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Why is the world's most expensive fungus disappearing?

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Abstract

Meet the world's most wanted *parasite*: a mummified caterpillar with a *fungus* growing right out of its face. Even stranger: it costs three times its weight in gold! This super expensive fungus grows in the alpine regions of the Himalayas and Tibetan Plateau where it is cold and dry. Its promised health benefits include increased strength and cures for many diseases. Recently, it has become very popular around the world. Its price has increased and collectors have started harvesting more. But lately, some people have become concerned that the fungus populations are declining. We wanted to see if that is the case, and if so, why? So, we interviewed local harvesters and analyzed environmental models of the region. Our results showed that there is a decline in the caterpillar fungus populations, and the main causes are o*verharvesting* and *climate change*.

Introduction

Fungi are life forms that are essential to humans and *ecosystems*. Recently, a parasitic fungus from the Tibetan Plateau has been in the headlines. And its life cycle is nothing short of strange.

Ghost moth caterpillars (Figure 1) spend years living underground, eating plant roots in the summer and hibernating for the rest of the year. *Ophiocordyceps sinensis*, the caterpillar fungus, also lives underground, and it invades the caterpillars' bodies with tiny *spores*. Once inside, this parasitic fungus eats its host alive – from the inside out. The brainwashed caterpillar crawls upward and dies slowly, ending up mummified right below the earth's surface. By late spring, the fungus grows out of the caterpillar's head, and a *stalk* pops up above the ground!

As if all this is not strange enough, local collectors dig up the caterpillar-fungus corpses for medicinal purposes (Figure 2). Caterpillar fungus has long been a part of traditional Asian medicine. People believe the fungus promises energy, stronger immunity, and even a cure for cancer. As the health claims have become more widely known, global demand has risen sharply. This increase in popularity has made the price of the fungus go up. Nowadays, one kilogram of caterpillar fungus can cost up to a shocking $140,000. This makes it the most expensive fungus and one of the most valuable *biological niche commodities* in the world.

The increased global demand has also led to more collecting by local harvesters. Many people are concerned about whether caterpillar fungus populations are declining. In this study we wanted to find out whether this is actually the case and if so, why?

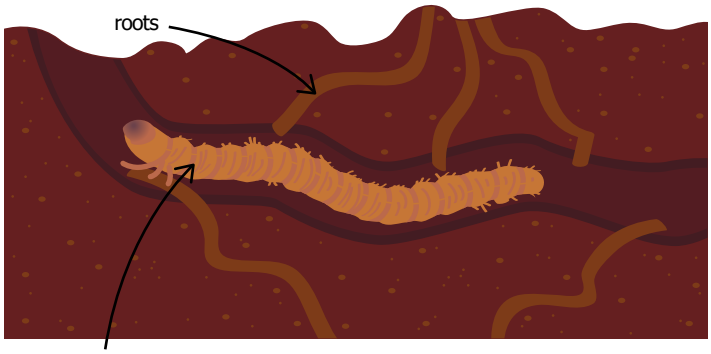

Figure 1:
More than 50 species of ghost moth caterpillar live in the Himalayas and Tibetan Plateau

Methods

The caterpillar fungus grows on the Tibetan Plateau in China and the Himalayan regions of Bhutan, India, and Nepal. The fungus production data in some areas were either lacking or unreliable (due to *poaching*). We overcame this limitation with a unique approach: integrating local harvesters' knowledge with environmental modeling.

Local knowledge: We interviewed harvesters about the change in their fungus production across the years they had been collecting it. Their responses were "no change," "fluctuating," "*per capita decrease*," (due to higher competition among collectors) "decreasing" or "increasing." As the causes of the change, the responses fell into five main categories: weather, climate change, competition, *habitat degradation*, and overharvesting.

We reviewed hundreds of publications dated from 1723 to 2017 and gathered *qualitative* and *quantitative data*. Combining our interviews with the results of interviews that had been reported in these publications, we determined how production trends have shifted and the factors affecting them.

Environment Modeling: We used computer models to analyze climate patterns, geographic factors, and environmental conditions such as precipitation, temperature, elevation, and *permafrost*. Determining the suitable habitat conditions, we created a caterpillar fungus production map of the region.

