require some refinement. Nevertheless, the technique is very promising in its ability to identify ways in which we can improve husbandry management. The techniques I have used are borrowed from ecology, wildlife and range management where, for years, multivariate statistical analysis has been used to describe and improve habitats (see for example Aspey and Blankenship, 1977; Pielou, 1984; Sparling and Williams, 1978). A transfer of such techniques to captive management seems natural but has not previously been attempted.

I had four objectives for this study. The first was to begin to collect a data set that would catalogue and profile prevailing red panda management practices in the North American SSP. I hoped this data base might highlight some basic management problems. Secondly, I wanted to determine the degree of heterogeneity in prevailing management practices. Despite a general consensus on management (as specified in the 'Husbandry and Management Guidelines', Roberts and Glatston, 1983, distributed to all zoos holding or contemplating holding red pandas) it is clear that each zoo really 'customizes' management to its own circumstances. This is no surprise, as we have deliberately tried to expand the captive range of red pandas into a wide variety of zoo habitats in order to determine the breadth of the captive niche. Thirdly, I wanted to see if management practices could be correlated with such key measures of program performance as reproductive success and survivorship of adults and young. If significant correlations could be made it might just be possible to prescribe specific management changes that could increase productivity and population growth. Finally I hoped the results of the survey would permit the development of objective and specific criteria for evaluating the suitability of applicant institutions for the program.

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Table 1. Survey variables were grouped into 4 clusters

A. Enclosure details
B. Climatic details
C. Diet details
D. Management details

Enclosure details	*Climatic details*
Amount of shade	Total annual rainfall
Indoor/outdoor configuration	# days above 90 F
Total area	# days below 32 F
Public proximity	Mean maximum humidity
Proximity of other exhibits	# days of snowcover
Public traffic flow patterns	
# Nest boxes	
Nest box material	
Nest box location	

Diet details	*Management details*
Amount of bamboo fed	Amount of veterinary care
Grass in enclosure	Amount of keeper care
Amount of grass eaten	# endemic local disease
% roughage in diet	# parasite screens
# forage suppliments provided	

Methods

I sent a questionnaire to 24 zoos in North America which hold red pandas and received 23 responses. I attempted to balance the survey by asking a roughly equivalent number of questions about climatic conditions, diet, enclosure details, husbandry, management, medical management and records. I even asked for some opinions. For each general category I asked as few questions as were necessary to cover the topic. I was, and remain, under no illusion about the variability of the responses or their accuracy. Most people fill out surveys as they do their tax returns - as late and as quickly as possible. So I admit that my analysis suffers from the 'garbage in, garbage out' principle - the accuracy of the conclusions is a function of the accuracy of the responses.

The survey consisted of 45 questions, but only 23 or about one half were actually used in the analyses (Table 1.) The remaining questions solicited opinions or queried administrative details which provided useful programmatic information but little that could be considered hard management data. These data were excluded.

I analyzed the responses in a variety of ways. Some were simply tabulated and were presented as graphs or tables. Some data were subjected to factor, cluster, and discriminant analyses in order to tease apart complicated inter-

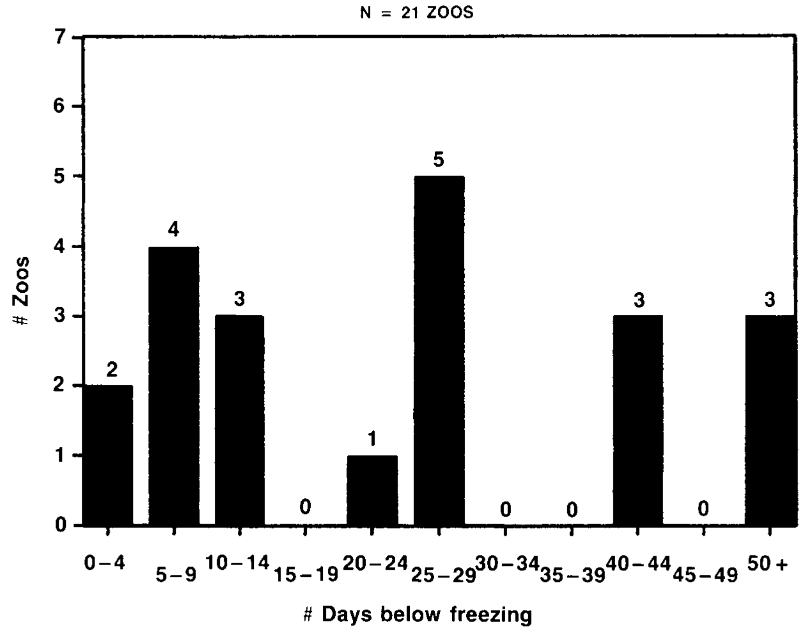

Fig. 1. Number of days below freezing.

actions and to get at answers to important questions like 'how much variation is there between zoo management practices' and 'can we tell what differentiates highly successful zoos from less successful ones?'

Results

The variables used in this analysis (Table 1) separated into four intuitively arranged groupings: climatic factors, enclosure characteristics, diet variables and medical/husbandry practices.

Climate

In the zoos surveyed, the number of days below freezing was quite variable ranging from none to over 120 (Figure 1). Judging from these data the majority of zoos have mild winters, but a few had severe ones. This is reflected again in the number of snowcover days which ranged from 0 to 28 (Figure 2). Seventy

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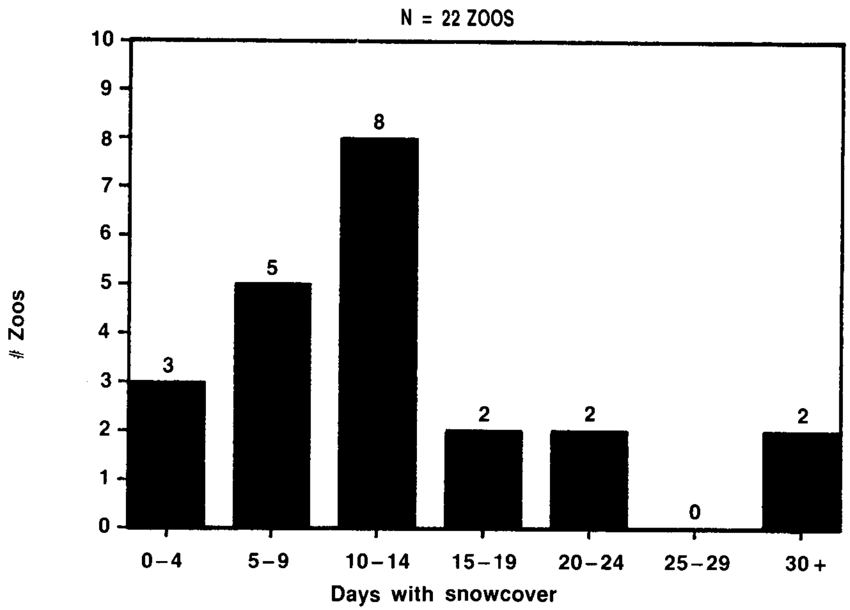
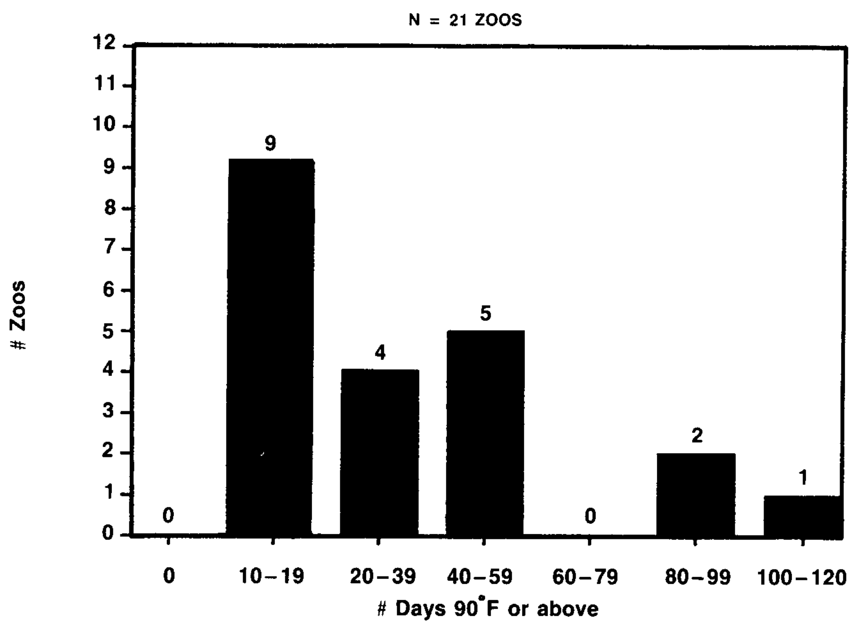

