SCIENCE·3D

TIGER REALM

In this packet, sample student answers are provided in red and notes to teachers are in blue.

In this **Science Mission**, students explore how changes in human population and land use in India affect animal populations. They will graph data and interpret maps to help make connections. Then, they will analyze data to test their predictions on how human interventions might influence animal populations. Finally, they will explore genetic variation and patterns of genotypes across India and use these data to propose management strategies for tigers. There is an optional essay component to this mission.

Note: Different colored writing utensils may be useful for graphing. Otherwise, students will have to use different shading patterns.

ACTIVITY I: CHANGES IN INDIA

India is an amazing country with incredible biodiversity. In fact, about 10% of the world's plant and animal species are found in India! India's biomes include tropical rain forests, deciduous forests, grasslands, shrublands, deserts, and wetlands. Because of the mountains, India also has biomes that are cold like the taiga and tundra.

The Nilgiri Biosphere Reserve is located in one of the world's "biodiversity hotspots." That means it has a very large number of plant and animal species. But the region is threatened. Before we study the tigers here, we need to understand what has happened to the human population and important biomes in India. Table 1 shows how the human population and the area of land covered by different biomes or human uses (called "land cover") has changed over time.

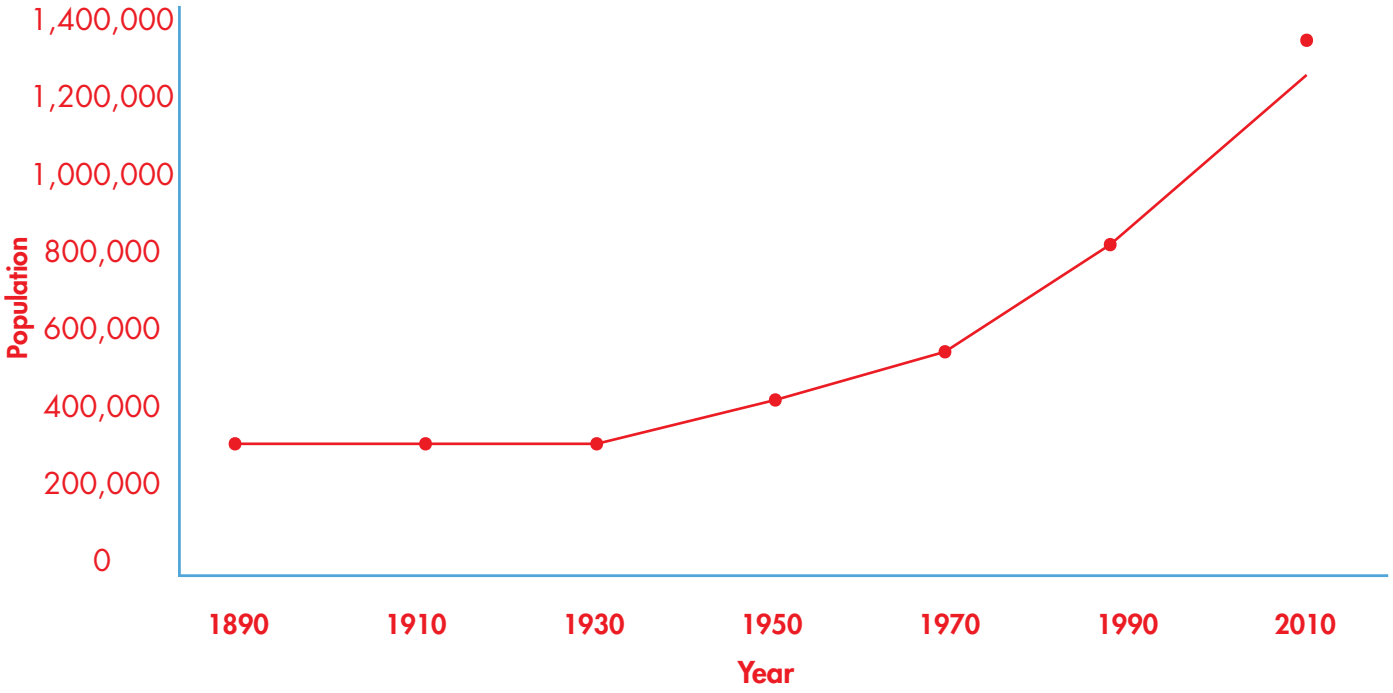
Table 1. Change in population and land cover in India from 1890 to 2010

