Interim Report

Ecological research of free-ranging dogs and interaction with snow leopards in Sanjiangyuan

Background

With the collapse of Tibetan mastiff market in China, many dog raisers abandoned dogs in Yushu Prefecture. As the Buddhist religion aims to be kind to all creatures, local monks provide refuges for abandoned and feral dogs. Free ranging dogs therefore are often found living around monasteries. However, Tibetan Buddhist Monasteries may also have a positive role for the conservation of snow leopards [1], which is a flagship species that helps maintain the health of whole local ecosystem. Due to high reproductive ability and adaptability, free-ranging dogs, are potential predators, prey, and competitors for local wildlife[2], and has potentially negative influence on endangered species conservation. There is evidence of such free-ranging dogs chasing local wildlife such as snow leopards, brown bears and wolves. This study aims to assess the ecological role played by free-ranging dogs, and the interaction with local carnivores especially snow leopard. Finally, we want to find an appropriate way to solve this problem.

Content

Study area

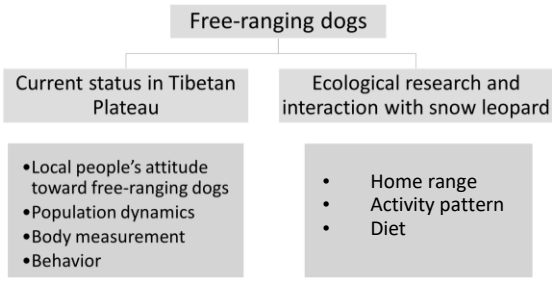
Figure 1 Research area

I selected four sites for the following reasons. The first is that they are all around temples. Li's study showed that there is a high degree of overlap between Tibetan monasteries and snow leopard habitats[1], and Shen's study showed that the sacred mountain culture derived from temples in Tibetan areas has a positive effect on wildlife conservation[3]. These regions have larger wildlife population size. On the other hand, as the Buddhist religion aims to be kind to all creatures, local monks provide refuges for abandoned and feral dogs, so many dogs gathered around temples. As a result, there might be more conflicts between dogs and wildlife, we can collect more data for further statistics and comparison. Finally, we select temples that are relatively far (> 10 km) from communities in order to reduce the impact of human influence on wildlife. As a result, we selected Zhaxiliwu temple in Zaduo County and Yaqu temple in Zhiduo County in Yushu Prefecture. These two regions belong to plateau climate, the average elevation of 4200 meters and 4600

meters, the average annual temperature of 2 ℃, the average annual rainfall of 532.2mm, the main habitat type is alpine meadow.

In contrast, we also chose two areas where dogs have less interaction with wild animals, Duma and Bama temple in Zaduo County. I chose these two places for several reasons: first, they are near Zhaxilawu and Yaqu temple, belong to the same type of terrain, their climate and conditions are similar. Second, according to preliminary investigations, I found that these two sites are in snow leopard habitat, infrared cameras nearby had photographed snow leopards and other carnivores. And last, there are also few people in these areas, as far as possible to exclude differences in human impact between different locations.

Research framework



1 Current status in Tibetan Plateau

1.1 Local people's attitude

Background

Some people already complain that free-ranging dogs has become a threat to them. Dogs attack people and calf. Local government want us have a survey on local people's attitude on this problem. By doing so, they want to know if it is necessary to have management program on dogs' population size, and find out a feasible way to do it. Questionnaire is one of the most commonly used methods in social surveys which has the advantage of collecting broad information. With well-designed and representative samples, it can fully reflect attitude, ideas and other information from the respondents of different backgrounds.

Aim

Acquire local people's attitude on free-ranging dogs. Whether they think it is a big problem in Tibet. If they think so, what is the appropriate method they think to solve this problem.

Method

I will use KAP model from questionnaire to evaluate local people's attitude toward free-ranging dogs. KAP model is a quantitative method that provides information on what is known, believed and done in relation to a particular topic.
Knowledge – Attitude – Practice model

K, knowledge: The ability of pursuing and using information, which has some background information like education…

A, attitude: The result of making reactions via some ways in some situations.

P, practice: indicates what knowledge and habit work together.

Statistics

Collect at least 30 valid questionnaire surveys for later analysis, in order to get the relationship among local people's knowledge, attitude and practice toward free-ranging dogs and wildlife conservation.

Preliminary results

I have interviewed local people and 21 herdsmen finished the questionnaire. 6 (29%) people thought population size of free-ranging dogs was increasing, 3 (14%) thought decreasing, 1 (5%) thought unchanging. Those 3 people thought decrease because of disease and starvation, those 6 people thought the increase was correlated with the decrease of Tibetan mastiff price. With the growing numbers, there might be more problems appeared.

Their average score of attitude towards free-ranging dogs from 1 (hate) to 5 (like) is 2.2. 4 (19%) people said those dogs would attack people and steal food in their tents, 9 (43%) said dogs would attack newborn livestock. Livestock loss from animal attack happened in 14 (67%) households last year, 4 (29%, 4/14) of them were from dogs, average loss from dogs was 4.5 annually of these 4 people. Of the 10 people who hoped there will be less free-ranging dogs, they all agreed with dog management program. They preferred to have animal shelters than killing or sterilization due to their Buddhism religion.

1.2 Population dynamics

Background

Free-ranging dogs are usually gregarious, often living in small groups. Groups of carnivores are likely to be more successful in hunting and fighting[4], reduce hunting distances, and can prey on larger preys than single individuals[5-9]. In Italy, dogs can rely on the advantage of numbers to drive away wolves near garbage sites[10]. Therefore, the threat of stray dogs on wildlife should not be overlooked.

Aim

For population dynamics, I will acquire data on population, survival rate, birth rate and growth rate of free-ranging dogs to see if their population have the trend of continually growth. Will they become a big threat for local carnivores?

Method

Photo re-capture

Statistics

Jolly – seber model (JS model)

Recording data: Birth rate (β), capture number (n), statistic results for 3 research times
Target parameter: annual apparent survival rate (φ), capture rate (p), population (N), new entrants number (B), growth rate (λ)

Preliminary works

JS model needs continuous data for 3 years, I just finished the data for first year. I have counted population size of free-ranging dogs in 3 sites, results are shown in table 1.

