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Brief Report

Behavioral Preferences for Bamboo in a Pair of Captive Giant Pandas (*Ailuropoda melanoleuca*)

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Giant pandas (*Ailuropoda melanoleuca*) are members of the order Carnivora. Their diet, however, consists almost entirely of bamboo. Herbivores are under strong pressure to be selective in what they eat because of the low digestibility of plant material. The purpose of this study was to determine whether two captive giant pandas exhibited preferences among three species of bamboo: black (*Phyllostachys nigra*), bissetii (*Phyllostachys bissetii*), and arrow (*Pseudosasa japonica*). Eighteen classic choice trials were conducted in which the species were randomly paired and placed in one of two predetermined locations in the giant pandas' indoor enclosures. The pandas preferred leaves to culms or branches for each bamboo species. In the first hour of exposure, both pandas exhibited a preference for arrow bamboo. A comparison of total bamboo consumption over the course of the night indicated a strong preference for arrow bamboo by the male. The female exhibited equal preference for both arrow and bissetii over black bamboo. Further examination of feeding behavior determined that the pandas processed arrow bamboo behaviorally more efficiently than the other two species. This is the first study to experimentally assess bamboo preferences in giant pandas, and may have implications for husbandry and management programs as well as strategies for in situ conservation. Zoo Biol 24:177–183, 2005. © 2005 Wiley-Liss, Inc.

Key words: behavioral mechanisms; diet selection; foraging efficiency; giant pandas; nutrition

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INTRODUCTION

Optimal foraging theory posits that animals are under strong selective pressure to maximize energetic gains and minimize energetic costs of foraging [MacArthur and Pianka, 1966]. Many factors contribute to dietary preferences such as the size of prey, palatability, handling time, encounter rate, susceptibility to predation while foraging, and digestibility of the nutritional components. Bamboo makes up 99% of the giant panda diet (*Ailuropoda melanoleuca*) [Schaller et al., 1985]. Giant pandas have traits that are presumably adaptive for processing bamboo. For example, they have flattened molars and extensive jaw muscles [Owen, 1980; Eisenberg, 1981]. Pandas also have a "pseudothumb" that they use to manipulate bamboo, stripping branches and leaves with their teeth to create a bundle of leaves that extend from the side of their mouths. After obtaining enough plant material in their mouth, giant pandas use their pseudothumb and forepaw to take hold of the leaves and eat it in smaller bites. The forepaw is also used for manipulation of the culm while stripping the sheath to expose the palatable pith. These morphological traits presumably increase foraging efficiency.

The panda's inability to digest a large proportion of the bamboo they eat should lead to dietary selectivity. Pandas in the wild and in captivity are selective for particular parts of bamboo plants [Dierenfeld et al., 1982; Schaller et al., 1985]. Leaves are preferred to culms or branches presumably because they are the most digestible. At certain times of the year, however, wild pandas shift their feeding preference to old culms [Schaller et al., 1985], perhaps as a result of increasing levels of silica in the leaves. It has been suggested that wild pandas have preferences for certain bamboo, but it may simply be that these species are the most abundant in the habitat [Wei et al., 2000].

Our objective was to determine whether captive giant pandas have preferences for certain bamboos and to identify the behavioral factors that may influence feeding preference. Three bamboo species were presented: black bamboo (*Phyllostachys nigra*), bissetii bamboo (*Phyllostachys bissetii*), and arrow bamboo (*Pseudosasa japonica*). They were chosen because both arrow and black bamboo were novel to the pandas, bissetii had only been offered on a few occasions, and all three were available on grounds at the Smithsonian National Zoological Park.

MATERIALS AND METHODS

Subjects

The subjects of this study were two giant pandas, a 4-year-old female born in 1998 and a 5-year-old male born in 1997. At night, the male and female panda were given 8 and 5 kg of yellow groove bamboo (*Phyllostachys aureosculcatea*) respectively in their separate holding areas. During choice trials, 8 and 5 kg of each of the test species were offered to each panda so that the pandas could feed to satiety on one species alone. All bamboo was collected twice a week and stored in a climate controlled shed where it was misted until it was used.

