Samantha Hammond

Centre for Applied Zoology
Cornwall College, Newquay

VIGILANCE BEHAVIOUR IN MEERKATS

A Resource written for
A Level, City and Guilds and
Undergraduates, brought to
you by The Association for the
Study of Animal Behaviour

CONTENTS

Aim of this resource

The primary aim of this resource is to provide educators with a comprehensive teaching pack to enable them to conduct behavioural observations in the classroom with students. The resource is designed to run as a complete programme of study for A-level students, further education students or higher education students with limited prior experience of studying animal behaviour. The activities start at a basic level and progressively get more advanced. With this in mind, educators are free to select or adapt activities suitable to the level of their students.

The pack aims to provide the educator with sufficient detail to run each activity with very limited preparation or additional research required. The materials are not intended to explain every aspect of behavioural research to the finest detail, but there are many textbooks and other ASAB resources which provide more detailed information about specific topics (see reference list.)

Background information on meerkats

Meerkats (*Suricata suricatta*) are small mongooses that live in the arid regions of southern Africa in groups of 3-40 animals (Doolan & Macdonald 1996; Clutton-Brock *et al*. 1998).

Group living, cooperation and vigilance Meerkats are social cooperatively breeding mammals whereby reproduction is usually monopolized by the dominant pair (Kutsukake and Clutton-Brock 2010). One of the benefits of group living is that coordinated vigilance can allow individuals to be less vigilant than solitary animals (le Roux *et al*. 2009). When one meerkat is on guard, or sentinel duty, optimal activities for the rest of the group are foraging or resting, one guard is as effective as 2 or 3 (Clutton-Brock *et al*. 1999).

Previous studies have indicated that individuals alternate as guards but do not maintain a constant order, the probability that an individual will be on guard is related to its nutritional status and amount of time it has been foraging (Clutton-Brock *et al*. 1999). Individual differences in contributions to cooperative activities are unrelated to levels of kinship (genetic relatedness), suggesting that direct benefits to the cooperating individual play an important role in the evolution and maintenance of cooperative behaviours (Clutton-Brock *et al*. 2002). For example males were found to contribute more to sentinel duty than females, possibly due to the direct benefits of being able to see where females disperse to (Clutton-Brock *et al*. 2002). Similar findings were found in mobbing behaviour, in which meerkats congregate around a potential predator in order to drive it away (Graw and Manser 2007).

Anti-predator behaviour and communication Meerkats are vulnerable to aerial predators such as raptors and many terrestrial predators including jackals (*Canis mesomelas*), African wildcats (*Felis lybica)*, and snakes (Graw and Manser 2007). Meerkats have several behavioural adaptations in response to high predation, including the vigilance behaviours mentioned above, as well as a complex graded alarm call system which denotes predator type and urgency level (Manser 2001). In response to aerial predators meerkats tend to run to bolt holes, whereas terrestrial predators (which are quite able to dig their way into the meerkats' bolt holes) cause the group to move away, or to mob the predator (Manser *et al*. 2001).

Meet the meerkats of Newquay Zoo

This group consists of 8 different members

Peggy - This is the oldest member of the group. She is the mother to all of the other members.

Bumble - Male - 08/05/09

Aleksander - Male - 27/07/09

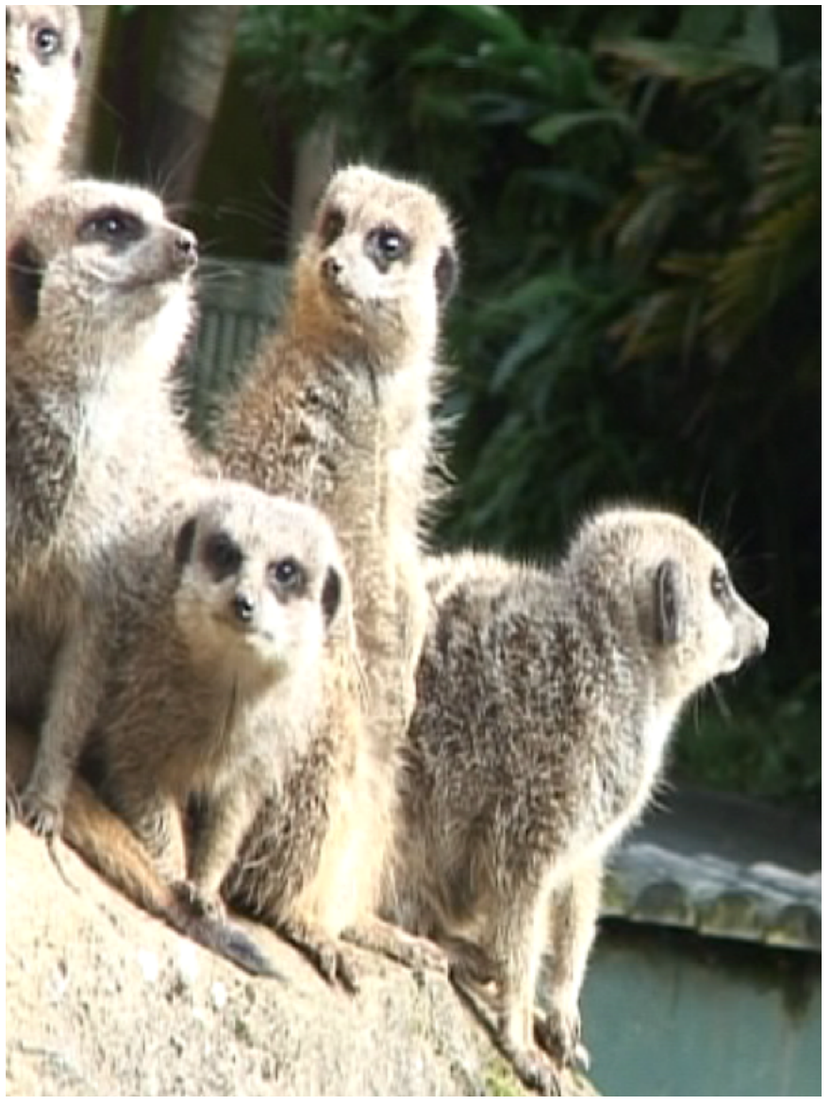
Simples - Female - 27/07/09

Jambo - Male - 02/05/10

Peanut - Male - 02/05/10

Titch - Male - 17/07/10

Maisy - Female - 17/07/10



ACTIVITY ONE

- Introductory role play task
- Learning Objective: To understand the importance of a scientific approach to the study of animal behaviour
- 30 minutes
- This is a fun, interactive activity which aims to assess students' ability to observe and record animal behaviour

Students should get into pairs:

One student will play the role of Sam - the head of conservation for really really interesting animals at the conservation society's headquarters in England (Sam will need to face down with eyes closed on the desk for the start of this activity). The other student plays the role of Robyn - the super keen field research intern (Robyn will need plain paper and pencil). This role play will involve Robyn observing some animal behaviour and conveying observations back to Sam via field notes, with the hope of saving an island, and the elusive enigma!