Table 1 Population size of free-ranging dogs during the first capture process

Site	Population size	Male	Female	Sub adult
Zhaxilawu temple	19	7	12	1
Yaqu temple	12	5	7	3
Duoma temple	47	11	24	0

Note: we were not sure the gender of some dogs in Duoma temple.

Future plan

After 2 years (3 data collecting cycles), I can get the annual apparent survival rate, population, and growth rate.

1.3 Body measurement

Background

In two-species interactions the effect of one competitor on the second is, in many cases, much greater than the reverse. It has been argued that this situation, termed asymmetrical competition, is the rule rather than the exception in natural communities[11]. A common case involving asymmetrical competition occurs when competing species differ in size and the larger enjoys an advantage because of its increased feeding and fighting ability. So, body size is a strong indicator of an animal's competition capacity in the wild.

Aim

We want to compare physical parameters of dogs and local carnivores as an indicator of dog's competition capacity.

Preliminary works

Some free-ranging dogs were measured for height, body length and weight, results are showed in table 2.

Table 2 Body measurement of free-ranging dogs

Site	Length/cm	Hip height/cm	Head height/cm	Weight/kg
Zhaxilawu temple	83.4 (18)	60.5 (17)	62.0 (17)	20.7 (15)
Yaqu temple	76.9 (11)	55.9 (8)	66.5 (8)	17.3 (11)
Duoma temple	81.5 (24)	56.5 (22)	65.3 (20)	20.0 (9)
Average	81.2 (53)	57.9 (47)	64.3 (45)	19.6 (35)

Note: since we could not have access to all those dogs, some data were deficient, measured numbers are in brackets.

Butler (1998) [12] measured the average weight of free-ranging dogs in Zimbabwe which was 14.7 kg, and therefore considered that they were not large enough to pose a threat to large herbivores and carnivores[13]. The average weight of dogs here in my research sites is 19.5kg, much higher than 14.7kg. While the sympatric Tibetan fox is only 4-5.5kg[14], red fox is 2.2-14kg[15,16], pallas' cat is 2.5-4.5kg , lynx is 18-30kg[17], wolf is 36-45kg[18], snow leopard is 27-55kg[19]. It can be seen that in the Sanjiangyuan area, free-ranging dogs have some advantages on size over Tibetan foxes, red foxes and Pallas' cats, and may at a dominant position in competing with such medium carnivores.

1.4 Behavior

Background

Dogs, like us, are social animals that need to maintain family relationships and friendships through sounds, smells, and gestures[20]. Dogs are one of the species with most diverse of population structure and composition of all the mammals. They live together, interact with each other, and form complex social structures and relationships that are important for adapting to group life. Understanding the relationships among dogs could give us a better understanding of the complexities of their social structures, and the direct and indirect consequences of their interactions[21]. Understanding their social behavior can also let us know if they could cooperate on fighting and predation, and pose threat to other carnivores

Aim

In this part, I focus on the behavioral ecology of free-ranging dog populations, assess their composition, social status and behavior among members.

Method

Observation.

Statistics

Social network analysis.

Social network analysis is the process of investigating social structures through the use of network and graph theories. It characterizes networked structures in terms of nodes and the ties, edges, or links (relationships or interactions) that connect them.

Ucinet will be used to analyze their social relationships.

2 Ecological research and interaction with snow leopard

2.1 Home range

Background

An animal's home range is defined as the area in which it conducts activities such as feeding, resting, breeding, dodging and parading[22]. Interactions between carnivores are mediated by behavioral responses of an individual towards the threat imposed by another species[23-25]. For these interactions it is expected that the weaker species will attempt to reduce the probability of encountering individuals from a stronger species. This will result either in the exclusion of one species by the other or in coexistence by partitioning space-time[26]. In this latter scenario, the subordinate carnivore will use lower-quality habitat[24].

Aim

We want to know if there were spatial exclusion between dogs and snow leopards.

Hypothesis

If dogs affect habitat use of native carnivores, I expected to see shifts in habitat use between areas with and without dogs, including reductions in the use of habitats most often used by dogs.

Method

GPS collar, camera traps.

Statistics

Minimum Convex Polygon, Fixed Kernel Estimation, two-way Analysis of Variance (ANOVA) and unpaired t-tests to compare home-range between dogs and snow leopards in different places

Preliminary works

To calculate their home ranges, 6 dog individuals were put on GPS collars in 3 sites. Only those individuals with ≥30 locations for at least one season were used to estimate utilization distributions (UD), which minimizes potential bias in home-range estimation due to small sample sizes[27,28]. I used home range tool 9 (HRT9) in ArcGIS for analysis. For FKE, I calculated 95% kernel home range which cut 5% least use areas.

I have already analyzed 2 dogs, "Collar" in Duoma temple and "Mu Mu" in Bama temple, details are showed in figure 2 and table 3.

Figure 2 a) Coordinates (pins) and b) FKE home range of 'Collar' (upper left in Duoma temple, purple) and 'Moo Moo' (lower right in Bama temple, green)

Table 3 Home range of free-ranging dogs

Name	Time (days)	MCP (km^2)	FKE (km^2)
Collar	60	29	6.1
Moo Moo	40	58	1.4

Comparing with data from other researches (MCP, 0.02-38.5 km^2; FKE, 0.45 km^2) [29-39], we can know that no research before has the same home range size as large as us, dogs in my research area would go further into the wilderness, might have more chance to interact with local carnivores.

Future plan

After analyzing pictures from camera traps, we will split these sites into 3 categories: no dog use, casually use or highly use. Each type, we calculate 90% adjusted Wald confidence intervals ($\hat{w}$) for expected proportions of use by snow leopard, compare observation value and expected value to know snow leopard preferred habitat.

By acquiring these data, we want to draw a picture of dog and snow leopard home range usage distribution.