N = 22 ZOOS
# Zoos
10
9
8
7
6
5
4
3
2
1
0
3
5
8
2
2
0
2
0-4
5-9
10-14
15-19
20-24
25-29
30+
Days with snowcover

3.


N = 21 ZOOS
# Zoos
12
11
10
9
8
7
6
5
4
3
2
1
0
0
9
4
5
0
2
1
0
10-19
20-39
40-59
60-79
80-99
100-120
Days 90°F or above

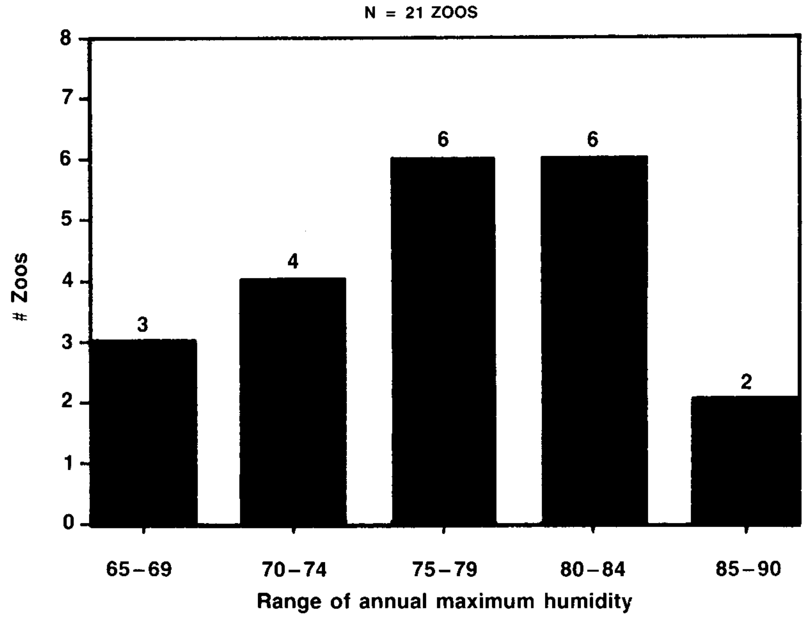


Fig. 4. Average maximum humidity.

five percent of zoos had fewer than 20 snowcover days but some had considerably more. The freezing and snowcover data indicated that the most severe winters occurred in the plains and Great Lakes states and the mildest in the southwest.

At the other extreme the number of days with temperatures above above 90°F ranged from 4 to 112 (Figure 3) with one third of the zoos having 40 or more days above 90°F. Some had prolonged periods of high temperature. The hottest summers were in the southwest and the coolest on the west coast and Great Lakes states. Maximum humidity (Figure 4) and rainfall patterns (Figure 5) tended to be correlated. Most zoos had modest and tolerable average maximum humidity and rainfall patterns but about one third had average humidity exceeding 75% and a quarter had rainfall exceeding 40 inches per year. The highest humidities occurred in the southwest and northwest and highest rainfall occurred in coastal regions.

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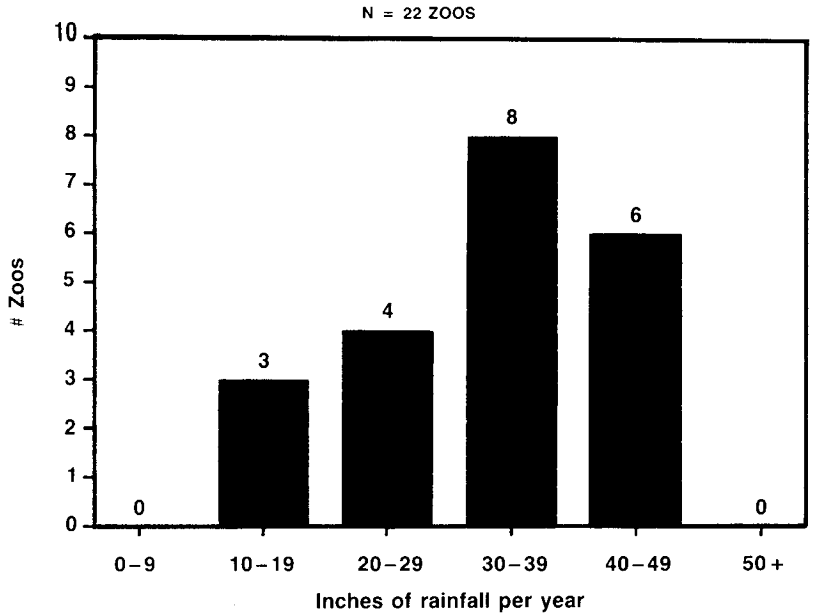
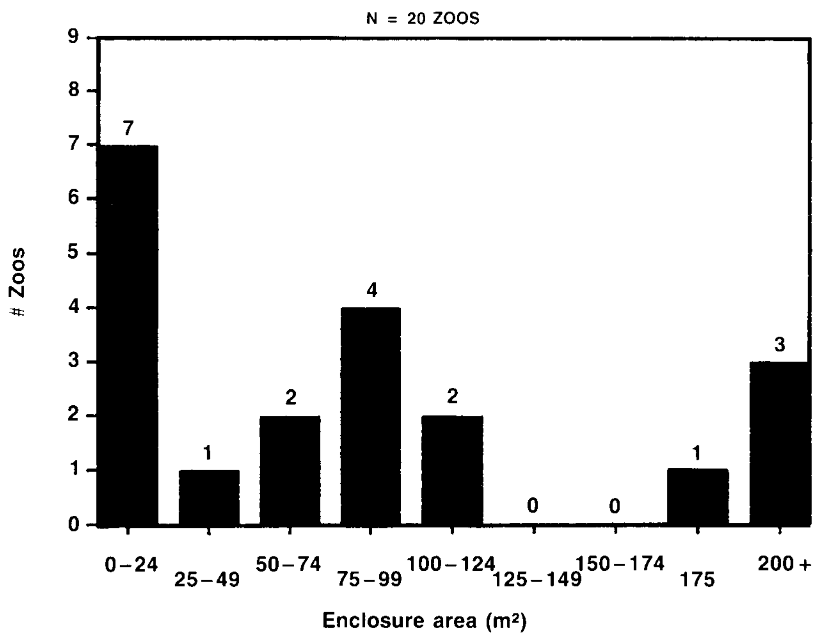
Fig. 2. Number of days with snowcover.
Fig. 3. Number of days above 90 F.