Year	Human population	Built area (km^2)	Agriculture area (km^2)	Forest area (km^2)	Grassland/ Shrubland area (km^2)
1890	300,000	5,000	900,000	850,000	430,000
1910	300,000	5,000	950,000	800,000	430,000
1930	300,000	6,000	1,000,000	750,000	430,000
1950	450,000	7,500	1,050,000	700,000	430,000
1970	550,000	10,000	1,100,000	650,000	430,000
1990	800,000	14,000	1,200,000	650,000	375,000
2010	1,200,000	21,000	1,300,000	650,000	250,000

Extend the Lesson: Have students calculate the percent decline in grasslands and forests and the percent increase in human population, built area, and agriculture area.

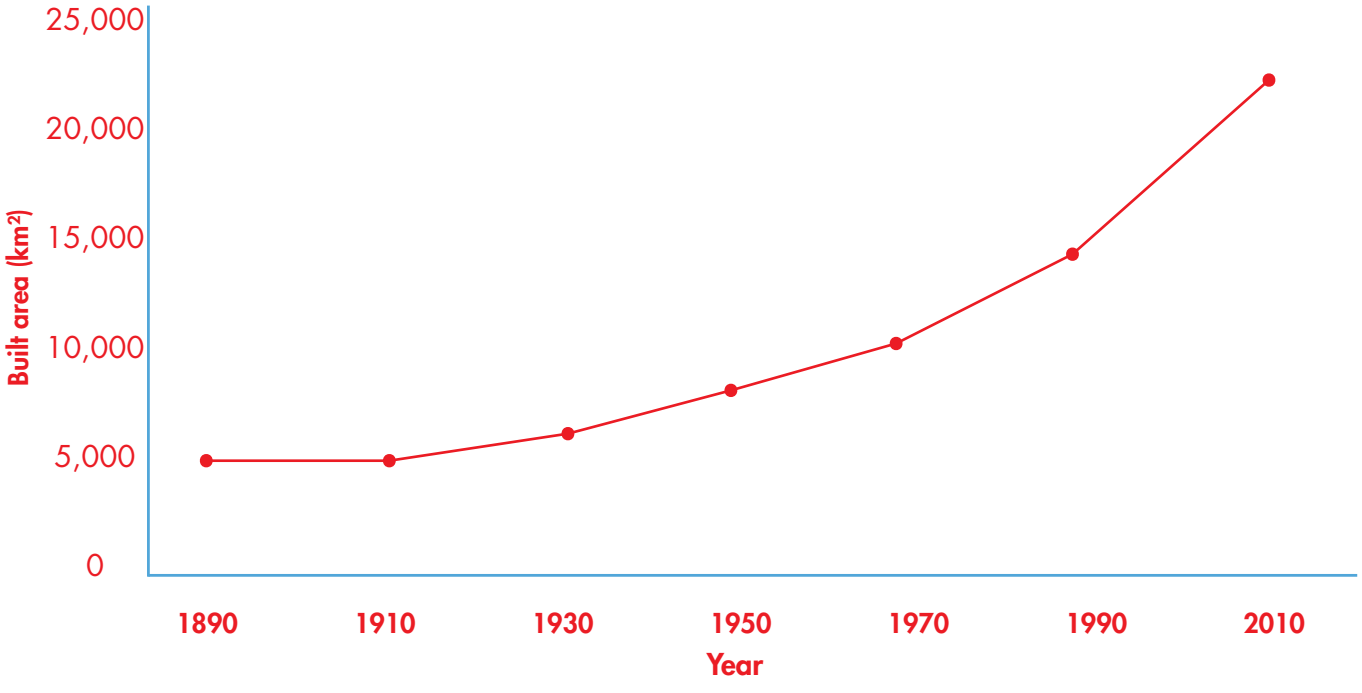
Note: There are quite a few graphs for students to draw in the following questions. Consider providing them with the first graph of human population changes so students who struggle with graphing have an example. Then, have them complete the next graph. Alternatively, you could have different groups complete different graphs and share them with the class or provide students with the graphs and have them interpret them (starting at question 4).

1. **Draw** a graph of the change in human population through time. Label the axes and write a figure caption.



Population growth in India from 1890-2010

2. **Draw** a graph of the change in built area through time. Label the axes and write a figure caption.