Procedure

Eighteen classic choice trials were conducted from 10/01/02–11/6/02, on alternating days. In each trial, two of three bamboo species were randomly paired and placed in one of two predetermined locations in the indoor enclosure to control for position effects. The pandas were observed for 1 hr immediately after exposure to the bamboo. The total amount of time the pandas spent feeding on each species and each plant part were determined. Total weights of bamboo provided at night and left over in the morning were recorded to determine the quantity of each species consumed overnight. Consumption values were corrected for water loss by expressing values on a dry matter basis. Preference was assessed by comparing the amount of time the pandas spent feeding on each bamboo during the first hour and total amount of bamboo consumed overnight in kilograms of dry matter [Peterson and Renaud, 1989; Manly, 1993].

We also examined the efficiency with which the pandas handled and processed the leaves of each bamboo. For 3 consecutive days, one of the daily feedings consisted of 10 kg of one of three species used in the choice trials. The total amount of time it took the pandas to strip the leaves from each species and form a bundle in their mouth and the number of bites of branches or leaves from the culm necessary to create each of 175 total bundles. Ninety-five percent confidence intervals (CI) were calculated about the mean of each of the dependent variables for the preferred species or plant part (defined as that species or part consumed for longer periods of time during the first hour or in greater amounts overnight than the other species). Means of the non-preferred species or part were considered significantly different from the preferred when they fell outside of the CI [Bard and Nadler, 1983; Hays, 1994].

RESULTS

The female panda preferred the leaves of each of the species of bamboo to either the culms or both leaves and culms (Table 1). The male also spent significantly more time feeding on the leaves of arrow bamboo than a combination of leaves and branches. The difference between the time he spent feeding on arrow bamboo leaves and culm was not significant. The male spent significantly more time feeding on bissetii and black bamboo leaves than culm or a combination of leaves and branches. In the first hour of exposure, both pandas spent significantly more time feeding on arrow bamboo than the others (Table 2). Furthermore, the male consumed significantly more arrow bamboo overnight when it was available than either bissetii or black bamboo. The female consumed significantly more bissetii bamboo and arrow than black bamboo. The difference between the amount of bissetii and arrow bamboo the female consumed overnight was not significant.

Of the three species of bamboo provided (Fig. 1), arrow bamboo required the least number of bites to strip leaves from the culm ($X = 4.11$; $CI = 3.66 < X < 4.55$) and the least amount of time in seconds to create a bundle of leaves for consumption ($X = 9.19$; $CI = 8.12 < X < 10.26$). Bissetii bamboo required an average of 5.71 bites to create a bundle and an average of 10.58 sec for consumption. Black required an average of 5.5 bites and 11.17 sec for consumption.

TABLE 1. Time feeding on different plant parts by the female and the male and the CI associated with the preferred plant part

	Plant Part Consumed[a]			
	Leaves	Culm	Both	CI based on preferred plant part
Female				
Arrow	99.2[b]	0.1	0.0	99.2–100
Bissetii	97.5[b]	2.1	0.4	92.3–100
Black	88.4[b]	4.0	7.6	71.8–100
Male				
Arrow	51.7[b]	47.5	0.8	39.9–63.4
Bissetii	67.2[b]	15.4	17.5	46.3–88.0
Black	53.8[b]	14.7	4.3	27.5–80.2

[a]Mean percentage of time.
[b]Preferred plant part was defined as that which was consumed for a greater percentage of the time during the first hour of exposure.