N = 22 ZOOS
# Zoos
0
3
4
8
6
0
0-9
10-19
20-29
30-39
40-49
50+
Inches of rainfall per year

5


N = 20 ZOOS
# Zoos
7
1
2
4
2
0
0
1
3
0-24
25-49
50-74
75-99
100-124
125-149
150-174
175
200+
Enclosure area (m²)

6

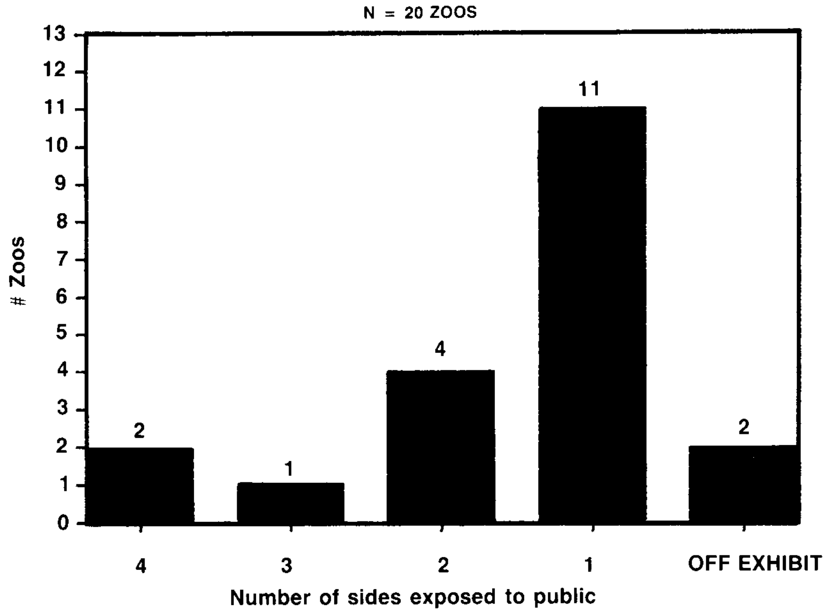


Fig. 7. Public access to the exhibit.

Three zoos were exceptionally hot and humid with 75 days above 90°F and mean year round humidity above 75%. Two zoos were cool and dry with fewer than 30 days above 90°F and mean year round humidity of less than 75%. The remainder were climatically intermediate.

Enclosures

There was a wide variation in enclosure area ranging from a low of 12 square meters to the high of approximately 650 square meters (Figure 6). Over half the zoos had enclosures larger than 50 square meters but a considerable number were in the 15-25 square meter range.

Fourteen zoos had exclusively outdoor enclosures and eight had combined indoor/outdoor ones. No zoos had exclusively indoor enclosures. Seventeen, or about two thirds of the zoos, had edible grass in their enclosures while the

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Fig. 5. Average rainfall per year.
Fig. 6. Average enclosure area.

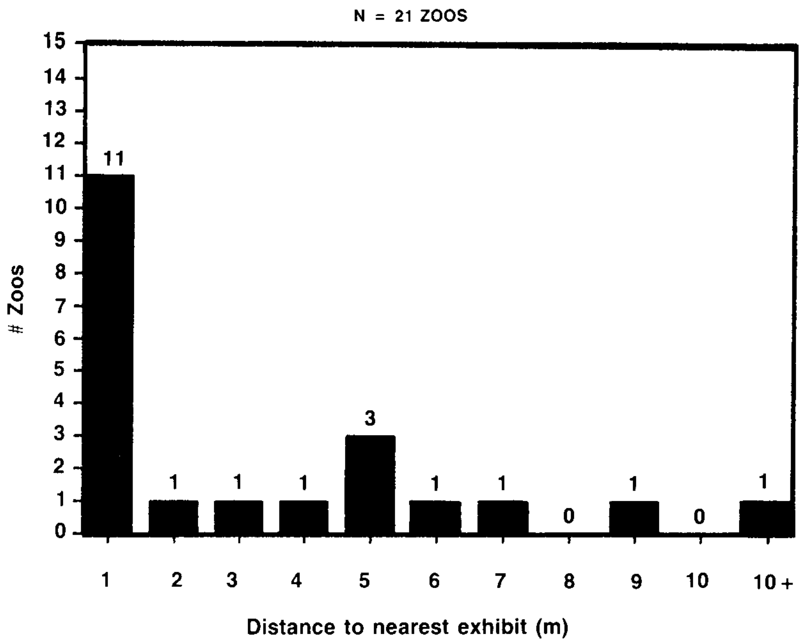


Fig. 8. Proximity to other exhibits.

others lacked any planting. A large majority of the respondents (17) allowed public access to two or fewer sides of the enclosure so that the animals could retreat from the public if they wanted (Figure 7). All enclosures provided some shade while 16 zoos indicated that their exhibits had heavy shade. The rest reported light to moderate shade. Two institutions had their animals off display but the rest had their animals on display within 3 meters of the public walkway. Many enclosures were in close proximity (1 meter or less) to other exhibits but about one third of the zoos placed their panda exhibits 4 meters or more from the next nearest enclosure (Figure 8).

The number of nest areas ranged from 2 to 11 per enclosure, the average being about three. The vast majority were made of wood and were situated above ground but some constructed cement dens which were situated partially or entirely below ground level or inside rockwork.