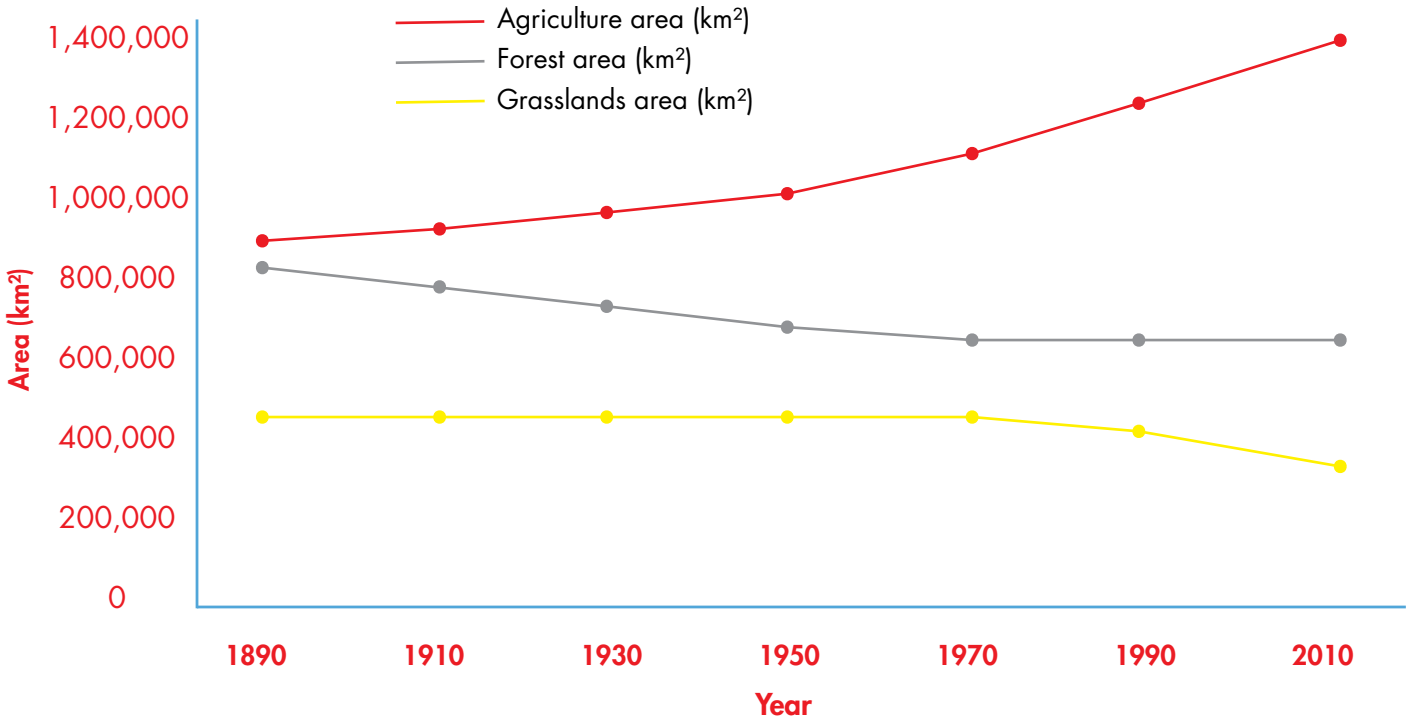


Change in built area in India from 1890-2010

3. **Describe** how the population of India and the area of land that has been built over by people has changed.

The population stayed about the same from 1890 to 1930, then it started to grow. In 1950 it started growing at a much quicker rate. The same pattern occurred for the area of built land. It grew slowly at first and then sped up from 1970 to 2010.

4. **Draw** a graph of the change in area of agriculture, forests, and grasslands/shrublands through time shown in Table 1. Label the axes and write a figure caption. Include a figure legend to identify each type of land cover.



Change in area of agricultural land, forest, and grasslands/shrublands in India from 1890-2010

5. **Describe** how the area of land used for agriculture has changed through time relative to human population shown in your figure above.

The amount of land for agriculture has increased constantly since 1890. The rate of increase started going up after 1970. Some students might notice that agricultural area was going up even when population was fairly stable through 1930. Consider discussing this.

Extend the Lesson: Challenge students by having them compare the rate of land conversion to agriculture to the rate of change in built up areas. They will notice that the land for agricultureincreases at a faster rate.

6. **Describe** whether the area covered by built area or agriculture has increased more quickly.

The amount of land area for agriculture is much higher than that of built area. It has increased by more than 10 times as much area as built areas.

7. **Describe** how the rate of land area used for agriculture relates to the land area covered by forests, shrublands, and grasslands. Use data from your figure and Table 1 to support your answer.