TABLE 2. Time feeding on and amount consumed of each species

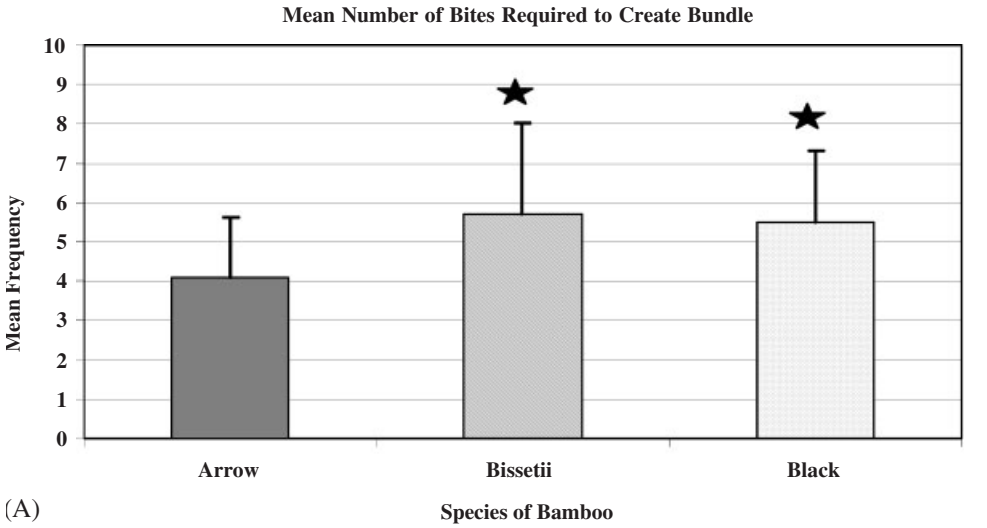
	Bamboo Species			
	Arrow	Bissetii	Black	CI based on preferred plant part
Female				
First Hour (mean % of time)	71.9[a]	49.3	28.8	63.4–80.4
Overnight (kg)	0.7	1.0[a]	0.6	0.7–1.2
Male				
First Hour (mean % of time)	73.7[a]	47.9	28.5	55.2–92.2
Overnight (kg)	1.7[a]	1.1	1.3	1.4–1.9

[a]Preferred species was defined as that which was consumed for a greater percentage of the time during the first hour of exposure or overnight.

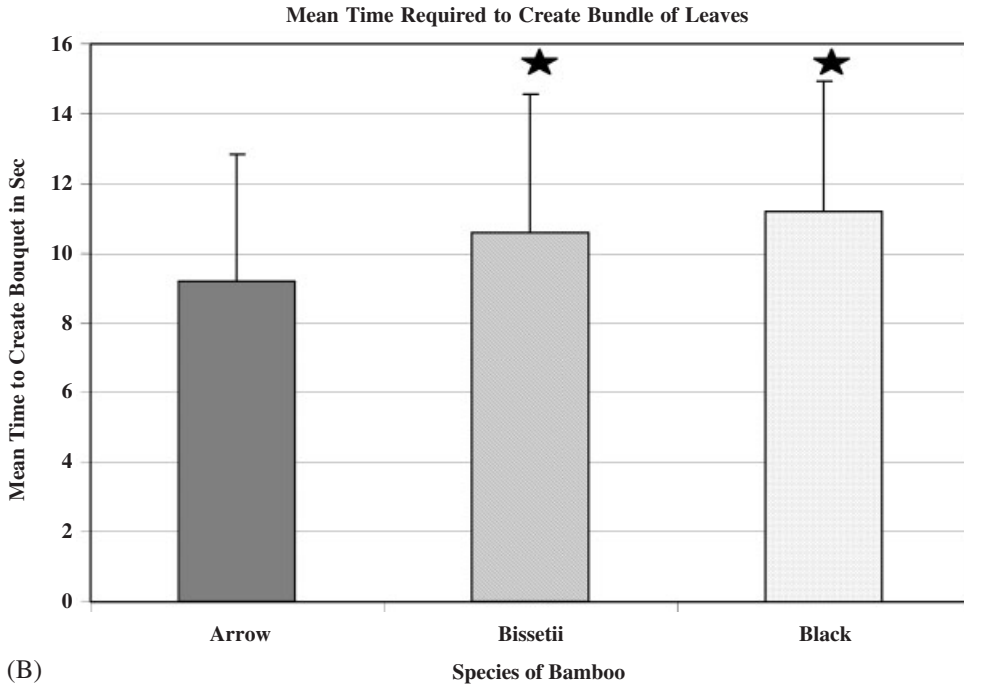
DISCUSSION

Like other giant pandas [Dierenfeld et al., 1982; Schaller et al., 1985; Mainka et al., 1989], our subjects preferred the leaves of bamboo to the culm or a combination of branches and leaves. Leaves are of greater nutritive value than culms or branches [Dierenfeld et al., 1982]. Both pandas exhibited a preference for arrow bamboo over the other species, as measured feeding in the first hour. The female consumed more kilograms of bissetii overnight than either arrow or black bamboo, although the difference between the amount of arrow and bissetii consumed was not significant.