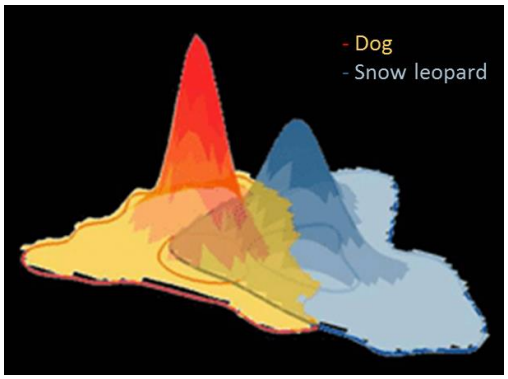


Figure 3 Expected home range usage distribution of dogs and snow leopards

2.2 Activity pattern

Background

The temporal distribution of activity and rest is what we call activity patterns, including daily and annual activity patterns[40], which may be influenced by climate, environment, food, natural enemies, and so on[41]. It is important for the animal to allocate the diurnal activity time in niche dimension[42,43]. In order to avoid and reduce the competition with the more powerful predators, the animals in the inferior position usually show the opposite activities rhythm by changing their own activity pattern[44], in order to increase niche segregation[45].

Aim

We want to know if there were temporal exclusion between dogs and snow leopards.

Hypothesis

If free-ranging dogs have negative influence on native carnivores, I expected to see the latter will avoid the former by temporal shifts in activity patterns.

Method

Camera trapping

Statistics

Relative abundance index, Shannon-Wiener index, Evenness index, Time-period relative abundance index, two-way Analysis of Variance (ANOVA) and unpaired t-tests to compare activity pattern between dogs and snow leopards in different places.

Expected results

We want to draw a picture of activity pattern from pictures taken by came traps in different places. When there are more dogs, I expect that snow leopard will shift activity pattern to avoid meeting dogs at the same place, as figure 4 shows.

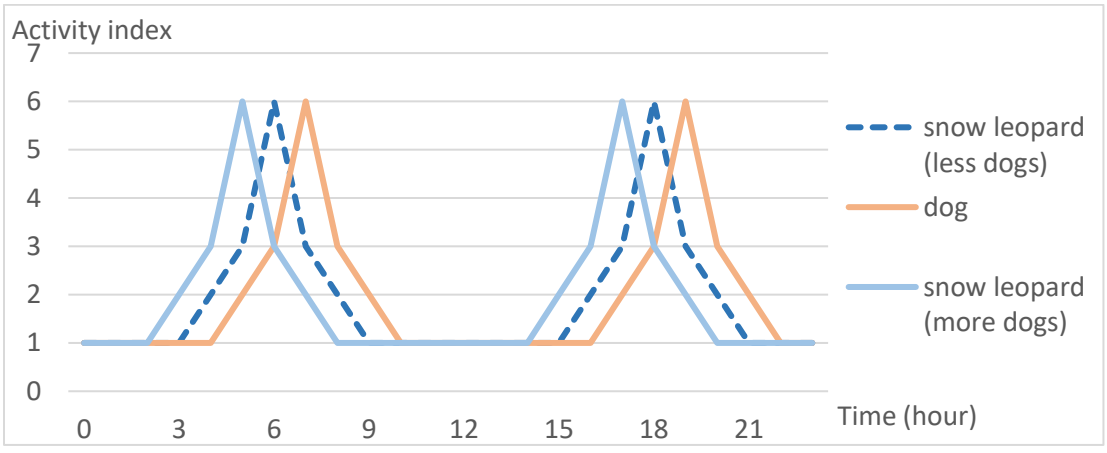


Figure 4 Expected activity pattern of dogs and snow leopards

2.3 Diet

Background

Diet is the sum of the food consumed by an animal. Examples have already demonstrated that dogs have negative influence on sympatric carnivores, herbivores and livestock, including predation, surplus killing, and scavenging[13,46,47]. Free-ranging dogs may also be a threat to livestock. In some areas, since it is difficult to distinguish livestock losses caused by wild animals or dogs, herders often thought wolf is the biggest enemies for livestock, which actually caused by dogs[48]. Therefore, the correct identification of prey to livestock is also a very important part of conservation work. Misidentification may lead to an increase in compensation for pastoralists[48-50].

Aim

The dietary composition and overlap between free-ranging dogs and snow leopards. We want to know if dogs have big influence on livestock, prey and predators.

Method

Morphology analysis under optical microscope or scanning electron microscope.

Statistics

Frequency of occurrence, dietary diversity, trophic niche overlap.

Preliminary works

Analysis results of 42 samples from dogs and 50 samples from snow leopards are shown in Figure 5. Both of them feeding on blue sheep and goats. The snow leopard's diet is mainly composed of its natural food, blue sheep, accounting for 3/4; and dogs mainly eat yak and goat. We need further exploration on dogs' feeding behavior, we want to know what is the percentage of the yak they eat are preyed by themselves.

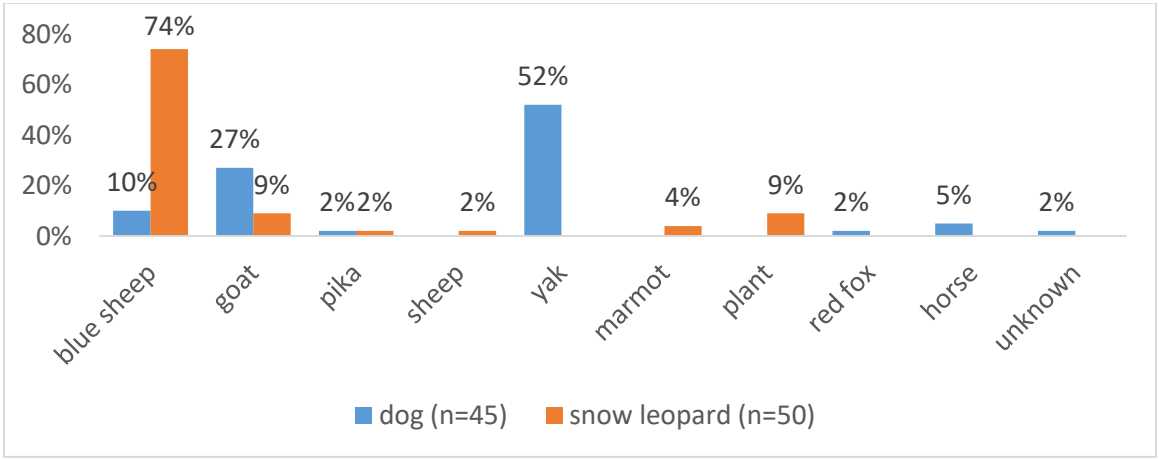


Figure 5 Morphological analysis results of scat samples

According to Levins index, the dietary diversity of snow leopard was 0.156 and dog was 0.465. It can be seen that the food diversity of dogs is higher than snow leopards. According to the Pianka index, the dietary overlap index was 0.158. According to the Schoener index, the trophic niche overlap was 0.155, indicating that the dietary overlap between dogs and snow leopards was still relatively low.

