In tribute to all your lovely cats on Zoom,

this year's exam will be dedicated to...cats.

Enjoy!

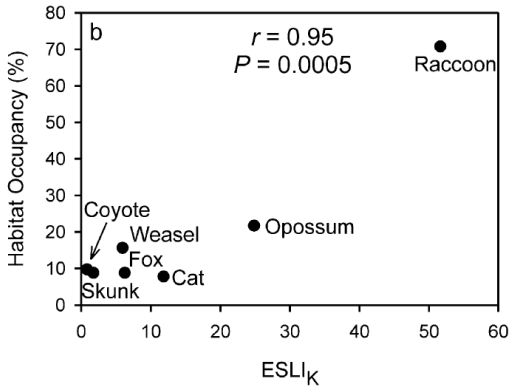
Section 1 – Short answer

1. (2.5 pts each; 10 pts total) The plot below is from a paper by Gehring and Swihart (2003) on the response of mammalian predators to landscape fragmentation. The x axis is a unitless measure of carrying capacity, and the y axis represents percentage habitat occupancy. If the best-fit regression line (not shown) has a slope of 1.2, which species (if any) have:

a) Large residual?

b) High leverage?

c) High influence?



d) In words, how would you interpret the p-value for this linear regression?

2. (5 pts) Two variables can be uncorrelated (in the sense of having $\rho = 0$) but not be independent, while two variables that are independent are necessarily uncorrelated. Draw a scatterplot of two variables that have $\rho = 0$ that are not independent.

3. (25 pts)

Woods et al. (2003) study the predation activities of cats in Great Britain.

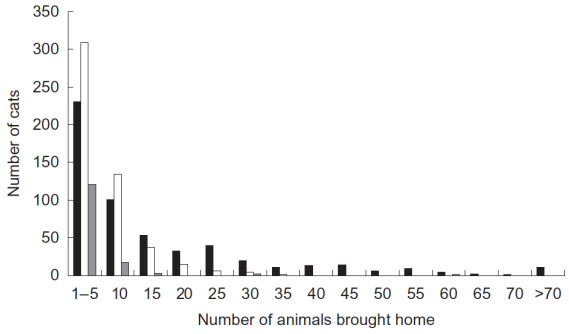


Fig. 1. Frequency distribution of the number of mammals (black columns), birds (white columns) and herpetofauna (grey columns) brought home by 696 individual cats. For numbers of cats that brought home none of these prey groups, see Table 3.

(a) Name a parametric distribution that might describe the number of mammals brought home by cats in this study. (2.5 pts)

(b) What distribution should be used to describe the allocation of predated animals in each of the three categories (mammals vs. birds vs. herpetofauna). (2.5 pts)

(c) Using the information provided in the text snippet below, calculate the (approximate) variance in the number of mammal species brought home by cats. (10 pts) (There are at least two ways to answer this question using the information provided. +5 bonus points if you list two ways.)

[redacted] The frequency distribution of the numbers of animals brought home by each cat was markedly skewed (Fig. 1). For 467 cats that brought home mammals that could be identified to species, the mean number of species brought home was 2.4 (95% CI 2.2–2.5, range 1–9). [redacted]

(d) Using the information provided in the text snippet below, calculate the number of cats used to estimate the correlation between the number of mammals and birds brought home. (5 pts)

mean condition was 2.0 (95% CI 1.9–2.1). There was a significant positive correlation between the numbers of mammals and birds brought home ($r = 0.23$, d.f. = 280, $P < 0.001$), though [redacted]% of the variation in the numbers of birds brought home remained unexplained by the number of mammals. The sex of the cat did not significantly affect either the numbers of

e) Using the same snippet from (d), calculate the % of unexplained variation (redacted from the text provided). (5 pts)

4. In the same study as the previous question, Woods et al. provide the following table for the distribution of prey items brought home by cats in their study. (4 pts each; 16 pts total)

Table 2. Prey items, grouped by taxon, that were brought home by 986 cats in 618 households. For a more detailed list of prey items see the Appendix

