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ASSESSING THE DIET OF DINGOES FROM FECES: A COMPARISON OF 3 METHODS

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Abstract: I assessed diet of the dingo (*Canis familiaris dingo*) from 2,495 fecal samples using frequency of occurrence of prey types, relative weight of remains of prey types, and biomass of ingested prey types. There were no significant differences between methods in ranking prey types provided that ≥70 fecal samples/month were analyzed. The widely used frequency method that is used to understand what and relatively how much is eaten is justified in diet studies of dingoes and other carnivores. Only the biomass ingested method allows an evaluation of the biomass or numbers of particular prey species that are eaten. For dingoes, and probably also for other carnivores, objective adjustments need to be applied to account for differences in size between juvenile and adult large prey species and for differences in the proportion of each age class eaten.

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Analysis of prey remains in feces is widely used to assess carnivore diets (Putman 1984), but methods of analysis vary in complexity and accuracy in representing the proportions of prey ingested. Discrepancies are due mostly to differences in prey size especially when the relative surface to volume ratio of small animals provides disproportionately more identifiable remains (primarily hair and feathers) than large animals (Mech 1970). Also, some ingesta have different rates of digestion (Putman 1984).

The most commonly used and easily applied method of diet analysis is frequency of occurrence of prey types/sample of feces (Leopold and Krausman 1986, Maehr and Brady 1986, Rabinowitz and Nottingham 1986). Individual prey types are scored on a presence or absence basis, and hence the frequency of small prey may be overemphasized. An additional problem of interpreting these data occurs when several related prey species occur within 1 fecal sample, so percent occurrence of a category of combined prey taxa in the total sample may exceed 100%. Other methods used to establish the relative importance of different prey involve estimating the relative amount (wt and vol) of prey remains in feces (Jenkins et al. 1979, Wise et al. 1981) or applying correction factors to convert feces content to the weight or number of prey ingested (Floyd et al. 1978, Greenwood 1979, Kruuk and Parish 1981). Despite the theoretically greater accuracy provided, correction factors are not widely used, presumably because methods are time-consuming, prey data are unavailable, and it is often assumed that use of correction factors would not alter the conclusions of general diet studies.

I tested 3 different methods of fecal analysis (frequency of occurrence, wt of prey remains, and biomass of ingested prey) for differential assessment of diets, and determined if differences influenced conclusions about the importance of different prey types. Dingo feces were analyzed because the dingo has a diverse diet (Corbett and Newsome 1987) and its feces often contain the remains of several prey species.

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METHODS

The study was conducted at the 614-km^2 Kapalga Research Station (12°37′S, 132°25′E) within Kakadu National Park in the Northern Territory of Australia. Radio-tracking studies indicated that the number of dingoes (approx 60 ad) remained relatively constant over the 2-year study (L. K. Corbett, unpubl. data). Fecal samples were collected each month between 1980 and 1982 from 55 0.5-km transects along roads. Pieces of feces within 1 m^2 were considered to represent 1 sample; different samples at the same site were distinguished by obvious differences in color and smell.

In the laboratory, individual fecal samples were oven-dried at 85 C for 2.5 days, weighed, and components separated. Most mammals were identified using hair structure (cuticle scales and/or medullary patterns). Mammalian remains (bones, ears, feet, teeth), bird remains (feathers, bones, feet, beaks), and insects were identified macroscopically, by comparison with museum specimens. Remains of flesh were assumed to be associated with other identifiable remains (hair, feathers, bones). Flesh remains in samples containing ≥2 prey species were apportioned proportionally. Most remains were identified to species or order; together they were defined as prey types.

All fecal samples were analyzed by 3 methods: frequency of occurrence (Leopold and Krausman 1986), relative weight of remains (Wise et al. 1981), and biomass of prey ingested (Floyd et al. 1978). Frequency of occurrence was calculated as the number of occurrences of each prey type divided by the number of fecal samples and expressed as a percentage of the monthly and total sample.

The relative weight of remains method was calculated by estimating visually the fraction of each prey type/fecal sample and then multiplying by the dry weight of the fecal sample. The resulting products were summed to provide a monthly and total score for each prey type.