2.4 Diseases

Shared parasites may be an important driver in structuring assemblages of species[51], can lead to dynamic competition among carnivores[52-55], and may ultimately turn out to be a common and important component of community structure[51,54,56-58]. Dogs, as carriers of disease, are an ideal medium to spread diseases. In many places, population density has exceeded the threshold value of disease control and may cause outbreaks of enzootics[59]. In some areas, due to high density and lack of immunity, dogs may have a greater impact on some rare species through cross-species-transmitted diseases[60].

Aim

To prove that dogs can indeed transmit diseases to wildlife and have negative impact on their health, we need to determine what diseases are shared by dogs and wildlife.

Method

Morphology analysis under optical microscope.

Statistics

Frequency of occurrence

Preliminary works

Of the 29 fecal samples from snow leopards, 26 were found to have parasites, and the overall detection rate of parasites was 89.66%, results are shown in Figure 6, 7 orders of parasites were determined.

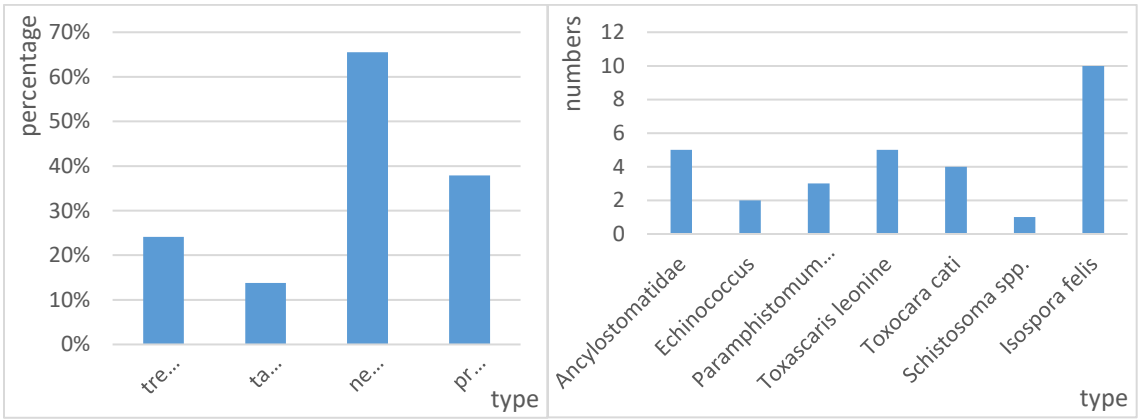


Figure 6 (left)Parasites occurrence in scat samples, (right) numbers of identified parasites