Class/order	Total	%	Class/order	Total	%	Class/order	Total	%
Mammalia	9852	68.6	Reptilia	144	1.0	Arachnida	9	0.1
Insectivora	1852	12.9			1.0			
Chiroptera	30	0.2	Amphibia	590	4.1	Crustacea	1	<0.1
Carnivora	17	0.1	Anura	568	3.9			
Rodentia	6369	44.3	Urodela	22	0.2	Gastropoda	6	<0.1
Lagomorpha	1243	8.6	Osteichthyes	31	0.2			
Unidentified mammal	341	2.4			0.2	Oligochaeta	21	0.1
Aves	3391	23.6	Insecta	134	0.9			
Anseriformes	6	<0.1	Coleoptera	4	<0.1	Unidentified	191	1.3
Charadriiformes	1	<0.1	Dermaptera	1	<0.1	Total	14370	100.0
Columbiformes	147	1.0	Diptera	6	<0.1			
Galliformes	21	0.1	Hymenoptera	7	0.2			
Passeriformes	2698	18.8	Lepidoptera	84	<0.1			
Piciformes	2	<0.1	Odonata	25	0.6			
Ralliformes	9	0.1	Orthoptera	7	<0.1			
Unidentified bird	507	3.5						

Use the information in Table 2 to answer the following questions about the probability of prey items (all probabilities should include the 191 unindentified prey items as well):

a) What is the probability $P(Mammal)$?

b) What is the $P(Aves \cup Gastropoda)$?

c) What is the $P(Lepidoptera|Insecta)$?

d) What is the $P(Lepidoptera|Insecta^C)$?

5. (50 pts)

Paw preferences in cats (*Felis silvestris catus*) living in a household environment

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Pike and Maitland study the "handedness" of domestic cats.

Paw preference	Total cats		Male cats		Female cats	
	n	%	*n*	%	*n*	%
Left-preferent	45	39	27	52	20	32
Right-preferent	56	49	21	40	33	53
Ambilateral	13	12	4	8	9	15
Total	114	—	52	—	62	—

Paw preference in domestic cats: A combination of data from Tan et al., 1990 and the present study.

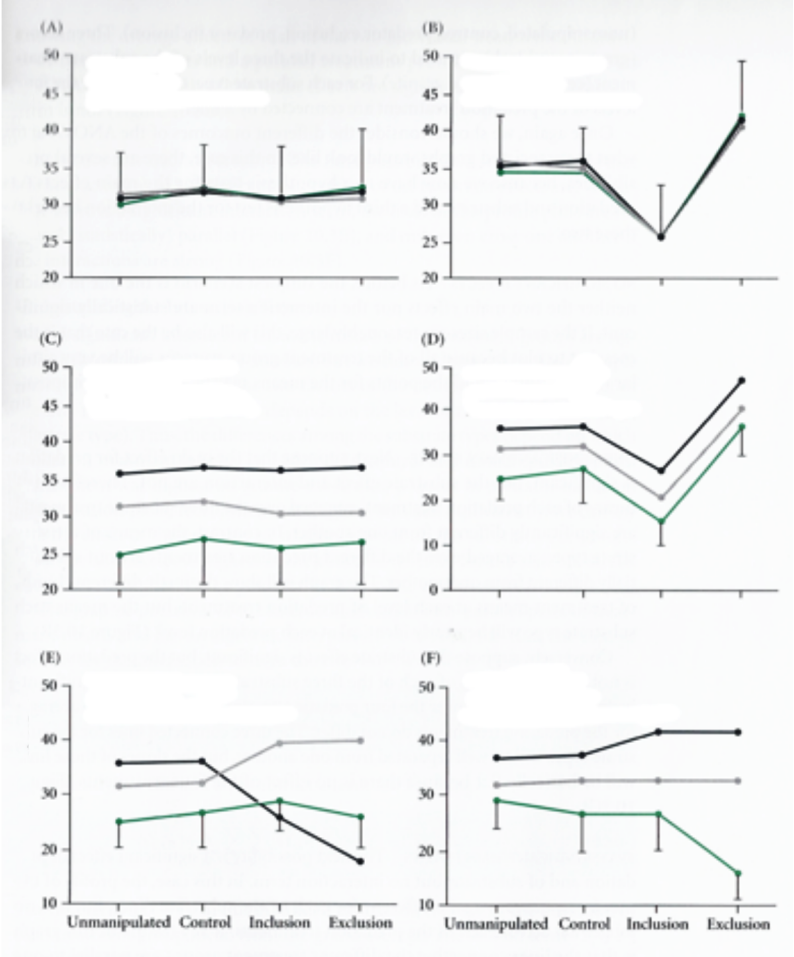
a) What is the maximum likelihood estimator for the percentage of cats (of either sex) that are ambilateral? (I'm looking for a number, not an equation.) (5 pts)

b) Describe a permutation-based method that you could use to test the null hypothesis that handedness (left, right, or ambilateral) was independent of sex. Be sure to identify a test statistic and a method for generating its distribution under the null hypothesis. (15 pts)

c) Write down the most appropriate parametric model to test this same hypothesis. Define all terms used. Be sure to identify the test statistic and its distribution under the null hypothesis. (15 pts)

6. (18 points)

The figure on the following page illustrates the possible outcomes for a hypothetical experiment testing for the effects of cats and rats on species richness. (Species richness is on the y-axis and is not labeled in the figure.)