Teacher to read the following:

a. "Sam is asleep at home (so now Sam face down on the desk with eyes shut). Meanwhile, Robyn is getting up for the final day of exploration of Swanhalolo in search of the elusive enigma. Swanhalolo is a tropical island currently under threat - the developers are moving in, and if the enigma's existence is not confirmed in the area, then there is little hope to prevent the destruction of this island."

b. "Robyn, you wake up at the crack of dawn tired, sweaty and drowsey. You haven't showered for over a week and the hard floor under your tent has left you aching. You are low on water and fear the onset of malaria. Your GPS, cameras, and all other electronic equipment have all stopped working, you have only a pencil and note book and map left. You have trekked the island for 3 months and you are running out of time. Tomorrow you meet the local guide who will lead you out of the forest to start your journey home. The few tracks and scats you have found will not be enough evidence to protect the island."

c."You start to pack up your tent. You hear the usual sounds of bird song and the distant river… but then…. a rustle in the leaves close by…. and again…. you drop the tent, grab your note book and pencil and conceal yourself behind a tree, and as you watch you see……"

At this stage 2 options:

EITHER teacher displays a short silent clip of animal behaviour on a screen - see youtube/ BBC nature pages for unusual forest animals,

e.g. https://www.youtube.com/watch?v=v-Fzf8CLg1s

or https://www.youtube.com/watch?v=AXHXJjxPX0Q (from 1:12 to 1:22)

OR a 'prepared' student appears in the guise of the enigma, performs some behaviours and then leaves. Robyn needs to write or draw what they see as it happens.

Next:

Robyn is now ignored (head down on the desk) and the teacher reads the following - directed to Sam.

"Sam, you wake up as usual and gather your post, an interesting, tatty envelope catches your attention. You open it to find a note.

Sam reads or displays the following note

'It is here! I am weak in hospital with malaria, can't get out, you need to stop the development!'

Teacher now instructs Sam to decipher Robyn's field notes - what is the enigma? How does it behave? The Parliament wanted film footage evidence of the species and its unique behaviours. So, if you produce a story board or film strip to present from the field notes, you might just be able to save the island and the species!

Then:

Sam (or/and the rest of the class) now produces a story board from field notes. Robyn is not able to give any more information due to being weak with malaria! (10 mins) Teacher now asks a student (Sam) to present to ' The Parliament' (the class) the enigma by displaying storyboards and describing the behaviour. After everyone has had a giggle at funny descriptions and drawings the teacher can display the video clip (or student performer) to the whole group to see how close the descriptions were, and whether or not this is enough to save the species?

Plenary:

What was difficult / easy? Did anyone have the exact same description (as they all saw the same thing) ? How could recording these observations be made more scientific?

ACTIVITY TWO

- Producing an ethogram
- Learning Objectives: To understand the importance of a scientific approach to the study of animal behaviour
- To understand how to construct an ethogram and why the descriptions are important
- 1 hour
- Ethograms are… ‘a catalogue of descriptions of the discrete, species-typical behaviour patterns that form the basic behavioural repertoire of the species’ (Martin & Bateson, 2007; p.34)

Background:

Ethograms are an essential tool in the study of animal behaviour. By defining behaviours, researchers are able to record behaviours more easily. Activity 1 might have demonstrated some overlap of categories and difficulty in recording what is being observed. As well as anthropomorphising differences in interpretation and the reliability between observers.

Task:

Display the short **clip** of meerkat behaviour to the class. Students should work in pairs / groups to produce a list of all of the behaviours which they see the meerkats perform during the clip.

Collate the ideas from all of the groups on the board. Did groups come up with the same names? Do any of the behaviours overlap or are different words used to mean the same thing e.g. foraging or digging? How can you tell the difference? Explain that in order to distinguish what each person meant or saw when they describe a behaviour, you need to define it.

Next explain what an ethogram is (discuss the definition on the left). Display and evaluate some example ethograms (see Appendix 1).

Students should then be given some time to watch the clip again and come up with definitions for the behaviour categories previously collated. Teacher to re-iterate that categories and definitions should be unambiguous, not overlap and describe what the behaviour looks like, so that any other person reading the description could clearly identify the same behaviours in the meerkats.

Plenary:

Ask students to feed back their definitions to the class. Then come up with a list of key features of a good ethogram. The final test would be to play one behaviour from the clip and ask students which category this fits in to. Repeat this a couple of times.

ACTIVITY THREE

- Investigate this question: 'Do meerkats display more vigilance behaviours in the presence of aerial or terrestrial predators?'
- Learning Objectives: Use Instantaneous scan sampling technique to collect behavioural data and analyse with Chi-squared test
- 2-3 hours
- Instantaneous scan sampling (regular, instant assessments of the behaviour of more than one individual) is useful when observing many individuals at the same time

This two-part session will allow students to collect behavioural data in the first part and interpret and analyse the results in the second. It is a simple comparison between two experimental conditions.

First Task: (One hour)

Introduce the task by asking students to describe the behaviours in **clip 2** (sentry duty and vigilance behaviours). What are the meerkats doing? What are the possible advantages (e.g. spot predators early, warn family group and avoid being killed)? What are the possible disadvantages (e.g. whilst looking up they are expending energy, they are not feeding or reproducing) of individuals performing this behaviour?

Virtually all animals face a major trade-off between the risk of starvation and predator avoidance (Brown and Kotler 2004; Lima and Dill 1990; Verdolin 2006). Therefore, it is highly beneficial for individuals to assess the actual predation risk and adjust their anti-predator investment according to the perceived danger. Evidence for this adjustment has been demonstrated in a number of species (Barta et al. 2004; Benhaiem et al. 2008; Daly et al. 1992; Jordan et al. 1997; Lima and Dill 1990; Sweitzer and Berger 1992). Zöttl 2009

Hand out / display appendix 2 scan sampling record sheet and ask the students: 'How do you think this could be used to record meerkat behaviour?'

'Why aren't all of the behaviour categories listed e.g. foraging, sleeping and sentry duty etc?' Answer - because we are only interested in investigating vigilance behaviours we can define our categories accordingly - refer to the categorised ethogram in appendix 1.

'What behaviours would come under the categories vigilant, not vigilant and out of sight?' Students to write the definitions of the behaviours under the data collection table.