Reference

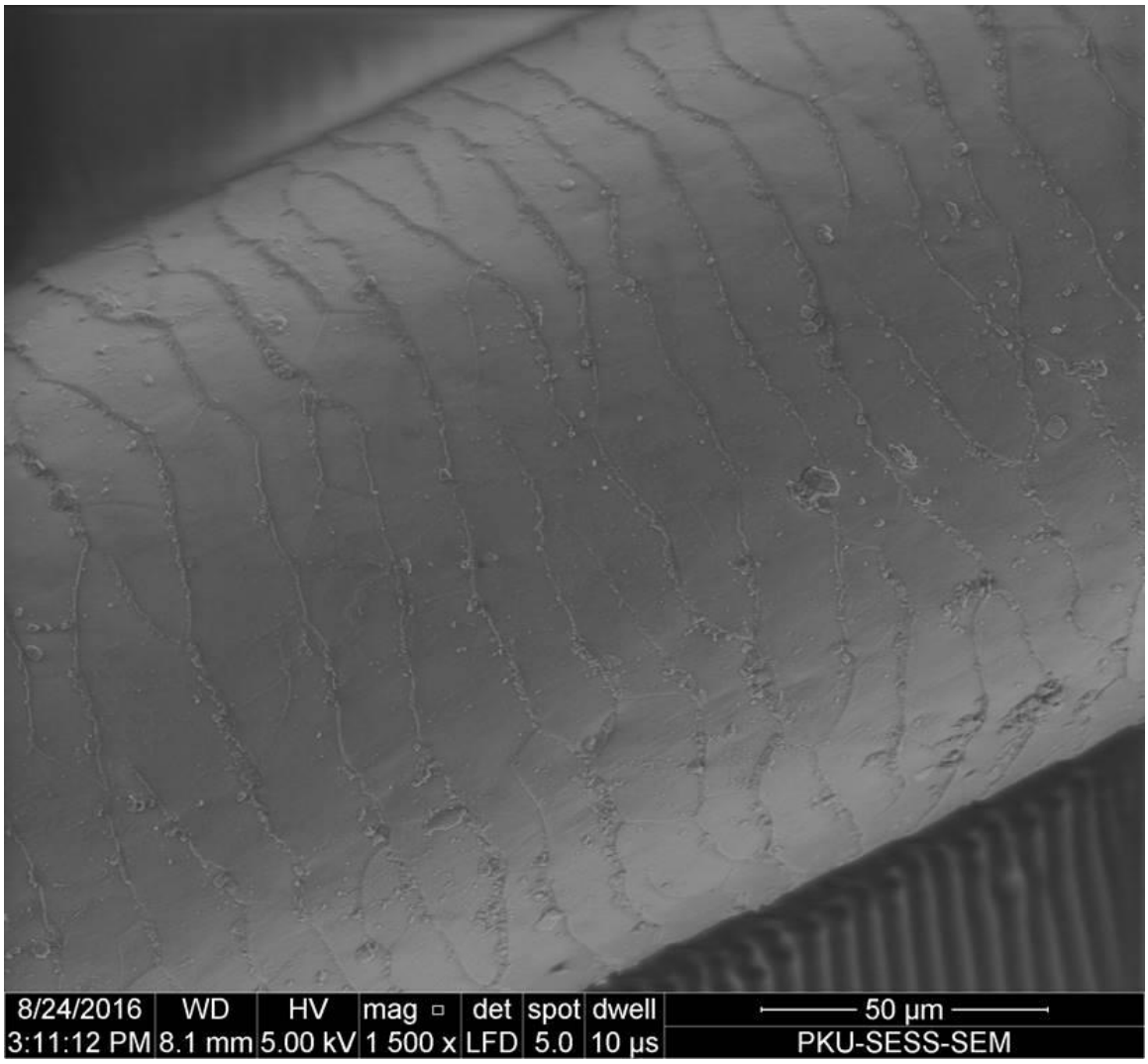
1. Li, J. *et al.* Role of Tibetan Buddhist monasteries in snow leopard conservation. *Conservation biology* **28**, 87-94 (2014).
2. Vanak, A. T. & Gompper, M. E. DogsCanis familiarisas carnivores: their role and function in intraguild competition. *Mammal Review* **39**, 265-283, doi:10.1111/j.1365-2907.2009.00148.x (2009).
3. Shen, X., Lu, Z., Li, S. & Chen, N. Tibetan sacred sites: understanding the traditional management system and its role in modern conservation. *Ecology and Society* **17**, 13 (2012).
4. Corbett, L. K. *dingo in Australia and Asia*. (UNSW Press, 1995).
5. Uhlenbroek, C. Animal Life. *Dorling Kindersley Ltd* (2008).
6. Taylor, C., Schmidt-Nielsen, K., Dmi'el, R. & Fedak, M. Effect of hyperthermia on heat balance during running in the African hunting dog. *American Journal of Physiology--Legacy Content* **220**, 823-827 (1971).
7. Gorman, M. L., Mills, M. G., Raath, J. P. & Speakman, J. R. High hunting costs make African wild dogs vulnerable to kleptoparasitism by hyaenas. *Nature* **391**, 479-481 (1998).
8. Wilson, A. M. *et al.* Locomotion dynamics of hunting in wild cheetahs. *Nature* **498**, 185-189 (2013).
9. Liebenberg, L. Persistence Hunting by Modern Hunter-Gatherers. *Current Anthropology* **47**, 1017-1026 (2006).
10. Boitani, L., Francisci, F., Ciucci, P. & Andreoli, G. 1C Population biology and ecology of+ S feral dogs in central Italy. *The domestic dog: Its evolution, behaviour, and interactions with people*, 217 (1995).
11. Persson, L. Asymmetrical competition: are larger animals competitively superior? *The American Naturalist* **126**, 261-266 (1985).
12. Butler, J. The ecology of domestic dogs Canis familiaris in the communal lands of Zimbabwe. *Harare, Zimbabwe: University of Zimbabwe* (1998).
13. Butler, J. R. A., du Toit, J. T. & Bingham, J. Free-ranging domestic dogs (Canis familiaris) as predators and prey in rural Zimbabwe: threats of competition and disease to large wild carnivores. *Biol Conserv* **115**, 369-378, doi:10.1016/s0006-3207(03)00152-6 (2004).
14. Harris, R. B., Wang, Z., Zhou, J. & Liu, Q. Notes on the biology of the Tibetan fox. *Canid News* **11**, 1-7 (2008).
15. Nowak, R. M. *Walker's Mammals of the World*. Vol. 1 (JHU Press, 1999).
16. Wilson, D. E. & Burnie, D. (New York: DK Publishing, 2001).
17. Lynx, E. Eurasian Lynx.
18. Mech, L. D. The Wolf: The Ecology and Behaviour of an Endangered Species. (1981).
19. Anderson, S. *Simon and Schuster's guide to mammals*. (Simon & Schuster, 1984).
20. Taylor, A. M., Reby, D. & McComb, K. Context-Related Variation in the Vocal Growling Behaviour of the Domestic Dog (Canis familiaris). *Ethology* **115**, 905-915 (2009).
21. Whitehead, H. *Analyzing animal societies: quantitative methods for vertebrate social analysis*. (University of Chicago Press, 2008).