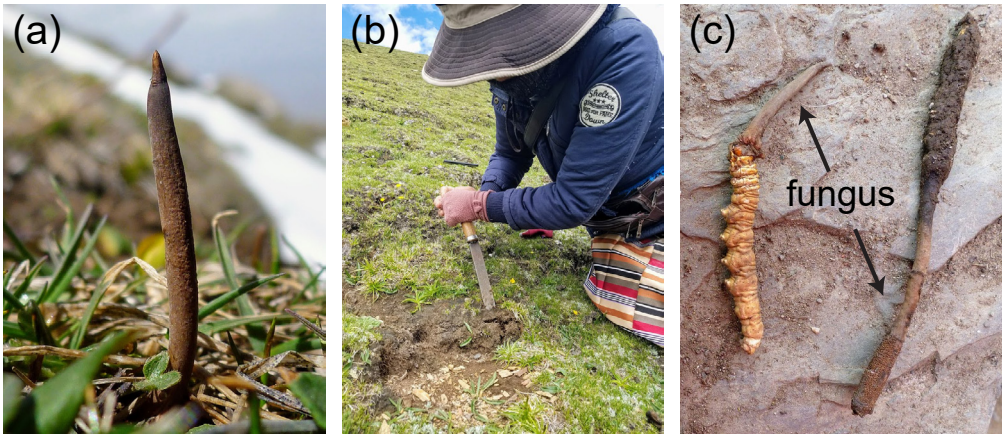

Figure 2:
a) Caterpillar fungus emerges after the snow melts. Collectors often have to crawl on the ground to spot the brown stalk.
b) It's not easy to dig up and extract the caterpillar while keeping it attached to the fungus. If the fungus breaks off of the caterpillar, its value drops.
c) Left: Cleaned and immature - not ready to spread spores yet. Right: Uncleaned and mature - ready to spread spores. The fungus on the left is more valuable. That encourages collectors to extract fungi before they get their chance to infect the next round of caterpillars.

Results

1. The majority of the harvesters observed a decline in fungus production. Since 2005, more and more harvesters have said the fungus populations are "decreasing" while fewer reported "not changing," "fluctuating," or "per capita decrease." (Figure 3a)

2. While a smaller group increasingly responded with "changing climate" as the dominant cause, recently, the majority of the harvesters reported "overharvesting." (Figure 3b)

3. The fungus grows in very high (average elevation 3200-4900 meters above sea level), dry, and cold areas (average winter temperatures between -15°C and -5°C). It is typically found in areas near permafrost. The habitat suitability drops dramatically with winter temperatures warmer than -4°C. (Figure 4)

4. Our analysis of the climate (1979-2013) indicated a significant increase in winter temperatures. The most warming was in Bhutan with an increase of about 4°C–nearly 1°C per decade.

Please see Figure 3 and 4 on Page 3

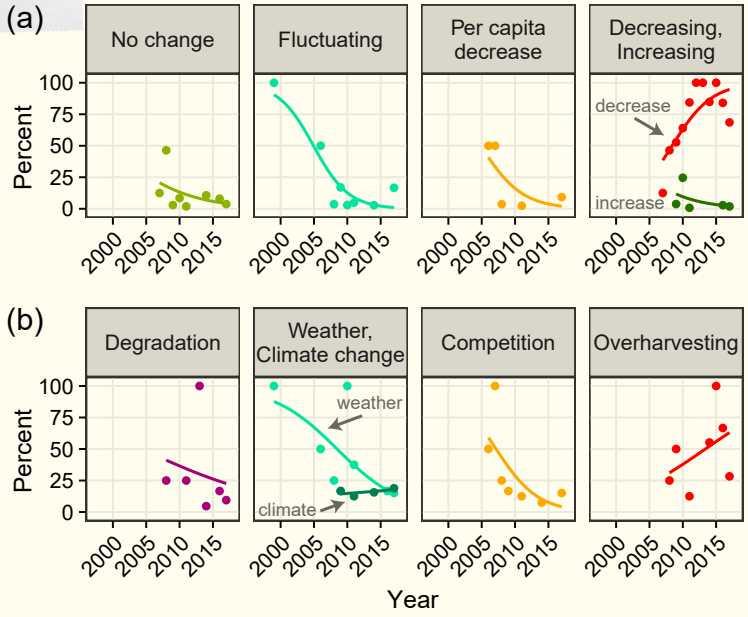

Figure 3:
a) Change in production: More and more harvesters said that fungus production is declining.
b) Causes of change: Harvesters increasingly recognize overharvesting and climate change as reasons for declining production, whereas previously they more often listed other reasons like weather or competition with others.

What is the major cause of decreasing fungus production?