Vigilant: Head raised at or above horizontal plain and eyes open (to include scanning / guarding / raised guarding). **Non Vigilant:** Eyes closed or head lower than horizontal plain (to include foraging, moving, sleeping, resting). **Out of sight:** Not visible by the researcher

Next:

Once students are clear on the definition, display **clip 3** scan sampling of a group of 8 meerkats without the presence of a predator.

Ask students to record behaviours on their data collection sheet. **Equipment:** Students will each need their own timer or stop watch, or nominate a student to make a sound every 10 seconds. At each interval, students should record the number of meerkats performing each behaviour.

Ask students to compare their results with a partner (check inter observer reliability).

Next introduce some background on meerkats and the aim of the study. Do you think meerkats will be more or less vigilant in the presence of predators? Will their behaviour vary depending on the type of predator? *'In response to aerial predators they run to boltholes in the ground for shelter, while terrestrial predators either cause the group to move away or to mob the predator (Manser et al. 2001); perched raptors are also frequently mobbed.'* Graw and Manser, p3, 2007

If this is the case what hypothesis might we come up with? 'Meerkats are likely to be more vigilant in the presence of land predators than aerial predators' (because with aerial predators the meerkats are more likely to hide out of sight.)

Repeat data collection and recording on another copy of appendix 2, using **clip 4** (scan sampling meerkat group in the presence of a terrestrial predator) and then **clip 5** (scan sampling meerkat group in the presence of an aerial predator).

Plenary:

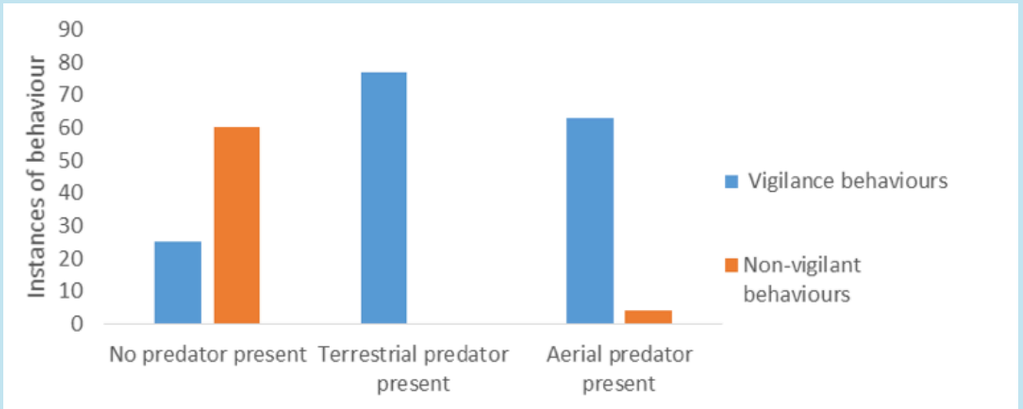
What is instantaneous scan sampling? Why are meerkats vigilant? What do we need to do next to answer our question? (draw graphs, analyse the data and statistically test it).

Second Task: (One Hour)

Students now complete a summary results table - see template in appendix 3. Correct results shown below:

	Total number of instances of vigilance behaviours	Total number of instances of non-vigilant behaviours
No predator present	25	60
Terrestrial predator present	77	0
Aerial predator present	63	4

This is then put into graphical form:



Then chi squared χ^2 analysis - Students to complete template tables (see appendix 3).

1x n chi squared (if only looking at number of instances of vigilance behaviours).

State null hypothesis: There is no difference in the likelihood of vigilance behaviours when an aerial predator is present or when a terrestrial predator is present.

Calculate 'expected' values (total number of instances divided by the number of categories (2)).

	Instances of vigilance in presence of aerial predator	Instances of vigilance in presence of terrestrial predator	Total
Observed	63	77	140
Expected	70	70	140

Calculate chi squared:

$$\chi^2 = \sum \frac{(observed - expected)^2}{expected}$$

	Instances of vigilance in presence of aerial predator	Instances of vigilance in presence of terrestrial predator	Total
Observed	63	77	
Expected	70	70	
O-E	-7	7	
$(O-E)^2$	49	49	
$(O-E)^2/E$	0.7	0.7	Total (∑) both columns in this row to give x^2=1.4

Calculate the degrees of freedom (this is the number of categories (n) -1)

In this case the degrees of freedom are 1. Generally speaking, when there is only one degree of freedom you need to perform a 'correction' on your data. This could be explained to students, but for the purposes of this basic exercise (to understand the basic principles of statistics and levels of significance) it will not be.

Next consult the chi squared distribution table (see appendix 3). Read across from the number of degrees of freedom to the significance level generally used in science (0.05). The value of χ^2 given here is 3.84. **If the calculated value is equal or greater to this then you reject the null hypothesis (so there is a significant difference between level of vigilance in the presence of land or aerial predators).**

Note: Levels of significance might need to be explained to students: The level of significance relates to a 'P' or 'Probability' value. If P is 0.05 then the probability of any difference (i.e. any difference in level of vigilance between the meerkats in the presence of a terrestrial or aerial predator) arising purely by chance (rather than as a result of the different treatments / conditions, in this case different predators) is less than 0.05, or 5%.

Extension activities:

Conduct this process but comparing all three datasets to test the null hypothesis: 'there is no difference in instances of vigilance behaviour in the presence of different classes of predators' e.g.

Note: the expected values in this case are calculated by totalling all observed instances and dividing by the 3 categories. The degrees of freedom are 3-1= 2. The critical value is 5.99. As the value of Chi squared is greater than this we reject the null hypothesis. Therefore there is a significant difference in instances of vigilance behaviour in the presence of different classes of predators.

	Instances of vigilance in presence of aerial predator	Instances of vigilance in presence of terrestrial predator	Instances of vigilance when no predator present	Total
Observed	63	77	25	165
Expected	55	55	55	165
O-E	8	22	-30	0
$(O-E)^2$	64	484	900	1448
$(O-E)^2/ E$	1.16	8.8	16.36	Total (∑) all columns in this row to givex^2=26.32

Conduct this process comparing all conditions and 2 behaviour categories in an n x n chi square analysis. This could test the following null hypothesis: 'there is no relationship between predator type (aerial / terrestrial / none) and type of behaviour (vigilant or not vigilant /or vigilant and out of sight). This requires additional measures in calculating the expected values.

Instead of taking equal values the rows and columns are totalled to get the grand total (coded Z).