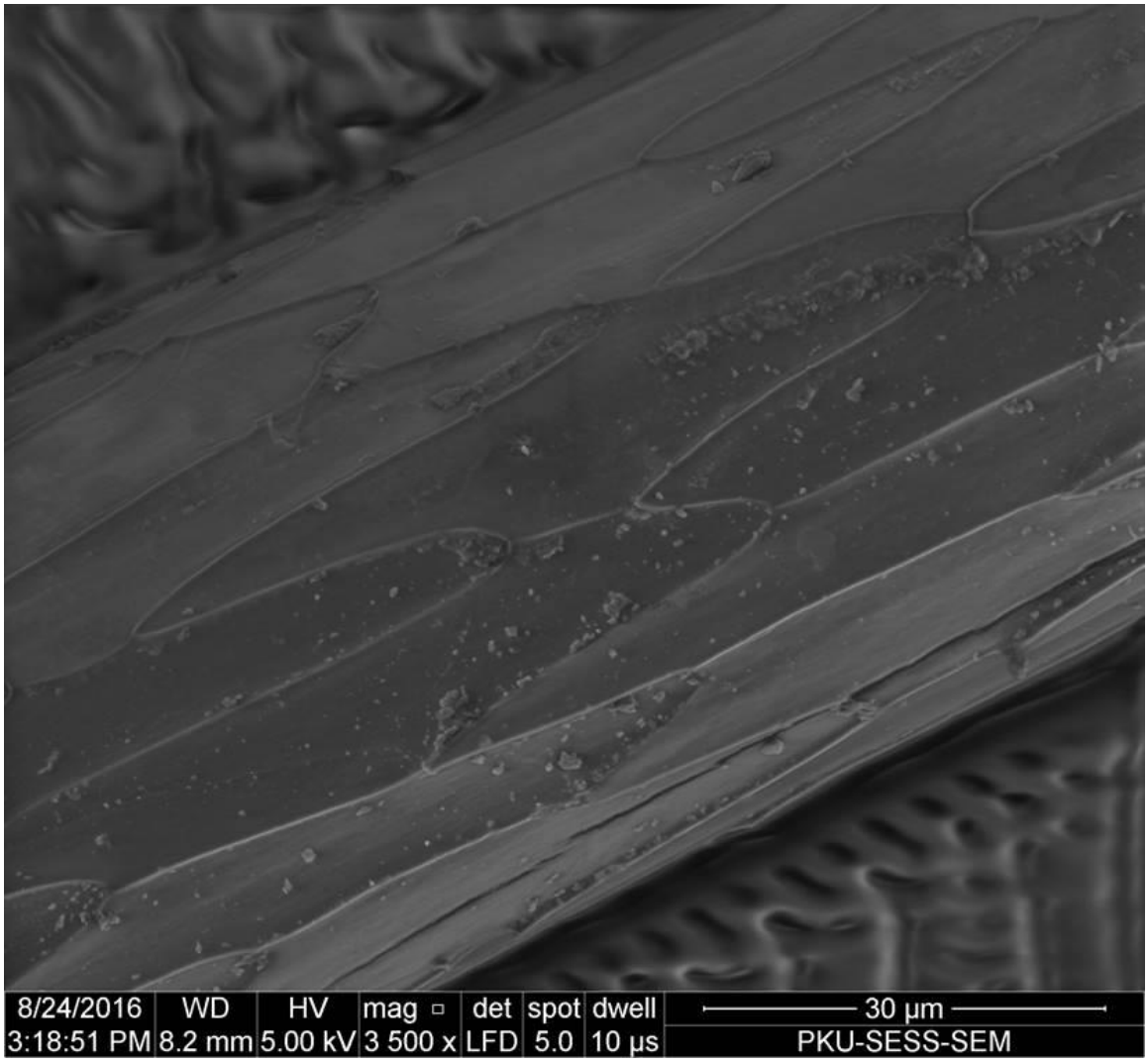
22. Burt, W. H. Territoriality and home range concepts as applied to mammals. *Journal of mammalogy* **24**, 346-352 (1943).
23. Palomares, F. & Caro, T. M. Interspecific killing among mammalian carnivores. *The American Naturalist* **153**, 492-508 (1999).
24. Linnell, J. D. & Strand, O. Interference interactions, co-existence and conservation of mammalian carnivores. *Diversity and Distributions* **6**, 169-176 (2000).
25. Donadio, E. & Buskirk, S. W. Diet, morphology, and interspecific killing in Carnivora. *The American Naturalist* **167**, 524-536 (2006).
26. Johnson, W. E. & Franklin, W. L. Spatial resource partitioning by sympatric grey fox (Dusicyon griseus) and culpeo fox (Dusicyon culpaeus) in southern Chile. *Canadian Journal of Zoology* **72**, 1788-1793 (1994).
27. Kernohan, B. J., Gitzen, R. A. & Millspaugh, J. J. Chapter 5 – Analysis of Animal Space Use and Movements. *Radio Tracking & Animal Populations*, 125-166 (2001).
28. Seaman, D. E. *et al.* Effects of sample size on kernel home range estimates. *The journal of wildlife management*, 739-747 (1999).
29. Vanak, A. T. *Intraguild interactions between native and domestic carnivores in central India*, University of Missouri--Columbia, (2008).
30. Nesbitt, W. H. Ecology of a feral dog pack on a wildlife refuge. *The wild canids*, 391-395 (1975).
31. Meek, P. D. The movement, roaming behaviour and home range of free-roaming domestic dogs, Canis lupus familiaris, in coastal New South Wales. *Wildlife Research* **26**, 847-855 (1999).
32. Scott, M. D. & Causey, K. Ecology of feral dogs in Alabama. *The Journal of Wildlife Management*, 253-265 (1973).
33. Fox, M., Beck, A. & Blackman, E. Behavior and ecology of a small group of urban dogs (Canis familiaris). *Applied Animal Ethology* **1**, 119-137 (1975).
34. Beck, A. M. The ecology of "feral" and free-roving dogs in Baltimore. *The Wild Canids*, 380-390 (1975).
35. Allen, R. D. & Westbrook, W. H. *The handbook of animal welfare. Biomedical, psychological, and ecological aspects of pet problems and control*. (Garland STPM Press., 1979).
36. Font, E. Spacing and social organization: urban stray dogs revisited. *Applied Animal Behaviour Science* **17**, 319-328 (1987).
37. Rubin, H. D. & Beck, A. M. Ecological behavior of free-ranging urban pet dogs. *Applied Animal Ethology* **8**, 161-168 (1982).
38. Daniels, T. J. The social organization of free-ranging urban dogs. I. Non-estrous social behavior. *Applied Animal Ethology* **10**, 341-363 (1983).
39. Berman, M. & Dunbar, I. The social behaviour of free-ranging suburban dogs. *Applied Animal Ethology* **10**, 5-17 (1983).
40. 李娟. *青藏高原三江源地区雪豹(Panthera uncia)的生态学研究及保护*, 北京大学, (2012).
41. Halle, S. & Stenseth, N. C. *Activity patterns in small mammals : an ecological approach*. (Springer, 2000).