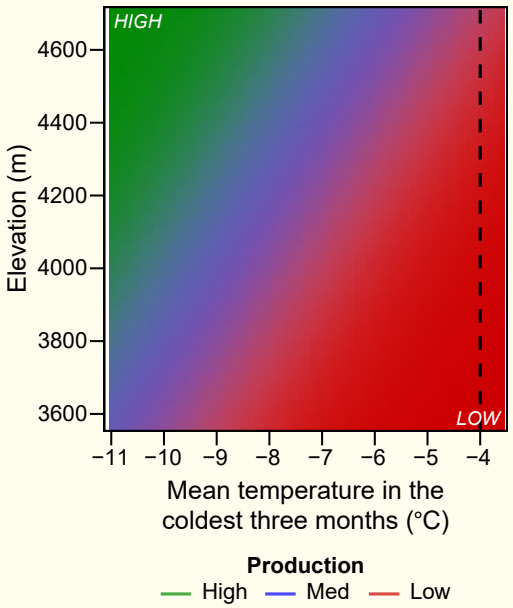

Figure 4:
Our computer model calculated caterpillar fungus production by the elevation and mean temperature during the coldest three months of the year. The vertical dashed line indicates the threshold: Caterpillar fungus doesn't typically grow in areas where the mean winter temperature is higher than (-4°C).

Discussion

Caterpillar fungus production is indeed declining. Our results pointed out the "double whammy" threatening this valuable resource: overharvesting and climate change.

- Harvesters extract fungi before they spread their spores and infect soil. This prevents the next round of caterpillar infections, and fungus production declines. Fortunately, some local communities are looking for ways of *sustainably* harvesting.
- Warmer temperatures cause permafrost thaw and changes in vegetation. It would likely be difficult for the caterpillar fungus simply to relocate to higher and colder areas because it depends on its host, the ghost moth caterpillar (and the plants the caterpillar feeds on). To understand species' responses to climate change, we need to consider the web of relationships that they have, and how environmental conditions affect each of these.

The caterpillar fungus trade is an important part of the economy in these parts of India, Nepal, Bhutan, and China. Collecting and selling caterpillar fungus is the primary source of income for thousands of families. Our study could be a warning of what many harvesters have already realized. Since both climate change and current harvesting strategies are decreasing the amount of fungus available for harvesters, they will likely need to find other income sources.

Conclusion

The Himalayan region, the rooftop of the world, is one of the areas most sensitive to global climate change. Any additional human impact on an already weakened species could cause extinction. Here are some things you can do:

1. Participate in citizen science projects to share your local knowledge, because local ecological knowledge is very valuable.
2. Practice and promote sustainable use of natural resources.
3. Take action against climate change. Check out other Science Journal for Kids articles like "**More Stuff More Climate Change**" for great info and ideas.

Glossary of Key Terms

Biological niche commodity – an expensive biological good or product that serves a specific group of customers.

Climate change – a change in the average and variability of weather conditions (not to be confused with weather, which is a temporary state - hot, cold, cloudy, rainy - of the atmosphere). Scientists overwhelmingly agree that the observed increase in global temperature of 0.8 degrees Celsius (1.4 degrees Fahrenheit) since 1980 is due to the release of greenhouse gases by human activities.

Ecosystem – a biological community of interacting organisms and their physical environment.

Environment – the surroundings or conditions in which a person, animal, or plant lives or operates.

Fungus – the kingdom of eukaryotic organisms (that are neither plants nor animals). Since they can't produce their own food, they must either decompose organic material or live as a parasite. Some examples are mushrooms, mold, mildew, yeast.

Habitat degradation – the process by which natural habitat becomes incapable of supporting its native species. In this process, the organisms that previously used the site are displaced or destroyed.

Overharvesting – taking more from the land (or sea) than it can replace. This includes extreme farming, grazing, fishing, and using fresh water.

Parasite – an organism that lives inside or attached to another organism, called the host. The relationship is always the same – good for the parasite, bad for the host. Examples: lice, tapeworms, pinworm.

Per capita – for each person.

Permafrost – ground including rock or soil at or below the freezing point of water for two or more years. Most permafrost is located in and around the Arctic and Antarctic regions, but at lower latitudes alpine permafrost occurs at higher elevations.

Poaching – Illegal hunting of wildlife or collection of plants and fungi.

Qualitative data – describing the quality of something in size, appearance, value, etc.

Quantitative data – information about quantities, information that can be measured and written down with numbers.

Spore – microscopic biological particles that allow fungi to reproduce, serving a similar purpose to that of seeds in the plant world.

Stalk – the slender attachment or support of a leaf, flower, or fruit.

Sustainable – the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance.

Check your understanding

1 Why is the caterpillar fungus such an important resource?

2 Local harvesters are aware that overharvesting causes fungus population decline. How does overharvesting cause a decline in fungus production?

3 What are the effects of climate change in the region where caterpillar fungus grows?

4 Why can't the caterpillar fungus respond to climate change by just relocating to colder and higher areas?

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