	Presence of aerial predator	Presence of terrestrial predator	No predator present	Total
Observed instances of vigilant behaviour	a	b	c	a+b+c= U (165)
Observed instances of non-vigilant behaviour/ or out of sight	d	e	f	d+e+f= V (64)
Total	a+d= W (67)	b+e= X (77)	c+f= Y (85)	U+V+W+X+Y= Z (458)
O-E	Xx	xx	Xx	xx
$(O-E)^2$	xx	xx	Xx	Xx
$(O-E)^2/ E$	xx	xx	xx	Total (∑) both columns in this row to givex^2=

Expected values are then calculated as (row total x column total)/ grand total. The degrees of freedom in this instance are 6-1=5. The critical value (11.1) is much lower than the calculated value of chi squared. Therefore we reject the null hypothesis. This indicates that there is a significant relationship between predator type (aerial / terrestrial / none) and type of behaviour (vigilant or not vigilant /or vigilant and out of sight). This test does not however identify where or what the relationship is.

Observed instances of behaviours	Expected instances of behaviours	O-E	$(O-E)^2$	$(O-E)^2/ E$
a 63	(UxW)/Z (165x67)/458= 24.14	38.86	1510.10	62.56
b 77	(UxX)/Z (165x77)/458= 27.74	49.26	2426.55	87.47
c 25	(UxY)/Z (165x85)/458= 30.62	-5.62	31.58	1.03
d 4	(VxW)/Z (64x67)/458= 9.36	-5.36	28.73	3.07
e 0	(VxX)/Z (64x77)/458= 10.76	-10.76	115.78	10.76
f 60	(VxY)/Z (64x85)/458= 11.88	48.12	2315.53	194.91
				Total this column (∑) to give x^2=359.8

Plenary:

Review results and check understanding of 0.05 significance level.

Why is statistical analysis used in science?

What are the limitations of this data?

ACTIVITY FOUR

- **Investigate this question: 'Is there a correlation between distance that a predator is presented and duration of vigilance during sample period?'**
- **Learning Objectives: Use the continuous focal observation technique to collect data and analyze with Spearman rank test**
- **2-3 hours**
- **Once a predator has been spotted are the meerkats more vigilant?**

Background:

'In some species such as Belding's ground squirrel (Spermophilus beldingi) or baboons (Papio ursinus), sentinels seem to go on guard only after a threat has been detected (Balph & Balph 1966; Hall 1960), while in others, such as meerkats (Suricata suricatta), sentinels may guard regardless of whether a predator has been detected or not.' Tatalovic 2008 p3.

This might be the case, but once a predator has been spotted, are the meerkats more vigilant? Furthermore, does the level of vigilance vary depending on the distance of the threat? As mentioned before, meerkats communicate the level of urgency and information about predators (Manser 2001), so one might predict that if the sentinel is on guard other meerkats in the group might continue to forage if a threat is not immediate. However, as the threat gets closer more time might be spent by the rest of the group being vigilant, possibly even mobbing.

A couple of other points which might be worth consideration in the discussion: Meerkats are thought to have excellent depth perception, using stereoscopic vision that allows sentinels to detect predators at great distances (Moran *et al*. 1983). Captive-born meerkats still correctly use the same alarm call repertoire and also respond correctly to predator cues (Manser & Hollén 2007).

Task:

Start with **clip 2**. If this has already been done, recap with some additional background above. The aim of this session is to investigate vigilance behaviour in meerkats using continuous focal sampling. Hand out or display appendix 4 focal sampling record sheet. Ask students 'How do you think this could be used to record meerkat behaviour?' 'Why aren't all of the behaviour categories listed e.g. foraging/ sleeping/ sentry duty etc?' Answer - because we are only interested in investigating vigilance behaviours we can define our categories accordingly - refer to categorised ethogram in appendix 1.

'What behaviours / definition would come under the categories vigilant, not vigilant and out of sight?' Students should write their definitions under the data collection table.

Vigilant: Head raised at or above horizontal plain and eyes open (to include scanning / guarding / raised guarding). Non Vigilant: Eyes closed or head lower than horizontal plain (to include foraging, moving, sleeping, resting). Out of sight: Not visible to the researcher.

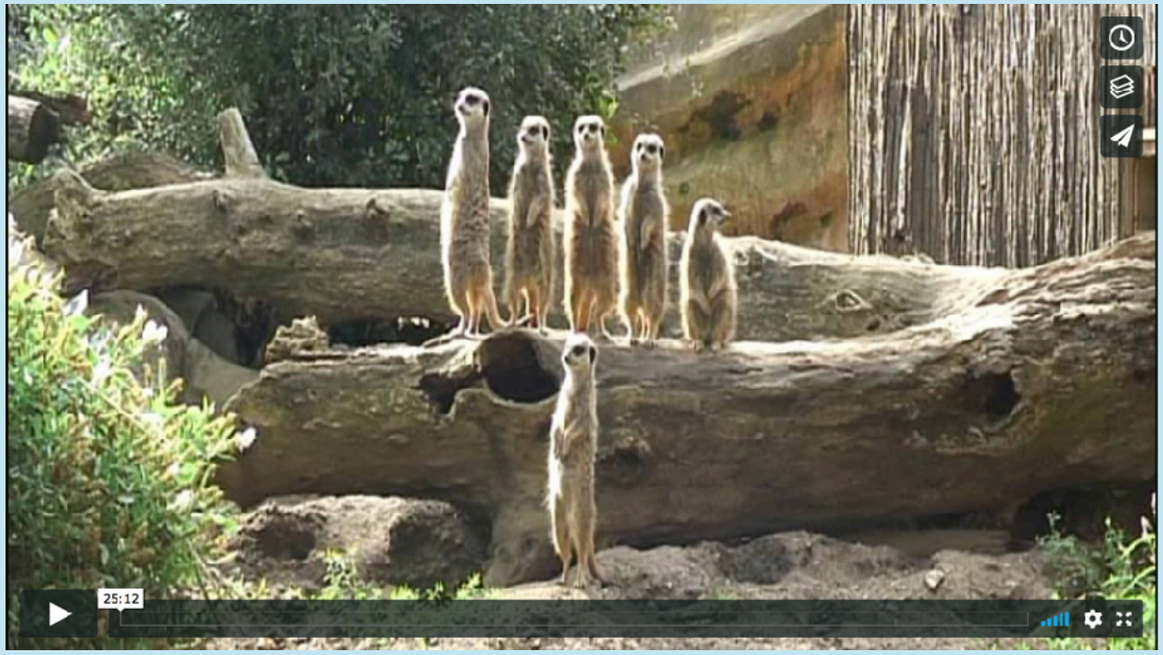
This should be filled out for ONE meerkat at each distance of predator presentation (0 m, 2 m, 4 m, 6 m, 8 m, 10 m, 12 m, 14 m) recording the start time of each behaviour on a new line as shown:

	Behaviour		
Time (seconds)	Vigilant	Not vigilant	Out of Sight
0		x	
20	x		
60		x	
180 (End)		x	

Note: an easier method might be just to get students to start a timer every time the meerkat is vigilant, pause it when it stops, start it again etc. but this wouldn't allow extension onto calculating time budgets or investigating more than one behaviour in the future.