The biomass of prey ingested method was calculated by (1) visually estimating the fraction of each prey type/fecal sample and then summing to give the equivalent number of fecal samples (n) representing a particular prey type in the monthly and the total sample, (2) estimating the weight of prey eaten/fecal sample (y) for each prey type using Floyd et al.'s (1978) regression equation: $y = 0.38 + 0.02x$, where x is the mean adult weight of a given prey type (Table 1), and (3) multiplying each y by the number of feces representing the corresponding prey type in the monthly and total sample. The product $[n(y)]$ provided the total weight of each prey type consumed for the monthly and the total sample. In this study, adjusted weights (x) were used for large prey (feral buffalo [*Bubalus bubalis*], cattle, horse, pig) to account for differences in size between juvenile (1–6 months) and adult (18–48 months) animals, and for differences in the proportions of juveniles and adults in dingo feces. For each species, adjusted weights were calculated by summing the products of mean animal weight and proportion in feces for juvenile and adult animals, respectively. Juvenile pigs ($\bar{x}$ wt = 16 kg) were distinguished from adults ($\bar{x}$ wt = 68 kg) in feces, based on the size of feet, ears, and bones. For all occurrences of pig in feces, the proportion of juvenile and adult remains was 22.3 and 1.3%, respectively. This provided a juvenile to adult ratio of 0.94:0.06 which I assumed was indicative of the indeterminate pig remains (76.4%) in feces. The adjusted weight for pig was calculated as $(16 \times 0.94) + (68 \times 0.06) = 19$ kg. Similarly, the proportions and ratios for juvenile buffalo ($\bar{x}$ wt = 85 kg) and adults ($\bar{x}$ wt = 371 kg) were 8.0, 0.5, and 0.94:0.06, respectively. Similar values were assumed for cattle and horse ($\bar{x}$ juv and ad wt = 68, 300 and 53, 364 kg, respectively). The derived adjusted weights for buffalo, cattle, and horse were 102, 82, and 72 kg, respectively.

Only prey types occurring in ≥5 fecal samples were used because I assumed that infrequently occurring prey were not likely to be important and could distort results. Prey types were ranked in order of greatest to least numerical value for each of the 3 methods. The Kendall coefficient of concordance (W) was calculated to simultaneously test the null hypothesis that there was no significant difference in the rankings of prey types in dingo feces using 3 methods, for the monthly and total sample. In addition, for each method, prey were ranked similarly and Spearman rank correlation coefficients (r_s) were calculated to test for differences between pairs of methods for the monthly and total sample. Significant values of W and r_s ($P < 0.05$) were assumed to indicate that there were no significant differences between methods and that any method could be used to assess the relative importance of prey in the dingo's diet.

RESULTS

I collected 32 prey types from 2,582 fecal samples over 23 months. Most (79.2%) contained a single prey type, 18.7% contained 2 prey types, and 2.2% contained 3–5 prey types. Prey types whose total occurrences were <5 (12 prey types, $n = 27$ occurrences), unidentified remains ($n = 105$), plants ($n = 287$, mostly grasses), and other remains ($n = 13$) where mean prey weights could not be estimated, were excluded; 2,495 fecal samples were analyzed. Data for some months were combined to provide adequate sample sizes.

I calculated the mean adult weight, rankings of frequency, score, and biomass eaten for 20 prey types (Table 1). All values of W were significant (Table 2) indicating good agreement between the 3 methods in ranking prey for monthly and total data, and suggesting all methods provided similar assessments of dingo diet.

Table 1. Prey in 2,495 dingo fecal samples from the Northern Territory of Australia, 1980–82, using 3 methods of analysis.

Prey	$\bar{x}$ adult wt (kg)	Methods of analysis: Frequency of occurrence *n*	Rank	Relative wt of remains Score	Rank	Biomass ingested kg	Rank
Dusky rat	0.06	1,001	1	16,102	1	328.8	1
Magpie goose	1.20	909	2	14,715	2	278.3	2
Agile wallaby (*Macropus agilis*)	15.00	318	3	6,154	3	192.3	4
Northern brushtail possum (*Trichosurus arnhemensis*)	1.50	277	4	4,565	4	100.7	5
Feral buffalo	102.00[a]	107	5	2,319	5	206.1	3
Antilopine wallaroo (*Macropus antilopinus*)	20.00	76	6	1,081	8	56.1	6
Feral pig	19.00[a]	70	7	1,340	6	40.0	8
Northern brown bandicoot (*Isoodon macrourus*)	1.60	65	8	1,214	7	24.6	9
Feral cattle	82.00[a]	25	9	577	9	47.0	7
Small mammal, undetermined species	0.04	19	11	312	10	5.8	11
Beetle, undetermined species	<0.01	19	11	75	17	1.7	17
Insect, undetermined species	<0.01	19	11	45	19	0.9	20
Small bird, undetermined species	0.32	11	13	172	11	4.6	12
Feral cat	4.20	8	14.5	127	13	3.7	13
Grasshopper, undetermined species	<0.01	8	14.5	18	20	1.5	19
Bush thick-knee (*Burhinus magnirostris*)	0.29	7	16.5	119	14	2.3	14
Northern rosella (*Platycercus venustus*)	0.12	7	16.5	53	18	1.6	18
Rajah shelduck (*Tadorna radjah*)	0.88	6	18.5	132	12	2.0	15
Northern quoll (*Dasyurus hallucatus*)	0.50	6	18.5	90	15	1.8	16
Feral horse	72.00[a]	5	20	87	16	6.0	10

[a] Adjusted wt to account for size differences between ad and juv animals, and the proportions of ad and juv eaten.