As the amount of area for agriculture has increased, the amount of area of forest and grassland/shrubland has decreased. Some students will notice the important pattern of forests initially being cleared for agriculture. But eventually, people stopped cutting forests down at a high rate. They switched to clearing grasslands and shrublands. The switch occurred in about 1970. You could **Extend the Lesson** by asking students to explore when India started creating national parks to see if this explains some of the change.

8. **Predict** what you think will happen to the area of land covered by forests, grasslands/shrublands and human uses (agriculture and built area) if human population continues to rise.

I think that as the population grows, more area will be used for agriculture and built-up areas. The amount of forest and grasslands/shrublands will decrease.

9. Some people argue that increasing the efficiency of land used for agriculture (how much food is produced per square kilometer of land) is necessary to protect natural habitats. **Describe** why this could be important.

If the land used for agriculture produces more food, then there won't be a need to clear more natural lands for agriculture. More natural habitats can remain intact and be protected.

Extend the Lesson: Have students discuss why some urban planners are trying to make sure that cities build "up" instead of "out." They think having cities with more people in a smaller area will be good for the natural environment. Have students debate whether they think this is a good idea or not and why. The reason for this type of planning is that it allows more area to remain as natural or agricultural areas because humans would occupy a smaller area of land. Also, environmental impacts of transportation can be reduced because people do not need to drive as much.

Optional: The optional questions that follow are meant to help students enhance their abilities to interpret data on maps. It also is useful for students to think about the different kinds of information the same data displayed in different ways can provide.

Complete the following questions if instructed by your teacher.

We have learned about how land cover has changed over time. But, has this change occurred in a similar way all over the country? Use the maps in Figure 1 to find out!