Display **clip 6** (5 minute focal observation practice). This could be used with a more detailed behaviour coding system to include more behaviours (see appendix 5) or only those in the example sheet. **Equipment**: Students will each need their own timer / stop watch. Discuss difficulties / inter observer reliability etc.

When all students are confident with the method start data collection for the investigation. This will involve each student conducting focal observations of the meerkat with the predator present at different distances **clip 7-clip 14**. Once students get the idea it could be possible to give them a few of the data sets (perhaps every other one) to save time.



Next:

The total number of seconds that the meerkat was vigilant for each sample needs to be calculated:

These results can then be put into a table (see appendix 6 for template and hypothetical data given below)

These results can also be displayed graphically

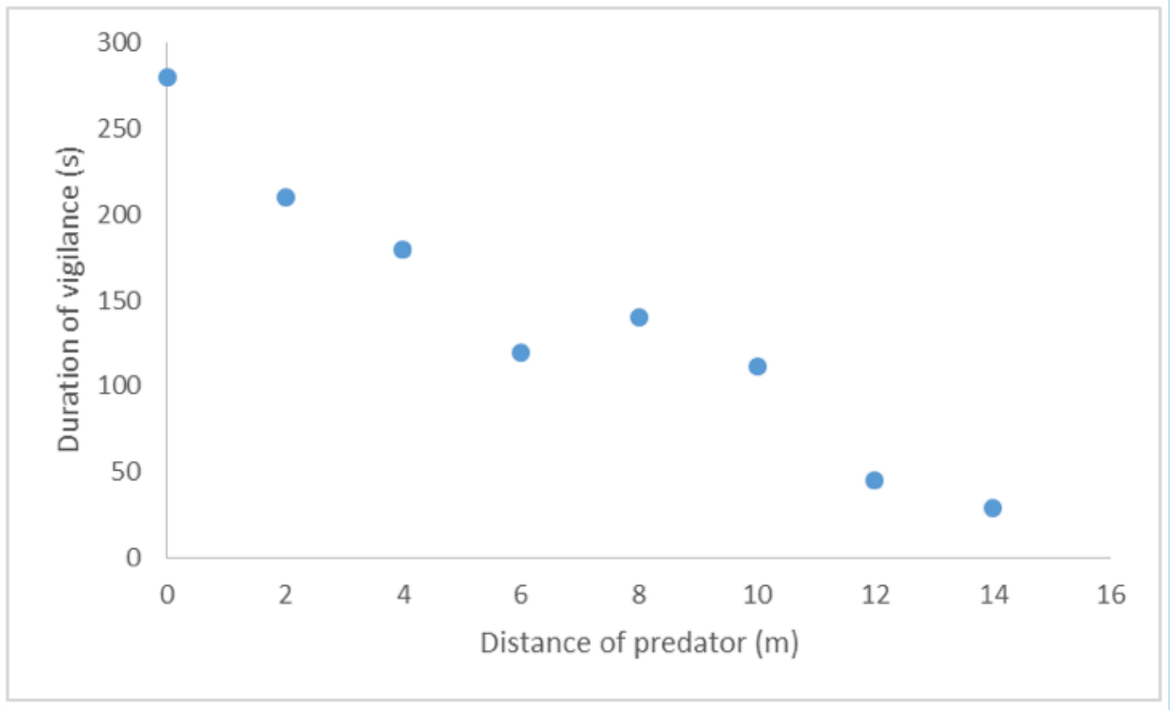
e.g. Predator at 0m

	Behaviour			
Time (seconds)	Vigilant	Not vigilant	Out of Sight	
0		x		
20	x			60-20=40s
60		X		
180 (End)		X		

e.g. Predator at 2m

	Behaviour			
Time (seconds)	Vigilant	Not vigilant	Out of Sight	
0	x			100-0= 100s
100			x	
180 (End)			x	

Distance of predator from enclosure (m)	Number of seconds of vigilance behaviour (s)
0	280
2	210
4	180
6	120
8	140
10	112
12	45
14	29



Carry out Spearman rank correlation test to see if there is a relationship between predator distance and vigilance behaviour (use table in appendix 6)

$$r_s = 1 - \frac{6\sum d^2}{n^3 - n}$$

Calculate the difference (d) between ranks (rank of distance - rank of vigilance)

Square these difference d²

Total all values of d² to give $\sum d^2$

Input this into the formula to calculate r_s (the Spearman rank coefficient). Note that n is the number of samples measured (8 in this case).

Is there a correlation? The value of r_s should range between -1 (perfect negative correlation) and +1 (perfect positive correlation). A value of 0 would indicate no correlation.

Distance of predator from enclosure (m)	Rank distance	Number of seconds of vigilance behaviour (s)	Rank of vigilance	Difference between ranks (d)	d²
0	1				
2	2				
4	3				
6	4				
8	5				
10	6				
12	7				
14	8				
					$\sum d^2$=

Extension:

In order to determine if the correlation you have found is significant you should consult the significance chart (see appendix 7). If this shows the correlation to be significant you can reject the null hypothesis 'there is no correlation between predator distance and vigilance behaviour'.

Discuss the results and evaluate limitations of the study.

Plenary:

How could you improve this study?

ACTIVITY FIVE

- **Use continuous focal observation technique to investigate the question 'does vigilance behaviour of meerkats vary between two different zoos'?**
- **Learning Objective: To carry out statistical analysis of data using the Mann-Whitney U test**
- **2 hours**
- **Also an opportunity to discuss optimality theory and kin selection**

Background:

There are several possible explanations as to why meerkat groups might be more or less vigilant (see below). This exercise seeks to analyse data in order to identify any differences between two groups and hypothesise explanations for the results.

- Meerkats spend more time on sentinel behaviour in habitats with higher predation threats (Clutton-Brock *et al.* 1999).
- Vigilance may be increased when offspring are present (Bell 2001).
- The predation risk might be higher if vegetation cover is increased, this could lead to greater levels of vigilance (Schooley *et al.* 1996).