Management

Twenty zoos had full time veterinarians on staff while the others had consulting veterinarians only. All zoos indicated that they had arrangements for perform-

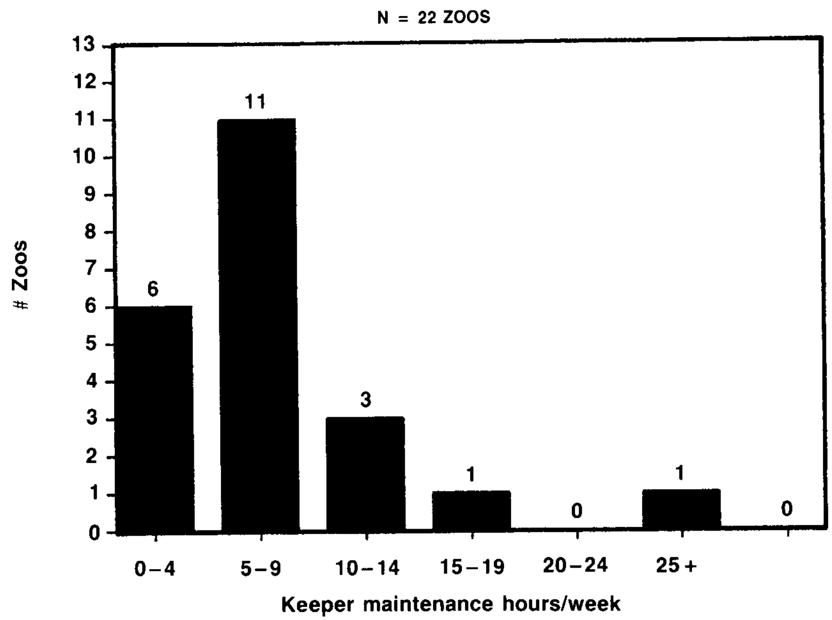


Fig. 9. Maintenance time required.

ing complete necropsies either on- or off-site. Maintenance time by keepers ranged from 5 to 56 hours per week (Figure 9) with the average being about 11 hours per week (about 1 1/2 hours per day). Most zoos had one or more endemic local diseases, such as rabies, distemper, parvovirus, heartworm, lungworm, that could be potential health problems for red pandas. Only 14 zoos vaccinated their animals against either rabies or canine distemper; seven vaccinated for both. All zoos screened for parasites at least once a year, one third on a quarterly basis or even more frequently. Nineteen reported having parasites or some other health problem for which the animals had to be treated.

Diet

All zoos provided at least one form of dietary fiber supplement. In most cases, if there was only one supplement it was bamboo but in two cases fresh and/or dried alfalfa was used in its place.

Of the twenty zoos that gave bamboo (Figure 10) fifteen also had edible grasses available in the enclosures which animals ate with varying frequency. Virtually all zoos fed some sort of gruel or porridge. These had a long and

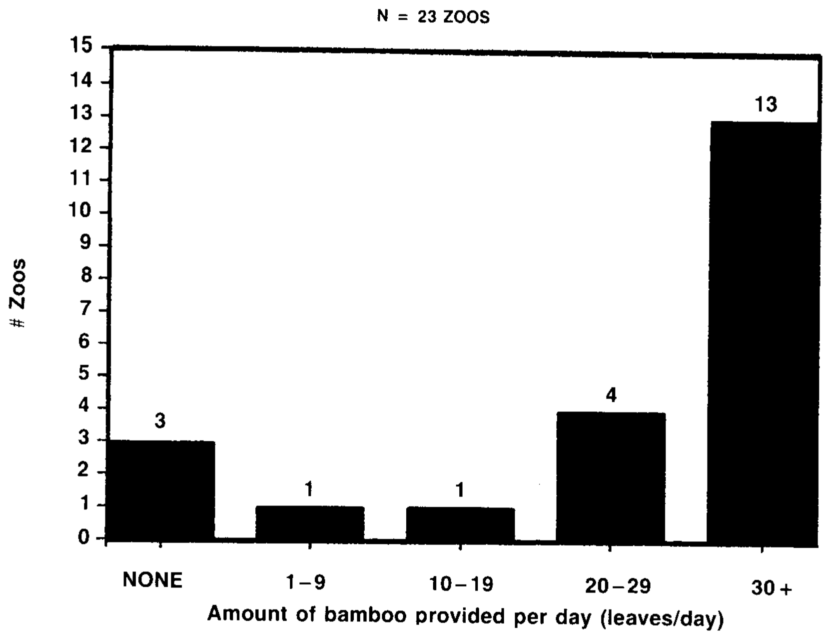


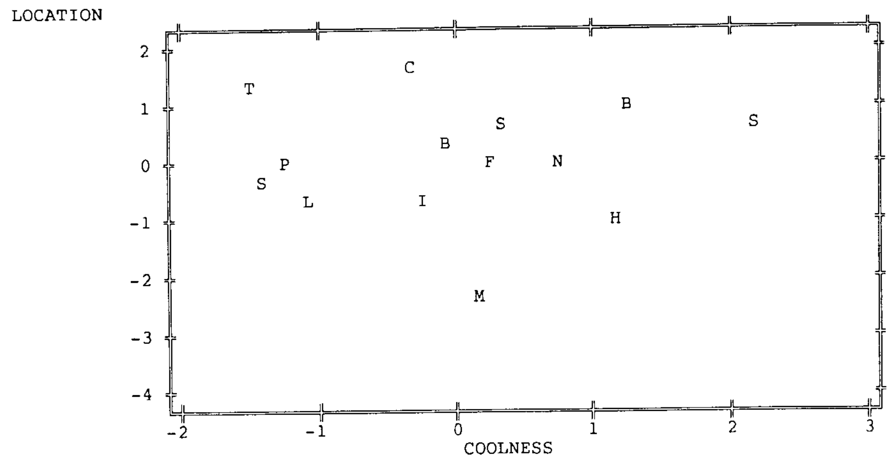
Fig. 10. Amount of bamboo provided.

variable list of ingredients. (Reviews of red panda, diets and nutrition are provided elsewhere in this volume by Warnell *et al.* and by Bleijenberg and Nijboer.)

Similarities among zoos

To what degree are zoo management practices within the SSP similar? To answer this question I had to turn to multivariate analyses. I first performed a factor analysis using the variables shown in Table 1 to determine whether some combinations of variables could be clustered in order to explain the variation found among zoo management practices. Factor analysis is a statistical technique which, by examination of emergent patterns in a correlation matrix, permits a set of variables to be represented by a smaller group of hypothetical variables. The underlying dimensions of the data may reveal patterns that can be used for further interpretation.

In this case, the first three factors, the maximum number easily interpreted accounted for only 58% of the variation in the data, suggesting a very complex pattern of variable interactions. Furthermore, the variable loadings for these factors were not readily interpretable and no variable grouping patterns were



9 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

FACTOR LOADINGS

	FACTOR 1	FACTOR 2
NEST BOX LOCATION	0.623	0.607
PUBLIC PROXIMITY	-0.620	0.264
TRAFFIC FLOW PATTERN	0.615	-0.303
# NEST BOXES	0.527	-0.079
PROXIMITY OF OTHER EXHIBITS	0.502	-0.107
AMOUNT OF SHADE	0.199	0.821
NEST BOX CONSTRUCTION	0.311	0.678
ENCLOSURE TYPE	0.433	0.327
ENCLOSURE AREA	0.427	-0.386
% VARIANCE EXPLAINED	24%	22%

Fig. 11. Factor analysis of enclosure variables.

discernible when the factors were plotted. This result suggested that the variables were very heterogeneous and thus the factor analysis was not very helpful. Therefore, I resorted to performing factor and cluster analyses on each of the natural variable groupings described above (climate, enclosure, diet, husbandry/vet management) individually.