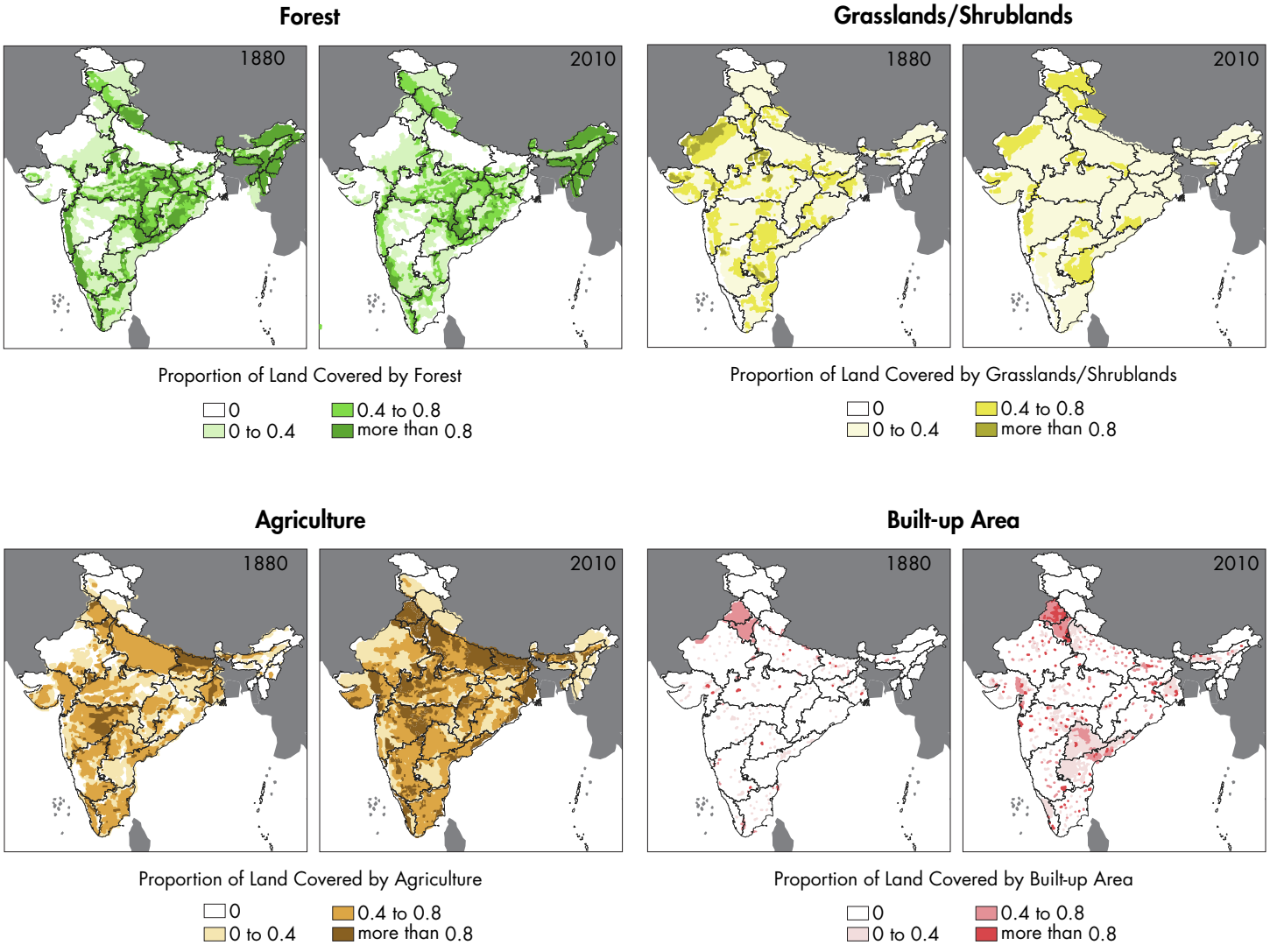


Figure 1. Change in land cover from 1890 to 2010 in India

10. **Compose** a brief essay that describes the changes in the landscape of India between 1880 and 2010. You should have at least 5 paragraphs in your essay. The paragraphs should include the following:
    - *Paragraph 1*: Introduction that states what has happened to the size of the human population, what habitats have decreased, and what types of use of land have increased.
    - *Paragraph 2*: Describe how the amount of agricultural area changed in India. Describe where there have been the most changes.
    - *Paragraph 3*: Describe how the amount of forest changed in India. Describe where there have been the most changes.
    - *Paragraph 4*: Describe how the amount of built-up areas have changed in India. Describe where there have been the most changes.
    - *Bonus Paragraph*: *Describe what habitats have been turned into different types of human use (built-up or agriculture).*
    - *Paragraph 5*: **Predict** how the changes in the land have affected tigers and their prey.

Complete answers will address the points in each of the descriptions. The key is that students include the important bullet points and that ideas flow logically.

ACTIVITY 2: CHANGES IN TIGER POPULATIONS

How have tiger populations changed through time as the landscape changed? Figure 2 shows the estimated number of Bengal tigers (the tiger type found in India) over time. It also shows how the total amount of tiger habitat has changed through time.