Significant correlations between pairs of methods for total data and for monthly samples (Table 2) supported the result.

DISCUSSION

Dusky rats (*Rattus colletti*) and magpie geese (*Anseranas semipalmata*) were always ranked first and were the most important prey identified by all methods (Table 1). Prey types occupying ranks 3–9 showed good agreement in ranking between all methods, but lower ranked prey types (10–20) showed least agreement. Two explanations for discrepancies and suggested solutions follow because differences in ranking between methods may be crucial to an understanding of the relative importance of different prey types.

First, very small prey (insect categories), predictably, were assigned relatively high rankings by the frequency of occurrence method, whereas very large prey (buffalo, cattle, horse) were emphasized by the biomass-ingested method. Although the biomass-ingested method accounted for differences in surface to volume ratios between large and small prey (Floyd et al. 1978), there are other inherent biases. For example, it is difficult to assess how much of each large prey is consumed. I attempted to reduce that bias by using adjusted weights for large prey to account for differences in size between juveniles and adults, and for differences in the proportion of each age class eaten by dingoes.

Secondly, major ranking discrepancies involved prey types rarely consumed (Table 1). For monthly samples, all correlations between pairs of methods were significant except for comparisons in February, March 1981, and March 1982 that used low numbers of fecal samples (29–70) and/or few comparisons of prey types (5–9) (Table 2). Given the significant positive relationship between the number of fecal samples collected/month and the number of contained prey types ($r = 0.83$, $n = 21$, $P < 0.001$) (Table 2), I suggest that a minimum of 70 fecal samples/month should contain sufficient numbers of prey types for a reliable assessment of dingo diet for all 3 methods of analysis.

Similar procedures should apply to other carnivores. If an investigator wishes to determine only the composition and relative amounts of prey eaten, the frequency of occurrence method is justified because, compared to other methods, it is simple to apply, least time consuming, and results may be compared directly with most other studies of the same and different carnivore

Table 2. Comparison of 3 methods of fecal analysis to assess dingo diet in the Northern Territory of Australia, 1980–82, using Kendall's coefficient of concordance (W) and Spearman rank correlation coefficients (r_s).

Date	No. fecal samples	No. prey types	Methods of analysis[a] All methods (W)	1 vs. 2 (r_s)	1 vs. 3 (r_s)	2 vs. 3 (r_s)
1980						
May	147	10	0.914**	0.94***	0.87**	0.85**
Jun	195	15	0.858**	0.74**	0.73**	0.93***
Jul	181	14	0.927***	0.93***	0.88***	0.90***
Aug	157	11	0.957**	0.95***	0.93***	0.94***
Sep	103	7	0.905**	1.00***	0.79*	0.79*
Oct	93	10	0.939**	0.97***	0.92***	0.94***
Nov	106	12	0.944**	0.97***	0.89***	0.96***
Dec	73	8	0.874*	0.92**	0.67*	0.86**
1981						
Jan	91	8	0.876*	0.89**	0.68*	0.90**
Feb	29	5	0.867**	1.00**	0.70 NS[b]	0.70 NS
Mar	70	9	0.794*	0.94***	0.56 NS	0.60*
Apr	55	10	0.860**	0.86**	0.66*	0.87**
May	143	11	0.890**	0.91***	0.79**	0.90***
Jun	185	13	0.927***	0.94***	0.89***	0.92***
Jul	172	11	0.850**	0.93***	0.66*	0.74**
Aug	205	14	0.928***	0.96***	0.91***	0.95***
Sep	225	14	0.945***	0.93***	0.92***	0.93***
Oct	117	13	0.919***	0.97***	0.83***	0.88***
Nov–Dec	68	11	0.829**	0.89***	0.75**	0.75**
1982						
Jan–Feb	39	8	0.860*	0.93**	0.71*	0.76*
Mar	36	7	0.716*	0.83*	0.31 NS	0.63 NS
Total	2,495	20	0.902***	0.85***	0.82***	0.94***

[a] Method 1 = frequency of occurrence; 2 = relative wt of remains; 3 = biomass ingested.
[b] NS = not significant ($P > 0.05$).
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

species. However, for studies conducted to determine the importance (biomass) of different prey species, only the biomass-ingested method uses a meaningful biological unit (kg eaten) that accounts for differences in size and age of prey. Biomass may be divided by mean prey weights to obtain the number of prey individuals consumed and more complex hypotheses about the feeding ecology of carnivores and predator–prey interactions (e.g., niche separation, competition, and the impact of predation on prey populations) can be investigated.

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