Why was arrow bamboo preferred over the other species? It is possible that arrow is somehow nutritionally superior to the other two bamboo species. Nutritional aspects are underway, but preliminary results based on a single sample of each species of bamboo did not indicate any striking differences in the nutritional components of each of the species (unpublished data, 2003). Furthermore, a recent study of the nutritional quality of 12 bamboo species, including *Pseudosasa japonica* and several members of the genus *Phyllostachys*, found very few differences between any of the species [Hunter et al., 2003]. Although their study did not include the same



(A)



(B)

Fig. 1. Mean number of bites necessary for the pandas to create a bundle of leaves (A) and the average amount of time in seconds for the pandas to create a bundle of leaves for each species of bamboo (B). Stars represent statistically significant results.

species of *Phyllostachys* as ours, these results suggest that features affecting selectivity other than nutritional differences may be more important.

It is possible that there were more leaves on the culms of the arrow bamboo than on the culms of black or bissetii, making it more attractive. Mainka et al. [1989]

reported that the pandas in their study consumed more of *Phyllostachys aureosulcata* (17.8% leaves) than *Fargesia spathaceus* (5.6% leaves) when both species were offered simultaneously. Although we did not count the number of leaves on each stalk of bamboo provided, arrow bamboo seems to have fewer leaves than black or bissetii when looking at the whole plant.

Another possible explanation for the observed preference for arrow bamboo may be ease of processing. A detailed examination of the efficiency with which the pandas were able to process the leaves of bamboo indicated that it required significantly fewer bites and less time for the pandas to create a bundle of leaves in their mouth for arrow bamboo compared to the other species. Therefore, the pandas were able to process arrow bamboo more efficiently than the other species. Arrow bamboo differs morphologically from the other species in that it has larger leaves (20–36 cm $\times$ 2.5–3.5 cm) and smaller diameter culms ($\sim$1.5 cm) than the leaves (4–13 cm $\times$ 0.8–1.8 cm) or culms ($\sim$20 cm) of species of the genus *Phyllostachys* [Darke and Griffiths, 1994]. Also, the leaves of arrow bamboo are basally aggregated, extending from a single primary branch from each mid-culm node [Watson and Dallwhite, 1994]. In contrast, the leaves of *Phyllostachys* are attached to many branches that radiate from a primary branch on each mid-culm node. These differences could affect handling time and foraging efficiency.

It could be argued that intake rate was higher for arrow bamboo because they simply ate the species they preferred more quickly. Intake rate has been shown in other studies to be controlled more by physical or morphological characteristics of the plant species than any other factor [Illius et al., 1995, 1999]. The results of our examination provide a compelling argument for a ''rule-of-thumb'' explanation of bamboo selectivity in the giant panda, whereby food items to be consumed are chosen on the basis of some discriminative feature of the food. In this study, the discriminative features may be the size and aggregation of the leaves. Rules-of-thumb allow foragers to increase foraging efficiency without having to have prior information about the specific chemical composition of the food [Cassini, 1994].

This is the first experimental examination of bamboo preferences in captive giant pandas Optimal foraging theory predicts that the bamboo species that has the greatest nutritive value and requires the least processing time should be the preferred species. Extensive nutritional analyses are being conducted on the species used in this study. Because of the small sample size, the results of this study are difficult to generalize to other giant pandas. Furthermore, our data were collected in the months of October and November. It is known that wild pandas are selective for species, parts or ages of bamboo and that these preferences change seasonally [Schaller et al., 1985; Taylor and Qin, 1987; Reid and Hu, 1991; Wei et al., 2000]. Clearly more longitudinal studies are needed; however, our results may have both ex situ and in situ implications. Research of this type may impact the feeding captive pandas in captivity as well as affect the management of pandas in the wild, informing choices of land allocation for reserves and reintroduction.

CONCLUSION

Giant pandas in our study preferred the leaves to the culm of the bamboo species tested. Arrow bamboo (*Pseudosasa japonica*) was preferred when it was paired with either black (*Phyllostachys nigra*) or bissetii bamboo (*Phyllostachys*

bissetii), perhaps because the giant pandas were able to process the arrow bamboo more efficiently. Research on diet selectivity in giant pandas could have implications for the choice and allocation of land for reserves and the planning of reintroduction programs.

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