Each symbol represents a different treatment combination mean. Rat exclusion treatments are indicated by the x-axis label (unmanipulated, control, inclusion, exclusion) and cat scenarios are indicated by the different shades of gray and green (black=cats indoors only; gray = cats fed but allowed to roam free; green = cats not supplementally fed and allowed to roam free). The partial error bars represent + or – 2 standard error and should be assumed equal across all three cat scenarios. (Most of the error bars have been left off the plot for clarity. The exact size of the error bars is inconsequential to the question.)

For each panel (A-F), decide whether the main effect of rat exclusion, the main effect of different cat scenarios, and the interaction of rat exclusion and cat scenario is significant ($p<0.05$) or not significant.

Panel A
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Panel B
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Panel C
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Panel D
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Panel E
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Panel F
Rats: significant / not significant (circle one)
Cats: significant / not significant (circle one)
Rats x Cats: significant / not significant (circle one)

Section 2 – Long answer

7. (91 pts)

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The prey of domestic cats (*Felis catus*) in two suburbs of Auckland City, New Zealand

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(Accepted 9 July 2002)

Gillies and Clout (2003) describe a study of domestic cat predation in Auckland City, New Zealand.

The number of prey items is recorded for a number of cats living in two locations (Oratia and Browns Bay) and the authors model the number of prey items as a function of the following covariates: prey taxa (divided into 4 categories: rodents, invertebrates, birds, lizards), site (Oratia vs. Browns Bay), cat sex (male vs. female) and cat age (measured as a continuous variable).

PART 1 (31 pts)

a. Write down the **complete** model equation for this model, using your best judgement to determine what the most appropriate linear model should be. (15 pts)

b. How many parameters does this model (from part a) have? (4 pts)

c. Is prey taxa best considered a fixed or random effect. Why? (2 pts)

d. Is cat sex best considered a fixed or random effect. Why? (2 pts)

e. Is cat age best considered a fixed or random effect. Why? (2 pts)

f. Is site best considered a fixed or random effect. Why? (Hint: This one is a bit tricky) (2 pts)

g. State the null hypothesis being tested with regards to the effect of ‘prey’. (4 pts)

PART 2 (60 pts)

Regardless of the model described in Part 1a, we are going to assume that the response variable (number of prey items caught) is modelled as a Normal distribution for the purposes of ANOVA. We will also simplify the model to include just two covariates (Site and Sex) that we will model as a two-way fixed factor ANOVA with an interaction. We will further specify that there were 40 cats total, evenly divided between Sites and Sex (10 female cats in Oratia, 10 female cats in Browns Bay, 10 male cats in Oratia, 10 male cats in Browns Bay).

h. Fill in the gray squares to complete the appropriate ANOVA table for the analysis of #Items ~ Sex + Site. (Since you don't have data, just fill in the appropriate equations in the ANOVA table.) I have labeled each box with a letter corresponding to the space below the table where you should write the equation. Be sure to include any and all subscripts/indices required in your equations. For E-I, I am looking for a number (not an equation). For the p-value column (U,V,W), write the R code you would need to calculate the associated p-value. (2 pts each; 46 pts total)

Source	Degrees of freedom	SS	MS (leave as ratio)	F-ratio (leave as ratio)	p-value
A	E	J	O	R	U
B	F	K	P	S	V
C	G	L	Q	T	W
D	H	M	N/A	N/A	N/A
Total	I	N	N/A	N/A	N/A

A:

B:

C:

D:

E:

F:

G:

H:

I:

J:

K:

L:

M:

N:

O:

P:

Q:

R:

S:

T:

U (R code):

V (R code):

W (R code):

i. In words, how would you interpret a significant interaction in this case? (4 pts)

j. Let's imagine that the experiment was imbalanced in the sense that there were only 8 male cats in Browns Bay. Which cells of the ANOVA table will change as a result? What impact will this have on your ability to test a hypothesis about the two main effects? (10 pts)

8. (40 pts)

Anim. Behav., 1986, **34,** 1016–1025

A method for rating the individual distinctiveness of domestic cats

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Feaver et al. (1986) set out to measure cat personality traits. They wanted to know whether multiple observers would record the same score for 18 cat traits shown in Table II. (The specific cat traits are not important for the question.) The traits were scored on a 7-point scale from "Not at all" to "Extreme".