Factor and cluster analyses on grouped variables

R-factor analysis was performed for each of the four groups of variables (enclosure, climate, diet and management) to determine if there were clusters of

DISTANCE METRIC IS EUCLIDEAN DISTANCE
SINGLE LINKAGE METHOD (NEAREST NEIGHBOR)

TREE DIAGRAM

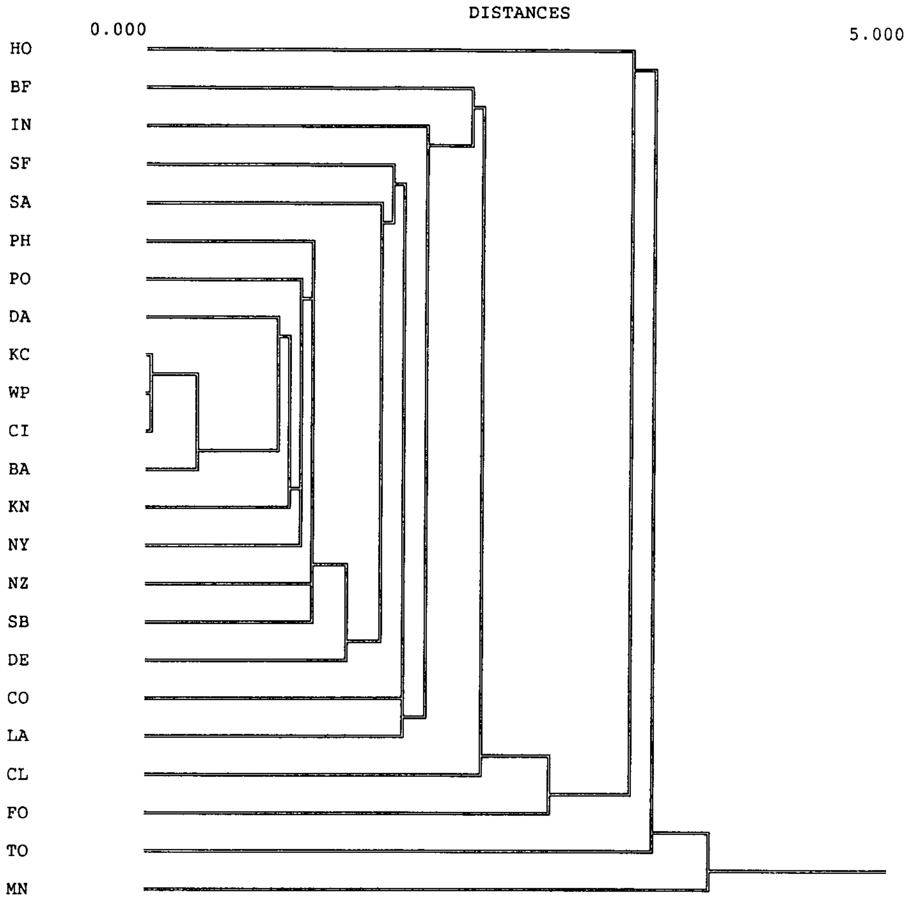
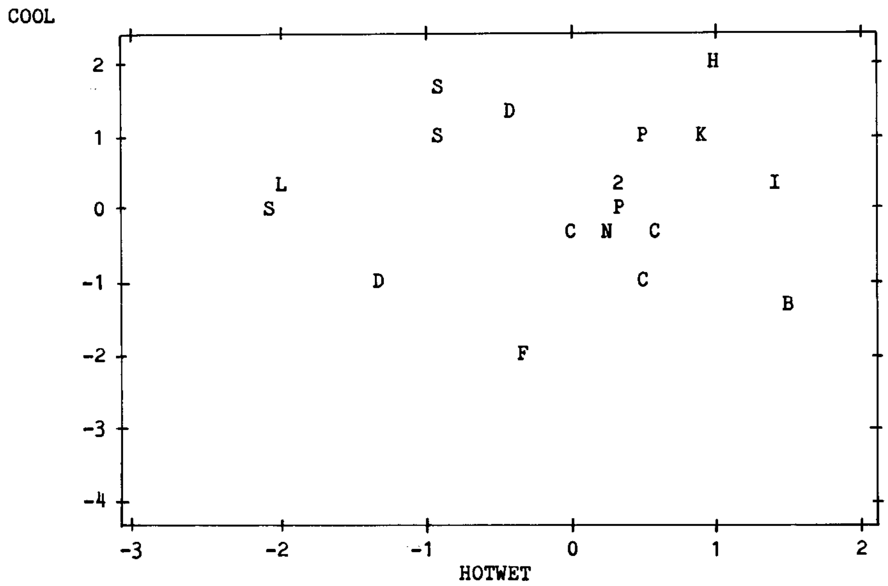


Fig. 12. Dendrogram of enclosure variables.

HO – Houston
BF – Buffalo
IN – Indianapolis
SF – San Francisco
SA – San Antonio
PH – Philadelphia
PO – Portland
DA – Dallas
KC – Kansas City
WP – Woodland Park
CI – Cincinnati
BA – Baltimore
KN – Knoxville
NY – New York
NZ – National Zoo
SB – Santa Barbara
DE – Denver
CO – Columbus
LA – Los Angeles
CL – Cleveland
FO – Folsom Children's Zoo
TO – Toronto
MN – Minnesota



4 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

FACTOR LOADINGS

	FACTOR 1	FACTOR 2
DAYS BELOW 32 F	-0.773	0.146
AVERAGE MAXIMUM HUMIDITY	0.751	0.423
DAYS OF SNOW COVER	-0.742	0.461
# DAYS ABOVE 90 F	-0.134	0.525
ANNUAL RAINFALL	0.232	0.892
% VARIANCE EXPLAINED	41%	25%

Fig. 13. Factor analysis of climatic variables.

zoos which could be defined by commonalities of variables. I also performed a cluster analysis on each of the variable sets so as to produce a dendrogram, or relational tree diagram, that would cluster zoos according to similarity. Cluster analysis is another multivariate technique that takes a correlation matrix and sequentially joins variables or cases on the basis of relative similarity. The dendrograms so produced suggest relationships amongst the data: the horizontal axis of the dendrogram indicates variable or case differences and the vertical axis clusters the most similar cases or variables within groups.