Task:

Introduce some background on meerkats and consider the aims of the session. Recap focal sampling technique (hand out data collection sheets from appendix 4). Display **clip 6** the 5 minute focal observation practise. This could be used with a more detailed behaviour coding system to include more behaviours (see appendix 5) or only those in the example sheet. **Equipment:** Students will each need their own timer or stopwatch. Discuss difficulties - inter observer reliability etc.

Display **clip 15** (10 minute long focal samples. Students to collect data as follows.

	Behaviour		
Time	Vigilant	Not vigilant	Out of Sight
0.07 (start on film clip	x		
2.05		x	
2.07			x
6.03		x	
6.32	x		
6.37		x	
6.41			x
7.17		x	
7.34	X		
7.41		x	
10.07	END		

Students to calculate the total amount of time that each the focal meerkat spent being vigilant throughout the clip. Collate data in a table along with example data given as below (data for all other meerkats at Newquay Zoo and Venton Zoo are included), see appendix 8 for template. This could be input on a spreadsheet (such as Excel) to enable students to create a graph showing the standard error.) Note for Mann Whitney samples do not need to be the same size, group of meerkats at Newquay Zoo= 7 whereas at Venton Zoo = 8.

As there is a difference in the mean vigilance between the meerkats this warrants further testing. The null hypothesis for the test is 'there is no difference in vigilance behaviour between the dominant meerkats at Newquay Zoo and the group at Venton Zoo'. The appropriate statistical test is a Mann- Whitney (see Barnard *et al*. 2017 for additional information in selecting appropriate statistics). There are several steps to this. It is recommended that this is carried out in Mini-Tab, or another statistical programme e.g. download AQB excel spreadsheet and open the tab 'two groups' for a spreadsheet which will conduct the analysis (free download from:http://www.pearsoned.co.uk/HigherEducation/Resources/BarnardAskingQuestionsinBiology4e/).

Alternatively see appendix 9 for guidance on completing the Mann-Whitney U-test by hand.

Discuss reasons for this difference or lack of difference.

Plenary:

When can we use the Mann Whitney test (looking for a difference / ordinal / interval data / not repeated measures / 2 independent samples / more than 5 pieces of data in each sample).

Evaluation of the method / how could this be improved?

Meerkat	Duration of vigilance during sample Newquay Zoo (s)	Duration of vigilance during sample Venton Zoo (s)
1	130	510
2	10	23
3	43	0
4	210	125
5	87	109
6	9	56
7	320	132
8	xx	0
Total time vigilant	809	955
Average time vigilant	115.57	119.38
Standard deviation	115.11	166.77

ACTIVITY SIX

- Extension or HE activity
- Learning Objective: To conduct a 1 way ANOVA - (Friedman test)
- 2 hours
- Using continuous focal observation to answer the question 'are there differences in duration of vigilance behaviour between individual meerkats?'

Background:

Optimality theory and kin selection are both key topics covered in HE animal behaviour courses. This activity can be conducted and discussions around either topic extended.

Task:

Teacher to introduce some background on meerkats and aims of the session.

Recap / introduce focal sampling technique (hand out data collection sheets from appendix Display **clip 6** (3 minute focal observation practise). This could be used with a more detailed behaviour coding system to include more behaviours (see appendix 5) or only those in the example sheet. **Equipment**: Students will each need their own timer / stop watch. Discuss difficulties / inter observer reliability etc. Display **clip 15** - students record focal observations. This data can be used and inserted into the table below to replace a data point (meerkat 1 day 1) or just explain that this method was used to collect data over a period of 5 days for each meerkat simultaneously and is given below. Use the example data in the table below. Input on a spreadsheet (such as Excel) and create graphs showing the error bars for each meerkat.

	Duration of vigilance during sample (s)						
Day	Meerkat 1	Meerkat 2	Meerkat 3	Meerkat 4	Meerkat 5	Meerkat 6	Meerkat 7
1	130	10	43	210	87	9	320
2	348	76	65	0	200	0	543
3	183	0	70	7	179	14	476
4	56	90	30	71	93	70	180
5	68	59	9	165	34	8	500
Total time vigilant	785	235	217	453	593	101	2019
Average time vigilant	157	47	43.4	90.6	118.6	20.2	403.8
Standard deviation	118.33	40.03748	25.18531	94.03882	69.0746	28.28781	150.7919

Copy or enter this data into a statistical analysis programme and conduct a non parametric 1-way anova for repeated measures (Friedman test). This could be done in Mini Tab or another statistical analysis programme such as AQB spreadsheets available as a free download from: http://www.pearsoned.co.uk/HigherEducation/Resources/BarnardAskingQuestionsinBiology4e/ - open tab np 1 way and refer to 'repeated measures' box)

Discuss the results- did meerkats 'share' vigilance duties (link to optimality theory). If not, why? (Links to dominance / kin selection?)

Plenary

When can we use the Friedman test (looking for a difference / ordinal / interval data / repeated measures - if not repeated measures use Kruskal Wallis / 3 or more independent samples / more than 5 pieces of data in each sample.

Evaluation of the method / how could this be improved?

APPENDIX 1- EXAMPLE ETHOGRAMS

Ethogram of Behavioural Repertoires for Meerkats (*Suricata suricatta*)

Eating	Manipulating food and taking it into their mouths
Drinking	Consuming water
Foraging	Digging and scratching for food on the ground
Allo-grooming	Reciprocal grooming between members of the group
Self-grooming	One individual grooming itself
Sentry Duty	Sat upright on the hindquarters, body elevated, observing and scanning the area for danger, conspecifics and invaders
Sitting	Sat on haunches on ground or above ground and alert
Sunning	Sat or lying stretched out in the sun
Sleeping	In a state of sleep when the eyes are closed
Climbing	Elevated on rocks, framework or branches
Jumping	Determined sudden upward movement
Running	Moving quickly on foot
Walking	Movement on all four limbs
Vocalising	Producing sounds from the throat
Playing	Engaged in play with another individual of the group
Out of Sight	Unseen from the researcher's point of view

APPENDIX 1- EXAMPLE ETHOGRAMS

Ethogram created to study Sulawesi crested black macaques' (*Macaca nigra*) activity budgets (after Nickelson & Lockard 1978)

Social	Allogrooming, play, non-copulatory mounting & copulation (excluding manipulation of objects). Fights (chasing, including attacks, usually associated with vocalisations), strutting, yawning, biting, pulling hair (usually the crest), and grimacing (submissive).
Moving	Locomotion, including walking, running, climbing & jumping.
Resting	Body stationary, usually sitting or lying & not engaged in social activity. Autogrooming included.
Foraging	Moving slowly with attention directed toward potential food source or manipulating substrates in search of potential foods. Includes: Manipulation of the environment (e.g. furnishings).
Feeding	Reaching for, picking up, manipulating, masticating, placing food in mouth or manipulating cheek pouch contents.
IN	When the macaques are INSIDE but not visible, e.g. in back dens.
Miscellaneous	Behaviours that cannot be described by any of the above categories, including situations where the macaques are not visible (Outside).