Table II. Behavioural definitions used in ratings

Behaviour	Definition
Active	Moves about frequently
Aggressive	Causes harm or threatens to cause harm
Agile	Moves lithely and in a well-coordinated manner
Curious	Approaches and explores a change in the environment
Equable with cats	Reacts to others evenly and calmly, not easily disturbed
Excitable	Reacts strongly to a change in the environment
Fearful of cats	Retreats readily from cats
Fearful of people	Retreats readily from people
Hostile to cats	Reacts with a threat and/or causes harm if approached by cats
Hostile to people	Reacts with a threat and/or causes harm if approached by people
Playful	Engages in play with cats and/or objects
Sociable with cats	Initiates proximity and/or contact with cats
Sociable with people	Initiates proximity and/or contact with people
Solitary	Spends time alone and/or avoids company
Tense	Shows restraint in movement and posture
Vocal	Readily vocalizes
Voracious	Eats greedily and/or in large quantities
Watchful	Looks readily at a change in the environment

The researchers then analyzed the correlation between the scores given by two independent observers.

Table III. Inter-observer Spearman correlations of personality items

Category	r_s	P (one-tailed)	Rank of r_s
Active	**0·76**	<0·005	5·5
Aggressive	0·61	<0·02	11
Agile	0·38	NS	16
Curious	**0·79**	<0·005	2
Equable with cats	**0·71**	<0·005	7
Excitable	0·35	NS	17
Fearful of cats	0·52	<0·05	15
Fearful of people	**0·76**	<0·005	5·5
Hostile to people	**0·78**	<0·005	3·5
Hostile to cats	0·67	<0·01	9
Playful	0·58	<0·02	13
Sociable with cats	0·64	<0·02	10
Sociable with people	**0·91**	<0·005	1
Solitary	0·31	NS	18
Tense	**0·78**	<0·005	3·5
Vocal	0·68	<0·01	8
Voracious	0·59	<0·02	12
Watchful	0·53	<0·05	14

Items in bold type are those in which the inter-observer correlation coefficients were greater than 0·78 and thereby qualified for use in further analysis.

a) Why did they use a Spearman rank correlation instead of the Pearson product moment correlation? (5 pts)

b) What is the equation for the Spearman rank correlation coefficient? (5 pts)

c) The researchers considered many traits and may be concerned about an inflated family-wise Type I rate. If they apply a Bonferroni's correction in the hopes of maintaining a 5% Type I error rate, what would be the new per-comparison Type I error rate be? (Full credit requires that you provide a numerical expression. In other words, all variables should be assigned numbers.) (5 pts)

d) If the instead apply the Dunn-Sidak method, what would the new per-comparison Type I error rate? (Again, full credit requires a numerical expression.) (5 pts)

e) Given the context of the question, which of these corrections would be more appropriate and why? (10 pts)

f) What will correcting for multiple comparisons do to your statistical power? (Define statistical power in your answer.) (10 pts)

9. (65 pts)

J. Zool., Lond. (1987) **212,** 439-455

Predation by domestic cats in an English village

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(*Accepted 18 November 1986*)

Churcher and Lawton (1987) studied predation by domestic cats. They model the relationship between the number of prey items and cat age as described in the following text. (Note that they use a dot to represent a decimal, and that "mid age" is the age of the cat half-way through the study year.)

Predation efficiency of individual cats

There was considerable variation in the total number of prey items brought home by individual cats (Fig. 5), with six cats failing to bring home any prey at all and one bringing 95 items over the 12 months. Part of this variation can be attributed to cat age (Fig. 6):

$$\log\ (\text{prey}+1) = -0{\cdot}083\ \text{mid age (years)} + 2{\cdot}744 \qquad (1)$$
$$r = 0{\cdot}24;\ P = 0{\cdot}038$$

a) Their model description is incomplete. Why? What are they missing? Re-write the model equation as it should be in order to be a complete description of the model fit. (10 pts)

b) Why do they include "+1" in the log transformation? (5 pts)

(c) Name three different ways that you could test the null hypothesis that age has no influence on the number of prey brought home. (5 pts each; 15 pts)

(d) There is a better way for them to model these data. What is it? Provide a complete model description of this improved model. (15 pts)

(e) Name two reasons why the model described in part (d) is better than the original model. (10 pts)

(f) Name one potential factor in this experiment that might lead to unintentional pseudoreplication. (10 pts)