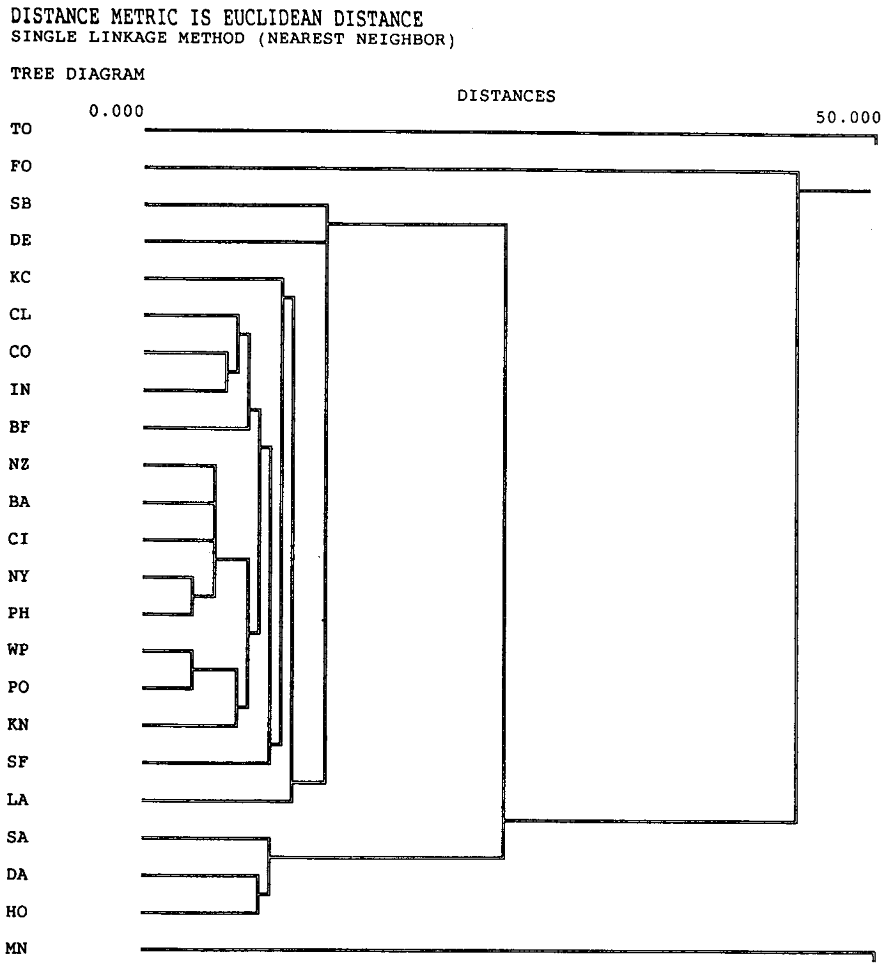
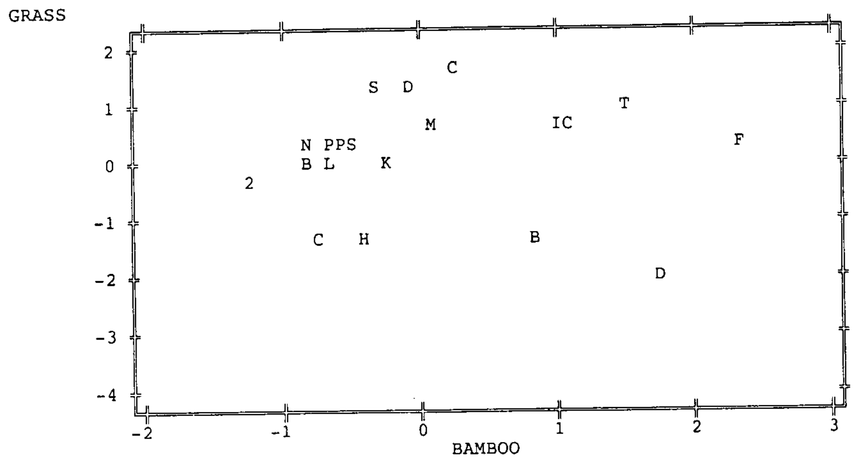


Fig. 14. Dendrogram of climatic factors. For key of zoos see legend Fig. 12 (p. 140).

Enclosure Variables: Factor analysis on the enclosure variables produced two factors accounting for 46% of the total variance (Figure 11). The factor loadings shown here suggest that the first factor described enclosure and nest box location while the second described how sheltered or cool the enclosure was. The factor diagram shows that zoos did not group tightly but produced a continuum along the two factor loadings. To put it another way, the factor plot shows the range of different responses but it fails to demonstrate significant grouping patterns among zoos.

The cluster diagram for enclosure variables supports this (Figure 12). My



2 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

FACTOR LOADINGS

	FACTOR 1	FACTOR 2
GRASS IN ENCLOSURES	0.826	0.188
ANIMALS EAT GRASS	0.737	0.522
% ROUGHAGE IN DIET	0.533	-0.246
AMOUNT BAMBOO FED	0.157	-0.853
FORAGE SUPPLIMENTS	-0.419	0.521
% VARIANCE EXPLAINED	34%	27%

Fig. 15. Factor analysis of diet variables.

interpretation of the factor and cluster analyses is that there is considerable heterogeneity among institutions in their enclosures design. However, there is a core group of about a dozen zoos that appear to have more in-group similarities than differences, at least relative to the other 11 zoos.

Climate: Factor analysis on climatic variables produced two factors accounting for 66% of the total variation (Figure 13). Factor 1 described temperature variables and factor 2 rainfall. Again, zoos were widely dispersed in the two dimensional space but four zoos separated out as cool and dry. The remainder followed a continuum from warm and dry to warm and moist.

Climate variables clustered in a satisfyingly intuitive fashion (Figure 14) with the northern and plains states zoos separating out from the others to form one cluster and the hot, humid southwestern zoos forming another. The clustering pattern of the third group was consistent with regional climatic patterns.