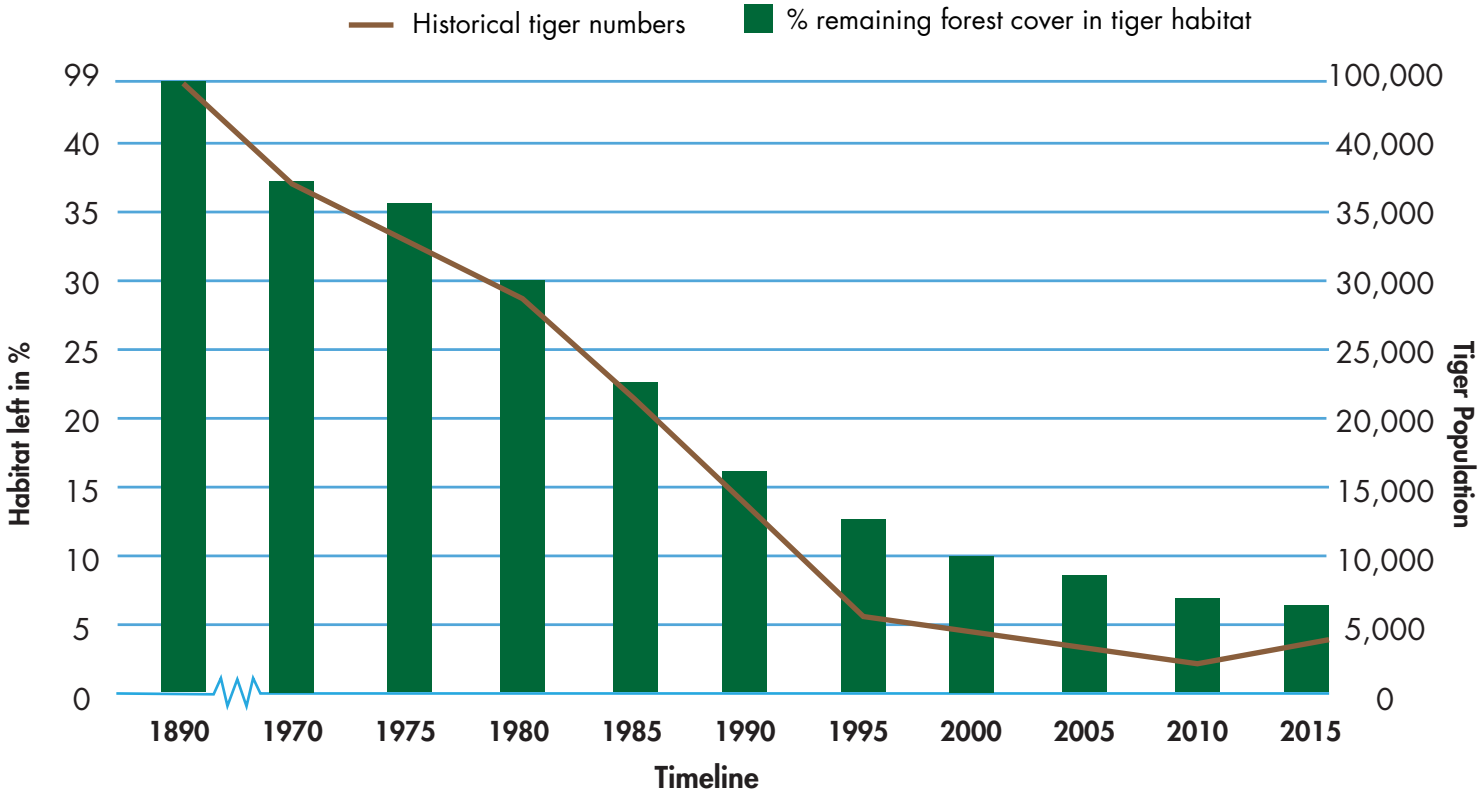


Figure 2. Change in the percent of remaining tiger habitat and change in tiger numbers over time

1. **Describe** the relationship between the amount of habitat left and the number of Bengal tigers.

As the amount of habitat has decreased, so has the number of tigers.

2. Do you think that the population size of people affects the amount of habitat left and the number of tigers? **Explain** your answer.

I think the number of people is an important factor. Based on the previous activity, more people need more space. With more agriculture and built space there will be less space for tigers and fewer tiger overall.

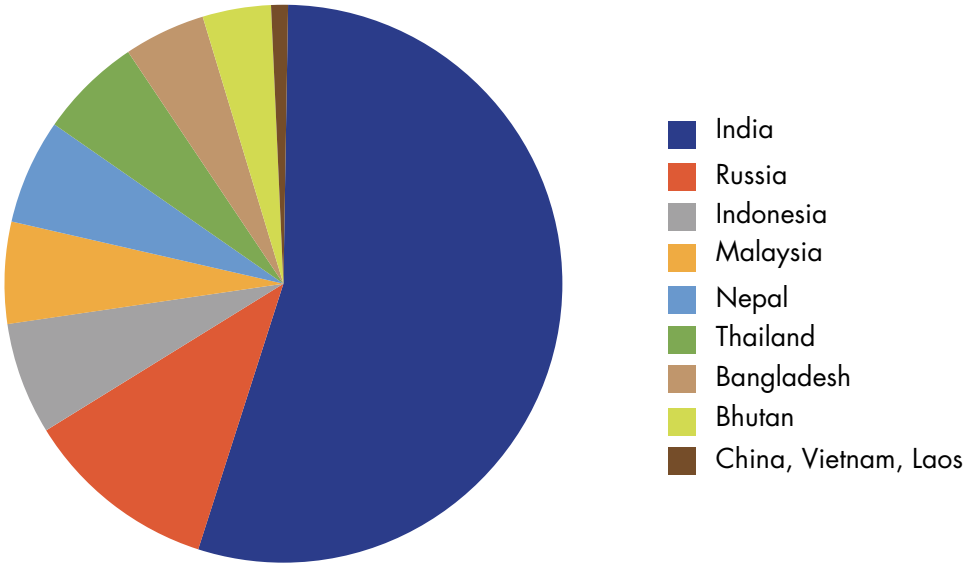


Figure 3. Proportion of remaining global tiger numbers living in different countries

3. Figure 3 shows the proportion of the world's tigers in different countries in 2016. **Describe** which countries you think are most important for ensuring tigers survive.