Links to other ethograms and resources:

http://pin.primate.wisc.edu/callicam/ethogram.html

APPENDIX 2

Scan sample data record sheet

	10 seconds	20 seconds	30 seconds	40 seconds	50 seconds	60 seconds
Vigilant						
Not Vigilant						
Out of sight						

	10 seconds	20 seconds	30 seconds	40 seconds	50 seconds	60 seconds
Vigilant						
Not Vigilant						
Out of sight						

	70 seconds	80 seconds	90 seconds	100 seconds	110 seconds	120 seconds
Vigilant						
Not Vigilant						
Out of sight						

	70 seconds	80 seconds	90 seconds	100 seconds	110 seconds	120 seconds
Vigilant						
Not Vigilant						
Out of sight						

	130 seconds	140 seconds	150 seconds	160 seconds	170 seconds	180 seconds
Vigilant						
Not Vigilant						
Out of sight						

	130 seconds	140 seconds	150 seconds	160 seconds	170 seconds	180 seconds
Vigilant						
Not Vigilant						
Out of sight						

APPENDIX 3

Template tables for activity 3 results

	Total number of instances of vigilance behaviours	Total number of instances of non-vigilant behaviours
No predator present		
Terrestrial predator present		
Aerial predator present		

Null hypothesis: There is no difference in the number of instances of vigilance behaviours when an aerial predator is present or when a terrestrial predator is present.

	Instances of vigilance in presence of aerial predator	Instances of vigilance in presence of terrestrial predator	Total
Observed			
Expected			
Total			

$$\chi^2 = \sum \frac{(observed - expected)^2}{expected}$$

Distribution table for χ^2

https://www.monarchwatch.org/grafx/read/eggs/table.gif

	Instances of vigilance in presence of aerial predator	Instances of vigilance in presence of terrestrial predator	Total
Observed			
Expected			
Total			
$O - E$			
$(O - E)^2$			
$\frac{(O-E)^2}{E}$			$\chi^2 = \sum of\ columns$

APPENDIX 4

Focal sampling data collection sheet

Meerkat ID:

Researcher ID:

	Behaviour		
Time	Vigilant	Not vigilant	Out of sight
0.00			

	Behaviour		
Time	Vigilant	Not vigilant	Out of sight

APPENDIX 5

Extension to focal observation of meerkats

Ethogram of Behavioural Repertoires for Meerkats (*Suricata suricatta*)

Vigilance behaviours

Bipedal Guarding (BG)	Horizontal or upward head position whilst standing on hind legs
Quadrupedal Guarding (QG)	Horizontal or upward head position while pausing on four legs
Resting guarding (RG)	Horizontal or upward head position while sitting in an alert state.
Vigilant pause (VP)	Brief pause in activity (less than 1 second) in which animal raises head to horizontal or vertical position in an alert state.

Non-Vigilance behaviours

Not-vigilant (NV)	Any activity in which the animals head is pointing downwards (e.g digging, foraging, sleeping, grooming etc.)
Off show (OS)	The meerkat is out of sight

Record the start time and behaviour code of each behaviour on the sheet every time it occurs.

Make each new entry on a separate line.

Date:

Observer:

Subject:

Start time of each behaviour	Behaviour Code

Start time of each behaviour	Behaviour Code

APPENDIX 6

Meerkat vigilance and predator distance - results table

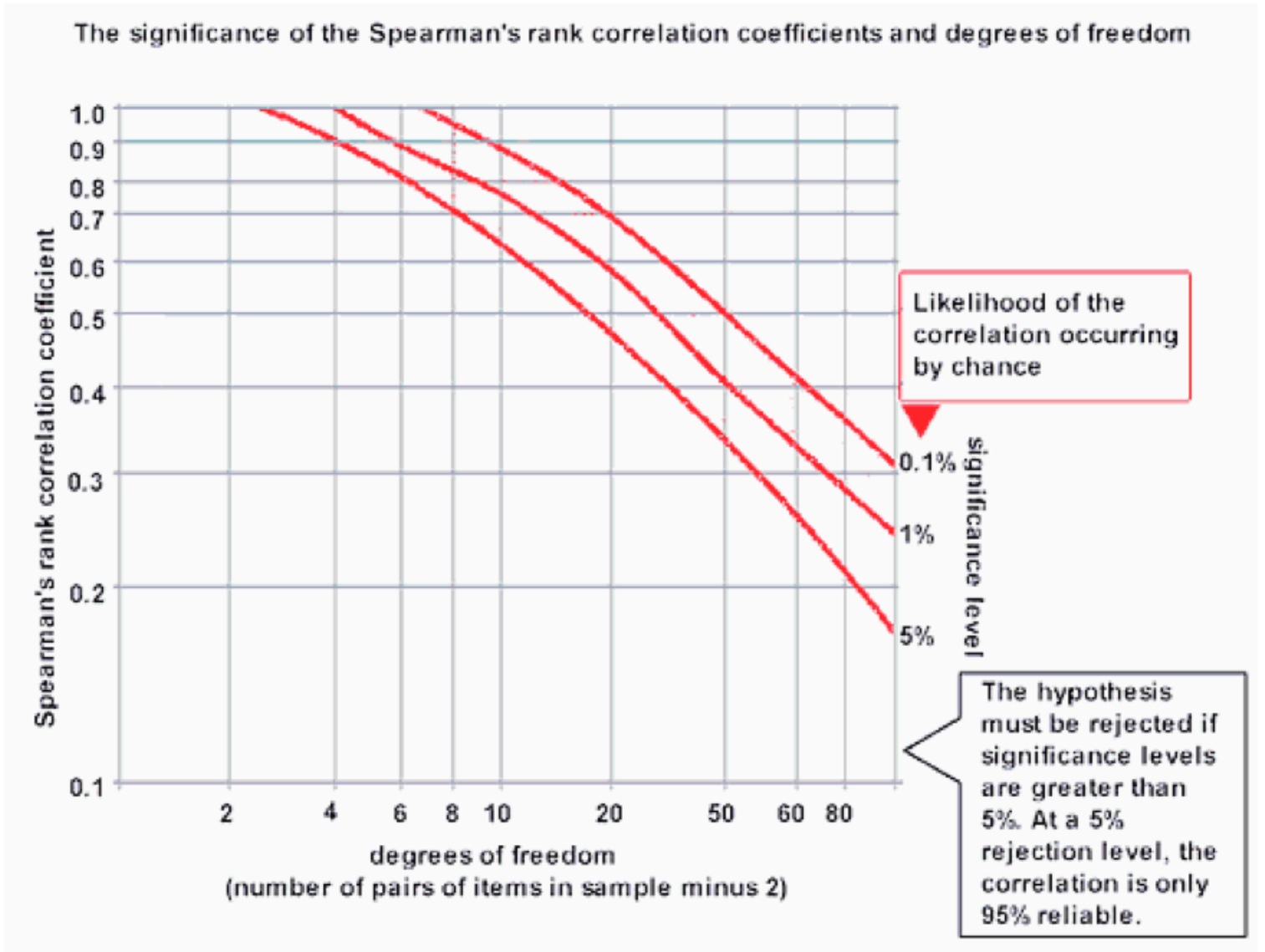
Distance of predator from enclosure (m)	Number of seconds of vigilance behaviour (s)
0	
2	
4	
6	
8	
10	
12	
14	