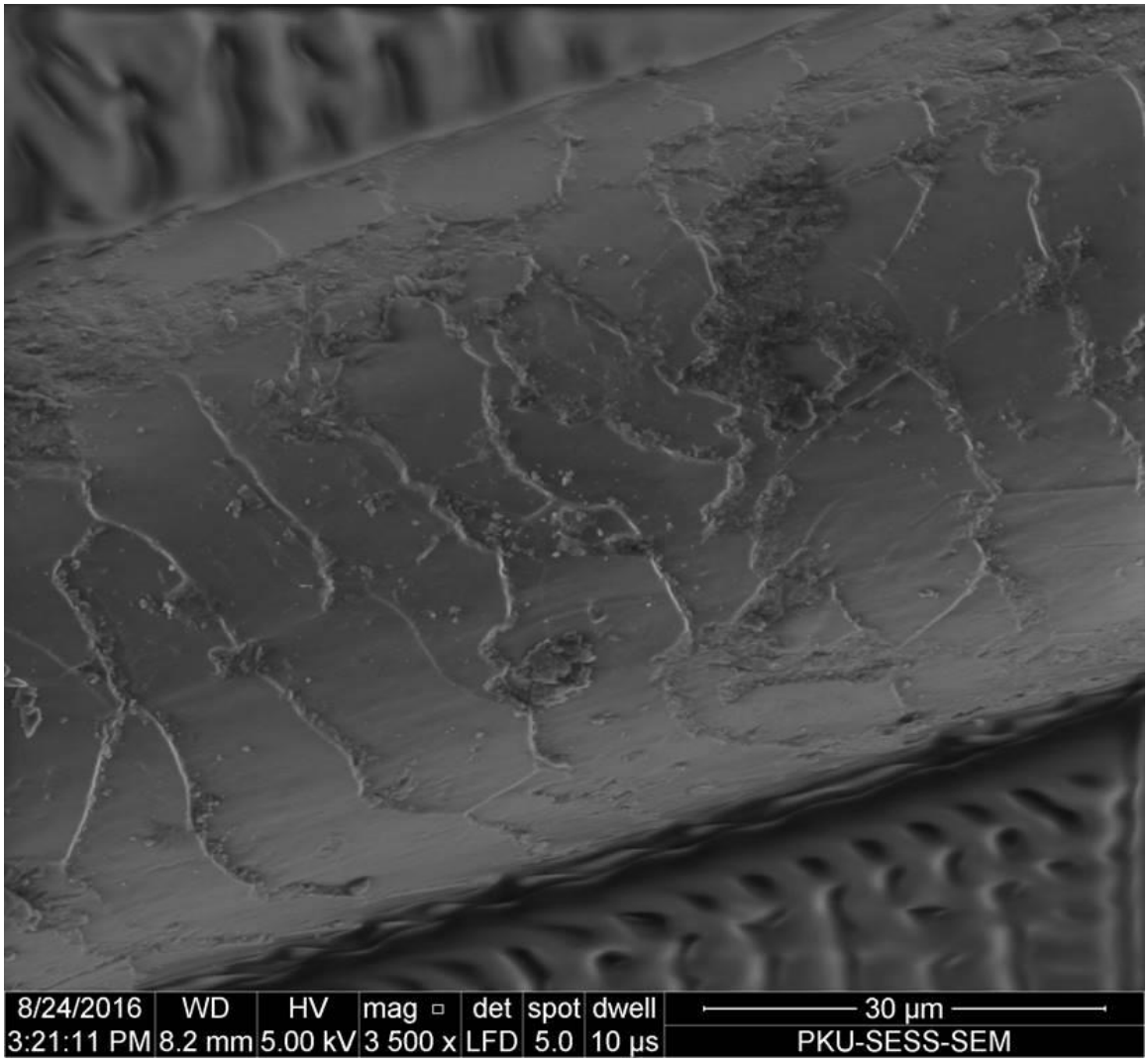
42. Norris, D., Michalski, F. & Peres, C. A. Habitat patch size modulates terrestrial mammal activity patterns in Amazonian forest fragments. *Journal of Mammalogy* **91**, 551-560 (2010).
43. Pianka, E. R. The structure of lizard communities. *Annual review of ecology and systematics*, 53-74 (1973).
44. Rasmussen, G. & Macdonald, D. Masking of the zeitgeber: African wild dogs mitigate persecution by balancing time. *Journal of Zoology* **286**, 232-242 (2012).
45. Kronfeld-Schor, N. & Dayan, T. Partitioning of time as an ecological resource. *Annual Review of Ecology, Evolution, and Systematics*, 153-181 (2003).
46. Laurenson, K., Shiferaw, F., Sillero Zubiri, C., SilleroZubiri, C. & Macdonald, D. The Ethiopian wolf: status survey and conservation action plan. *Disease, Domestic Dogs and the Ethiopian Wolf: the Current Situation (Eds C. Sillero Zubiri & DW Macdonald)*, 32 (1997).
47. Aiyadurai, A. & Jhala, Y. V. Foraging and habitat use by golden jackals (Canis aureus) in the Bhal Region, Gujarat, India. *JOURNAL-BOMBAY NATURAL HISTORY SOCIETY* **103**, 5 (2006).
48. Cozza, K., Fico, R., Battistini, M.-L. & Rogers, E. The damage-conservation interface illustrated by predation on domestic livestock in central Italy. *Biol Conserv* **78**, 329-336 (1996).
49. Echegaray, J. & Vilà, C. Noninvasive monitoring of wolves at the edge of their distribution and the cost of their conservation. *Animal Conservation* **13**, 157-161 (2010).
50. Sundqvist, A.-K., Ellegren, H. & Vilà, C. Wolf or dog? Genetic identification of predators from saliva collected around bite wounds on prey. *Conservation Genetics* **9**, 1275-1279 (2008).
51. Rushton, S. P., Lurz, P. W. W., Gurnell, J. & Fuller, R. Modelling the spatial dynamics of parapoxvirus disease in red and grey squirrels: a possible cause of the decline in the red squirrel in the UK? *Journal of Applied Ecology* **37**, 997-1012 (2000).
52. Holt, R. D. Predation, apparent competition, and the structure of prey communities. *Theoretical population biology* **12**, 197-229 (1977).
53. Holt, R. D. & Pickering, J. Infectious Disease and Species Coexistence: A Model of Lotka-Volterra Form. *American Naturalist* **126**, 196-211 (1985).
54. Tompkins, D. M., Draycott, R. A. H. & Hudson, P. J. Field evidence for apparent competition mediated via the shared parasites of two gamebird species. *Ecology Letters* **3**, 10-14 (2000).
55. Tompkins, D., Greenman, J., Robertson, P. & Hudson, P. The role of shared parasites in the exclusion of wildlife hosts: Heterakis gallinarum in the ring-necked pheasant and the grey partridge. *Journal of Animal Ecology* **69**, 829-840 (2000).
56. Tompkins, D. M., White, A. R. & Boots, M. Ecological replacement of native red squirrels by invasive greys driven by disease. *Ecology Letters* **6**, 189-196 (2003).
57. 57 Hatcher, M. J., Dick, J. T. A. & Dunn, A. M. How parasites affect interactions between competitors and predators. *Ecology Letters* **9**, 1253-1271 (2006).