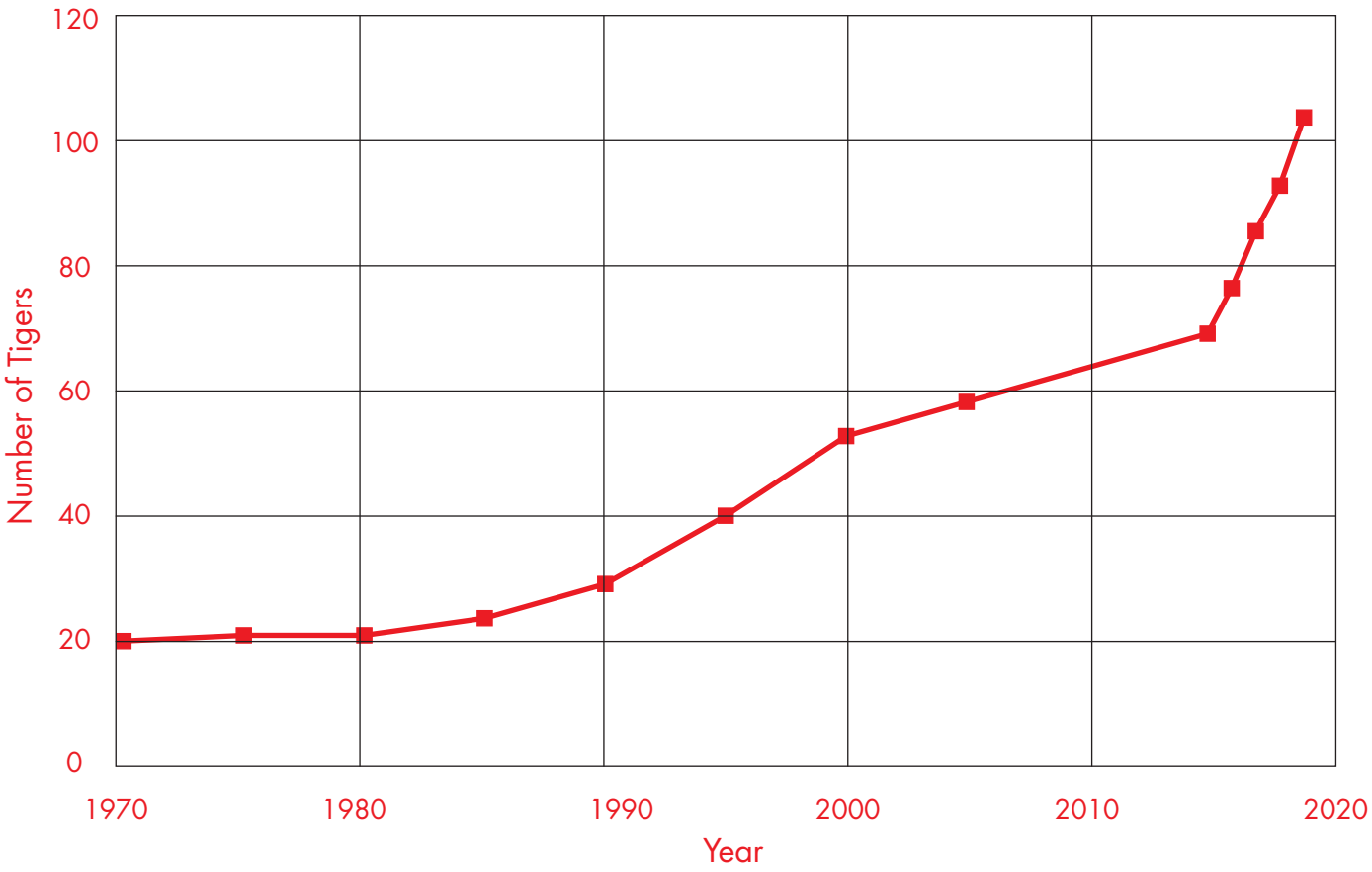
I think that India is the most important country because they have more than half of the world's remaining tigers. Russia, Indonesia, Malaysia, Nepal, and Thailand are also fairly important. Some students might think countries with small tiger populations are more important because tigers are about to disappear from those areas. Accept reasonable arguments, but engage in a class discussion and have students think about how protecting big numbers is critical for the survival of a species.

How has the tiger population been doing in national parks? Nagarhole National Park, in southwest India, was declared a wildlife sanctuary in 1955 and was made a national park in 1988. Like the rest of the world, tiger numbers were not very high when people started to protect them. The data in Table 2 show the change in the number of tigers in Nagarhole National Park through time.