Meerkat vigilance and predator distance Spearman rank analysis

Distance of predator from enclosure (m)	Rank distance	Number of seconds of vigilance behaviour (s)	Rank of vigilance	Difference between ranks (d)	d^2
0					
2					
4					
6					
8					
10					
12					
14					

APPENDIX 7

Spearman rank correlation chart



http://geographyfieldwork.com/SpearmansRankSignificance.htm

APPENDIX 8

Made up data on second group of meerkats' vigilance behaviour

Bipedal Guarding (BG)	Horizontal or upward head position whilst standing on hind legs
Quadrupedal Guarding (QG)	Horizontal or upward head position while pausing on four legs
Resting guarding (RG)	Horizontal or upward head position while sitting in an alert state.
Vigilant pause (VP)	Brief pause in activity (less than 1 second) in which animal raises head to horizontal or vertical position in an alert state.
Not-vigilant (NV)	Any activity in which the animals head is pointing downwards (e.g digging, foraging, sleeping, grooming etc.)
Off show (OS)	The meerkat is out of sight

Record the start time and behaviour code of each behaviour on the sheet every time it occurs.

Make each new entry on a separate line.

REFERENCES

Barnard, C., Gilbert, F. & McGregor, P. 2017. Asking questions in biology: A guide to hypothesis testing, experimental design, and presentation in practical work and research projects. 5th Edition. Pearson Education ltd, Harlow. ISBN 978-1-292-08599

Bell, M. 2001.The presence of pups changes patterns of vigilance in a cooperative mammal, the meerkat (*Suricatta suricatta*). Undergraduate thesis, University of Cambridge, Cambridge.

Clutton-Brock, T. H., Gaynor, D., Kansky, R., McColl, A. D. C., McIlrath, G., Chadwick, P., Brotherton, P. N. M., O'Riain, J. M., Manser, M. & Skinner, J. D. 1998. Costs of cooperative behaviour in suricates (Suricata suricatta). *Proceedings of the Royal Society of London, Series B,* 265, 185e190.

Clutton-Brock, T.H., O'Riain, M.J., Brotherton, P.N.M., Gaynor, D. &Kansky, R. 1999. Selfish sentinels in cooperative mammals. *Science* 284:1640-1644

Clutton-Brock, T.H., Russell, A.F., Sharpe, L.L., Young, A.J., Balmforth, Z. and McIlrath, G.M. 2002. Evolution and development of sex differences in cooperative behavior in meerkats. *Science* 297: 253-256

Doolan, S. P. & Macdonald, D.W.1996.Dispersal and extra-territorial prospecting by slender-tailed meerkats (*Suricata suricatta*) in the south-western Kalahari. Journal of Zoology, 240: 59-73.

Graw, B. & Manser, M.B., 2007. The function of mobbing in cooperative meerkats. *Animal Behaviour*.74: 507-517

Kutsukake, N. & Clutton-Brock, T.H. 2010. 'Grooming and the value of social relationships in cooperatively breeding meerkats. '*Animal Behaviour.*79: 271- 279.

Le Roux, A., Cherry, M. I., Gygax, L. & Manser, M.B. 2009. Vigilance behaviour and fitness consequences: comparing a solitary foraging and an obligate group-foraging mammal. *Behav.Ecol.Sociobiol* . 63, 1097–1107.

Manser, M. B. 2001. The acoustic structure of suricates' alarm calls varies with predator type and the level or response urgency. *Proceedings of the Royal Society of London, Series B*, 268, 2315-2324

REFERENCES

Manser, M. B. & Hollén, L. I., 2007. Persistence of alarm-call behaviour in the absence of predators: a comparison between wild and captive-born meerkats (*Suricata suricatta*). *Ethology* 113, 1038-1047.

Manser, M. B., Bell, M. B. & Fletcher, L. B. 2001. The information that receivers extract from alarm calls in suricates. *Proceedings of the Royal Society of London, Series B*, 268, 2485-2491.

Martin, P. and Bateson, P. 2007. Measuring behaviour: An Introductory Guide. Cambridge University Press: Cambridge

Moran, G., Timney, B., Sorensen, L., De-Rochers, B. 1983. Binocular depth perception in the meerkat (*Suricata suricatta*). *Vision Research* 23, 965-969.

Nickelson, S.A. and Lockard, J.S. 1978. Ethogram of Celebes monkeys (*Macaca nigra*) in two captive habitats. *Primates* 19, 437-447.

Schooley, R. L., Sharpe, P. B. & Van Horne, B. 1996. Can shrub cover increase predation risk for a desert rodent? *Canadian Journal of Zoology* 74, 157-163.

Tatalovic, M. 2008 Meerkat (*Suricata suricatta*) sentinel behaviour:variation in height and contribution. A dissertation submitted to the University of Cambridge in application for the degree of Master of Philosophy, University of Cambridge.

Zöttl, M. 2009.Benefits of secondary predator cue inspection and recruitment in a cooperative mammal (*Suricata suricatta)* Unpublished thesis: markusz@gmx.at Diploma Thesis, University of Zurich, Zurich.

ACKNOWLEDGEMENTS

ASAB would like to wholeheartedly thank Samantha Hammond and Peter McGregor for all their hard work and determination. Credit and many thanks also go to Sarah Galley, Jason Birt, Robyn Silcock, Kathy Baker and Newquay Zoo. Photographs are reproduced with kind permission from Samantha Hammond, Jacqueline E. Noble and Charlotte Evans. For more resource please look at our website www.asab.org/education our Vimeo Channel https://vimeo.com/asabeducation and follow us on Twitter @ASABeducation. You can always email our education officer education@asab.org with any comments or requests.