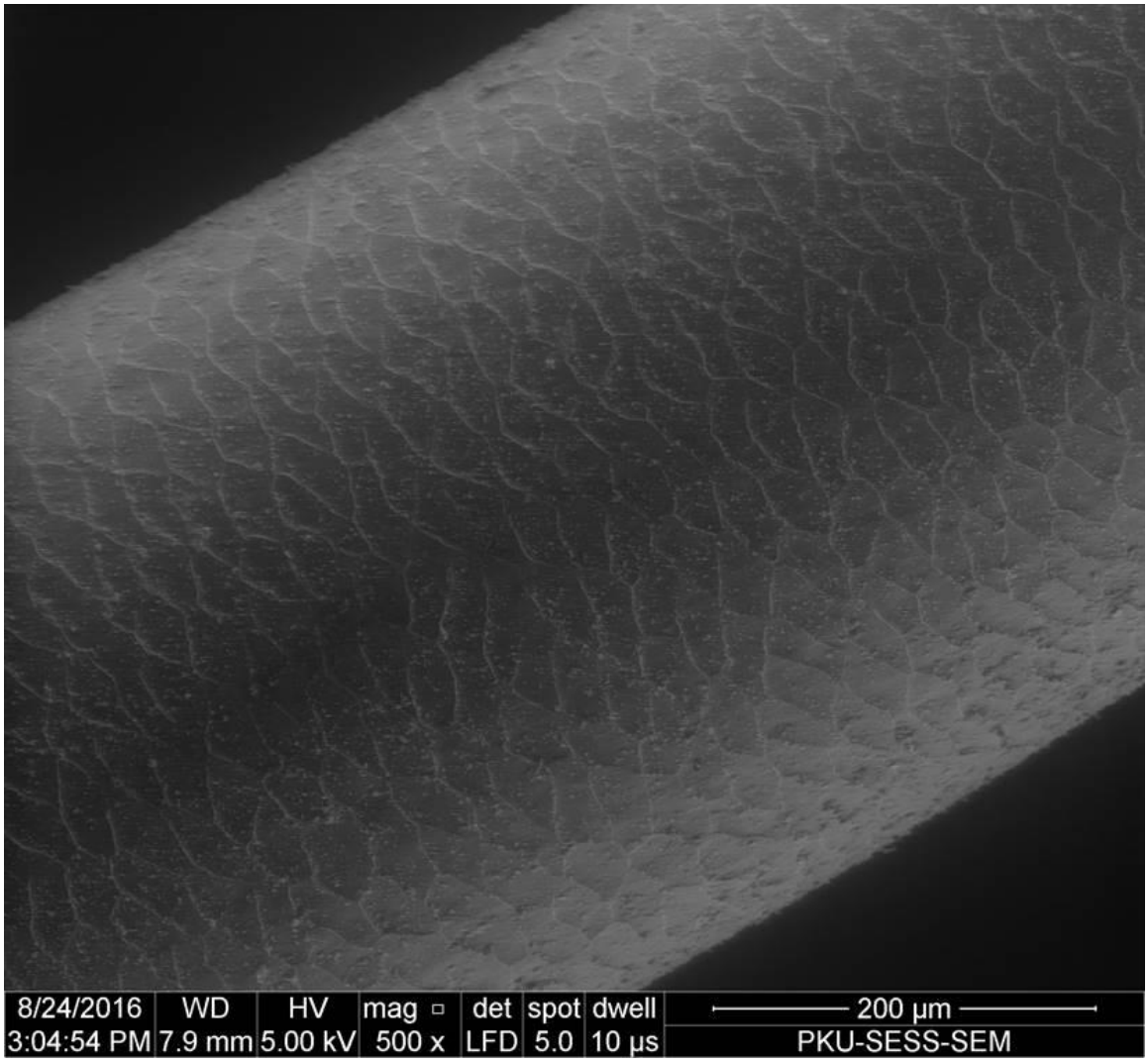
58. 58 Holt, R. D. & Dobson, A. P. Extending the principles of community ecology to address the epidemiology of host-pathogen systems. *Disease ecology: community structure and pathogen dynamics*, 6-27 (2006).
59. 59 Vanak, A. T., Gompper, M. & Belsare, A. Survey of Disease Prevalence in Free-ranging Domestic Dogs and Possible Spill-over Risk to Wildlife. *Rufford Small Grants Foundation*, 1-13 (2007).
60. 60 Tompkins, D. M., Greenman, J. & Hudson, P. J. Differential impact of a shared nematode parasite on two gamebird hosts: implications for apparent competition. *Parasitology* **122**, 187-193 (2001).

Photos under scanning electron microscope they are lamella patterns of different animals.




8/24/2016 WD HV mag ▫ det spot dwell 30 µm
3:18:51 PM 8.2 mm 5.00 kV 3 500 x LFD 5.0 10 µs PKU-SESS-SEM


8/24/2016 WD HV mag ▫ det spot dwell 30 µm
3:21:11 PM 8.2 mm 5.00 kV 3 500 x LFD 5.0 10 µs PKU-SESS-SEM


8/24/2016 WD HV mag ▫ det spot dwell 200 µm
3:04:54 PM 7.9 mm 5.00 kV 500 x LFD 5.0 10 µs PKU-SESS-SEM