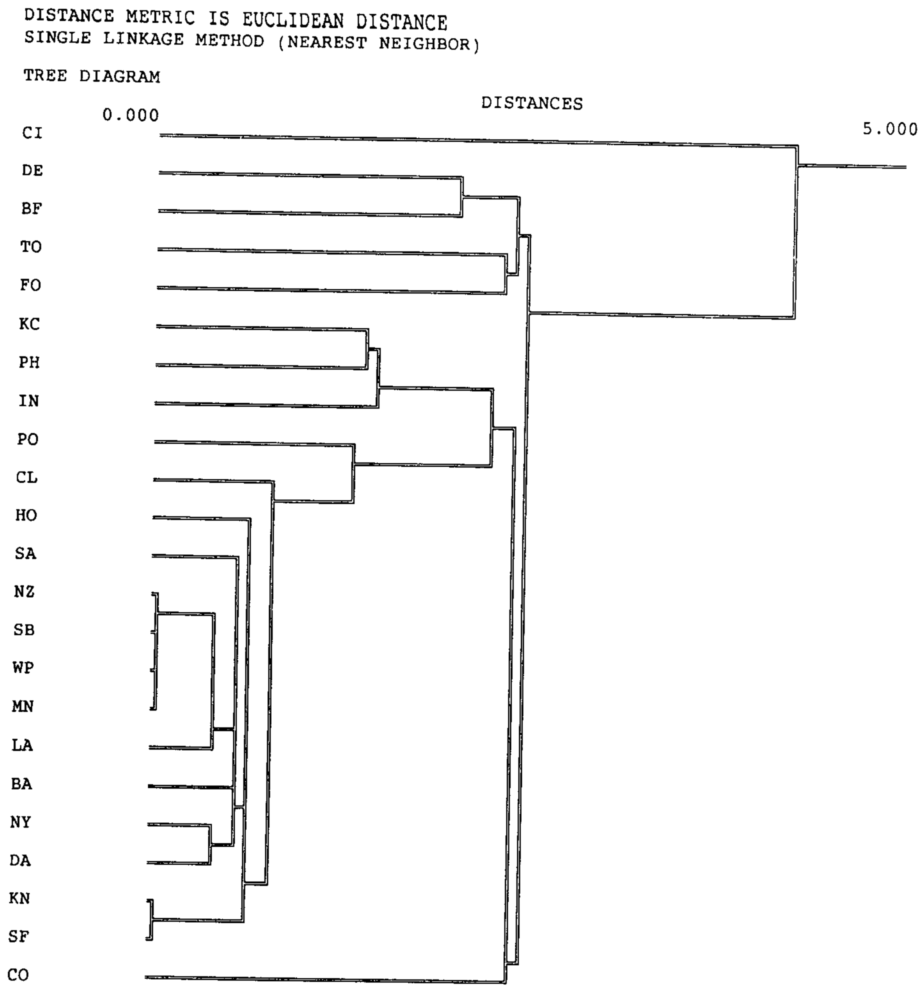
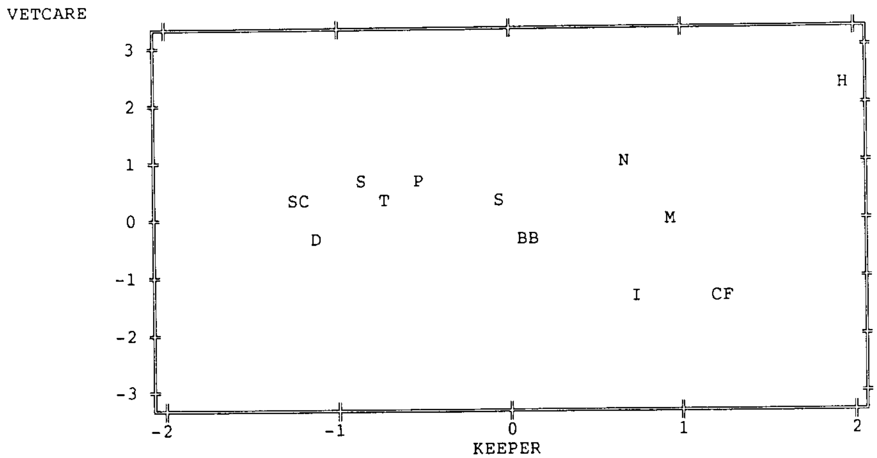


Fig. 16. Dendrogram of diet variables. For key of zoos see legend Fig. 12 (p. 140).

Diet: Diet variables were compressed into two factors describing 61% of the total variation (Figure 15). Factor 1 described grass availability and consumption and factor 2 the bamboo availability and consumption. Two groups were apparent: one provided much grass and bamboo while zoos in the other group provided less bamboo and a range of grass/forage supplements.

Diet clustering separated one zoo, which estimated a very high roughage intake, from the others which estimated less (Figure 16). The second branching separated zoos that fed little bamboo from the others and the next separated



8 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

FACTOR LOADINGS

	FACTOR 1	FACTOR 2
# FECAL SCREENS	-0.868	0.138
TYPE OF VET HELP	0.747	-0.417
HOURS OF KEEPER CARE	0.540	0.523
# LOCAL DISEASES	0.155	0.824
% VARIANCE EXPLAINED	42%	29%

Fig. 17. Factor analysis of husbandry and medical care.

zoos that provided bamboo and other roughage but estimated low roughage intakes.

Management: Two factors accounted for 71% of the total variation in management practices (Figure 17). Factor 1 described the amount of medical care available and factor 2 the amount of keeper time. Medical care showed little variation but keeper time showed considerable scatter. However, no clear grouping could be discerned.

The management cluster diagram shows substantially more homogeneity than found in any other group of variables (Figure 18). The first bifurcation separates off one zoo that reported a very high number of keeper hours per week in cage maintenance. The second separated a zoo reporting a large number of endemic diseases requiring veterinary attention. The remaining cluster was relatively homogeneous.

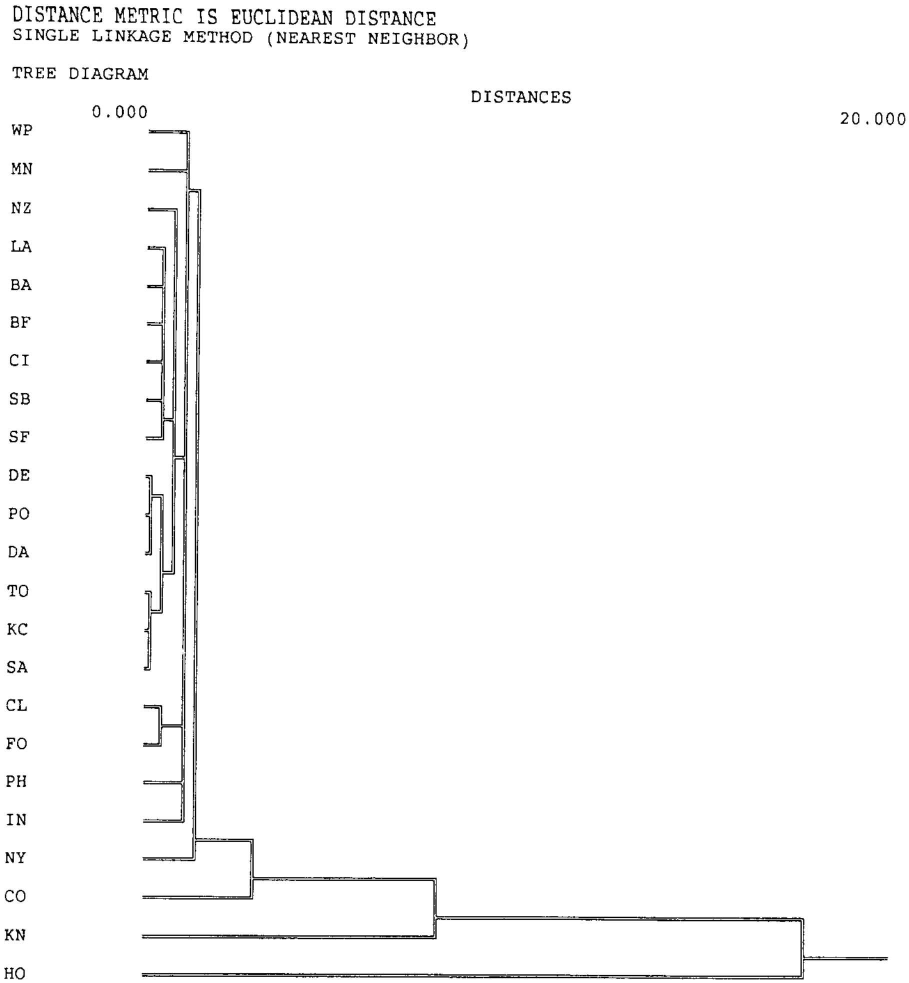


Fig. 18. Dendrogram of husbandry and medical care. For key of zoos see legend Fig. 12 (p. 140).

Synopsis

The foregoing analyses should make it clear that when groups of similar variables are examined, institutions can be clustered to show prevailing patterns of management. The analysis shows that enclosure variables are the most heterogeneous, followed by climate and then diet. Management shows a fairly homogeneous distribution, at least with the variables that I selected.

However, while these analyses organize the data and reveal some interesting patterns, no conclusions have been drawn as to what constitutes satisfactory or less than satisfactory management practices. In the next section I use discriminant analysis to determine which, if any, specific variables can differentiate zoos that have had successful management histories from those that have not.

Discriminant analysis: getting to the point

Discriminant analysis is a statistical technique that allows the researcher to study differences between groups with respect to several variables simultaneously. The analysis reduces the input variable list into one or more hypothetical functions which maximize the differences between groups. The hypothetical function(s) is then used to classify each case into one group or another based on how the case variables score on the function loadings. When the discriminant function(s) perfectly describes differences between groups, the classification will be 100%. Less than perfect discrimination results in a poorer percentage of correct classifications. Thus, the percentage of correct classifications can estimate the effectiveness of the discriminant function and its variable loadings. I arbitrarily selected 80% or better correct discrimination as my criterion for a 'good' discriminating function. Anything less was not acceptable.

First, I separated zoos on the basis of whether or not they had reproduction and asked the discriminant function to tell me what variables best discriminate successful from non-successful zoos. I performed this analysis for each variable group (enclosure, climate, diet, management). The second analysis divided zoos into those that had 50% or more adult mortality from those that had less than 50% and I asked the discriminant analysis to identify those variables that discriminate between these two groups.

Discriminant analysis for reproduction

Discriminant functions were derived for each variable grouping. In three cases the discriminant functions correctly classified more than 70% of the cases into their correct groups. The discriminant factor loadings and their percentage correct classification are presented in table 2. Enclosure variables discriminated and classified better than diet variables, followed by management and climate. These results suggest that some variables in each of these groups were important in determining success or failure in reproduction. However, the classification rate was not completely convincing. Only one discriminant function (that for enclosure variables) met the '80% or better' criterion, suggesting that additional, or better, variables were needed to refine the analysis.

Table 2. Discriminant analysis

Variable group	Reproduction		Adult mortality	
a. Enclosure	*Loading*	*P*	*Loading*	*P*
Amount of shade	0.209	0.522	0.12	0.347*
Indoor/outdoor	0.019	0.953	−0.044	0.728
Total area	−0.436	0.192*	−0.073	0.166*
Public proximity	−0.087	0.79	0.202	0.124*
Prox. of other exhibits	0.181	0.579	0.148	0.249
Public traffic flow	0.018	0.956	−0.521	0.001***
# Nest boxes	−0.354	0.284*	0.055	0.664
Nest box material	0.396	0.233*	0.01	0.935
Nest box location	0.248	0.448	0.065	0.609
% Correct discrimination	82%		94%	
b. Climate				
Total rainfall	−0.291	0.405*	0.399	0.114*
# Days 90+	−0.077	0.824	−0.044	0.856
# Days below 32	−0.19	0.585	0.648	0.014***
Mean max. humidity	0.614	0.088**	0.028	0.909
# Days snowcover	−0.134	0.699	0.524	0.042**
% Correct discrimination	71%		86%	
c. Diet				
Amount bamboo fed	−0.441	0.28*	0.233	0.359*
Grass in enclosure	0.37	0.362	0.127	0.616
Amount grass eaten	0.926	0.03***	0.144	0.57
% Roughage in diet	0.238	0.555	0.896	0.002***
Forage supplements	0.135	0.737	0.182	0.472
% Correct discrimination	77%		77%	
d. Management				
Amount keeper care	−0.616	0.315*	0.359	0.142
Amount vet care	0.359	0.554	−0.474	0.06**
# endemic diseases	−0.139	0.818	0.422	0.089**
# parasite screens	0.445	0.464	0.268	0.266
% Correct discrimination	75%		88%	

Discriminant analysis for adult survival

Here the results were much more unequivocal (Table 2). Discriminant functions for all variable groups met the '80% or better' criterion and could be considered highly predictive. This result suggested that enclosure considerations were the most important in determining red panda adult mortality rates, followed closely by climatic and management considerations.

Table 3. Discriminant analysis for adult reproduction

Variable	Loading	P
Total area	0.336	0.249
Nest box material	−0.348	0.233
No. of nest boxes	0.523	0.082
Mean maximum humidity	−0.403	0.171
Total annual rainfall	0.141	0.623
Amount of grass eaten	0.276	0.339
Amount of bamboo fed	−0.288	0.320
Amount of keeper care	−0.068	0.812

	Not classified	Reproduction	No reproduction	Total
Reproduction	5	6	1	12
No reproduction	1	2	8	11
Total	6	8	9	23
	82% correct classification			

A reliably predictive reduced variable set

Finally I wanted to see if some combination of all variables could be combined into one encompassing discriminating function. To do this I extracted the statistically most significant variables from each of the individual variable group discriminant analyses and plugged them again into two analyses for the 'successful reproduction' and '50% survivorship' questions.

The discriminant function for reproduction resulted in 82% successful classification (Table 3). Three variables, the number of nest boxes, average annual humidity and enclosure area had high loadings, suggesting they may be important to reproductive success. However, the classification percentage just met the criterion suggesting a more refined analysis should be undertaken before any firm conclusions can be drawn.

The discriminant function for adult survival resulted in 100% correct classification (Table 4). Six variables, public traffic flow patterns, % roughage in the diet, amount of veterinary help, the number of days below freezing, annual rainfall and the number of days with snowcover, had highly significant loadings. A seventh, the amount of bamboo provided, was also important.

The significance and direction of the loadings suggest the following profile of a successful zoo: moderate to high rainfall, a relatively low number of days below freezing or with snowcover, a high proportion of dietary roughage, especially with the provision of bamboo, and full time veterinary help.

Table 4. Discriminant analysis for adult survivorship

Variable	Loading	P
Public traffic flow patterns	0.334	0.003
Public proximity	−0.099	0.299
Amount of shade	−0.089	0.352
Total area	−0.061	0.517
No. of days below 32°F	−0.204	0.045
No. of days of snowcover	−0.187	0.062
Total annual rainfall	−0.192	0.056
Per cent roughage in diet	0.215	0.036
Amount of bamboo fed	0.147	0.132
Amount of veterinary care	0.209	0.040
No. of endemic local disease	−0.065	0.494

	Not classified	High (>50%)	Low (<50%)	Total
High (>50%)	6	8	0	14
Low (<50%)	2	0	7	9
Total	8	8	7	23

100% correct classification

Conclusions

1. This analysis shows that red pandas are being housed under a very wide range of management conditions. We can retrospectively examine these conditions to devise a plan to improve management.

2. Cluster analysis can successfully group zoos according to whatever variable associations one cares to arrange. Finding zoos with common management practices could facilitate the development of regional management based on real commonalities.

3. A list of critical variables was derived that perfectly discriminated successful zoos from others. This analysis should form the basis for development of improved management programs in the future. It can also serve as the basis for screening zoos who wish to participate in the SSP program in the future.

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