Table 2. Estimated number of tigers in Nagarhole from 1970 to 2019

Year	Number of Individual Tigers
1970	18
1975	19
1980	19
1985	22
1990	28
1995	40
2000	54
2005	60
2015	72
2016	80
2017	90
2018	98
2019	110

4. **Draw** a line graph of the number of tigers in Nagarhole through time. Label the axes and write a figure caption.



Change in tiger numbers in Nagarhole National Park

5. Do you think that having enough habitat was the only threat to tigers around 1970? Remember that the amount of forested area did not increase from the 1930s until today. But the amount of area that was protected from hunting increased. **Describe** your reasoning and use data from your figure.

Accept reasonable answers. This is more for students to really think about the different effects humans have on tigers. A strong sample answer is: I do not think having enough habitat was the only problem. There was the same amount of habitat in 1970 as 2010 but the tiger population increased. The bigger problem was probably that tigers were being hunted.

6. **Describe** whether you think that the protections to Nagarhole have helped the tigers.

I think that the protections have helped because the population has increased a lot. Some students may notice that there may not have been an immediate effect when the park was declared a sanctuary. The real gains have occurred after it was declared a National Park.

Across India, tiger conservation has been successful. Tiger numbers are on the rise across the country, just like in Nagarhole National Park. The government is now considering how to make more protected areas or grow existing protected areas. But, with tiger numbers increasing, are they leaving the protected forests to enter areas where there are people? Young tigers need to move to find their own territories. What happens if there are no good territories left in a protected area? If tigers enter agricultural land or villages, it could be dangerous for people and their livestock.

7. **Predict** what should happen to the number of tigers detected by camera traps in agricultural lands near protected areas as the number of tigers has increased.

Answers will vary. What is important is to have a logical and testable idea. I think as tiger numbers increase, the camera traps will show more tigers going into areas where there are people and agriculture. Young tigers will be looking for new territories.

8. **Describe** how you would test your hypothesis.

Answers will vary. Examples include: I could set camera traps in human areas or track young tigers' movements.

Table 3. Number of tigers seen at the forest edge near the park boundary and the number of tigers detected by camera traps in a coffee plantation between the park and another forest

Year	Forest (Near Boundary)	Coffee Plantation
2014 to 2015	6	0
2015 to 2016	9	0
2016 to 2017	11	2
2017 to 2018	13	4
2018 to 2019	15	6

9. **Describe** whether the data in Table 3 support or reject your hypothesis.

If students have the hypothesis suggested above, the answer should be: It supports my hypothesis because not many tigers were seen in the coffee plantation until the tiger population started to grow large.

Note: For a story on increasing tiger-human conflict see: https://www.bbc.com/news/world-asia-india-49148174

ACTIVITY 3: GENETIC DIVERSITY AND ENSURING A FUTURE FOR TIGERS

When population sizes get very small, they can lose genetic variation. Some traits may be lost from the population. This can be very bad for populations. Some of the lost traits may be ones that help individuals fight off new diseases. Some of the lost traits may be ones that help the population survive if the environment changes. Also, if all individuals are too genetically similar, the rate of reproduction may decrease because genetic diseases can become more common. More genetic variation helps populations survive!

Sometimes wildlife managers face difficult decisions. When two populations are very genetically different, they may be subspecies. That means the population may be turning into two different species. For example, there are at least six subspecies (types) of tigers. Some, like the Siberian tiger are quite different from other subspecies. Usually, wildlife managers want to preserve these unique genetic lines. But, when one subspecies has a population that gets too small it might lose too much genetic variation. Then, managers might need to increase genetic diversity by mixing subspecies. For example, in the 1970s there were only around 20 Florida panthers left alive. Florida panthers are a subspecies of mountain lions. They are unique. Since the population was too small, managers brought in mountain lions from Texas to help grow the population. This introduced different genes into the population. The introduction of new mountain lions helped the population in Florida grow larger. Now there are more than 100 panthers (mountain lions) in Florida.

So, what about tigers? We know that the amount of genetic diversity has declined as their populations dropped from100,000 to just a few thousand. That means that it is important to not lose any more genetic diversity.

Are there different genetic groups in India? Should managers keep these groups separate or try to help them interbreed? Scientists have been racing to find out.

Figures 4 and 5 show where tiger populations in India have been sampled for their genetic diversity.

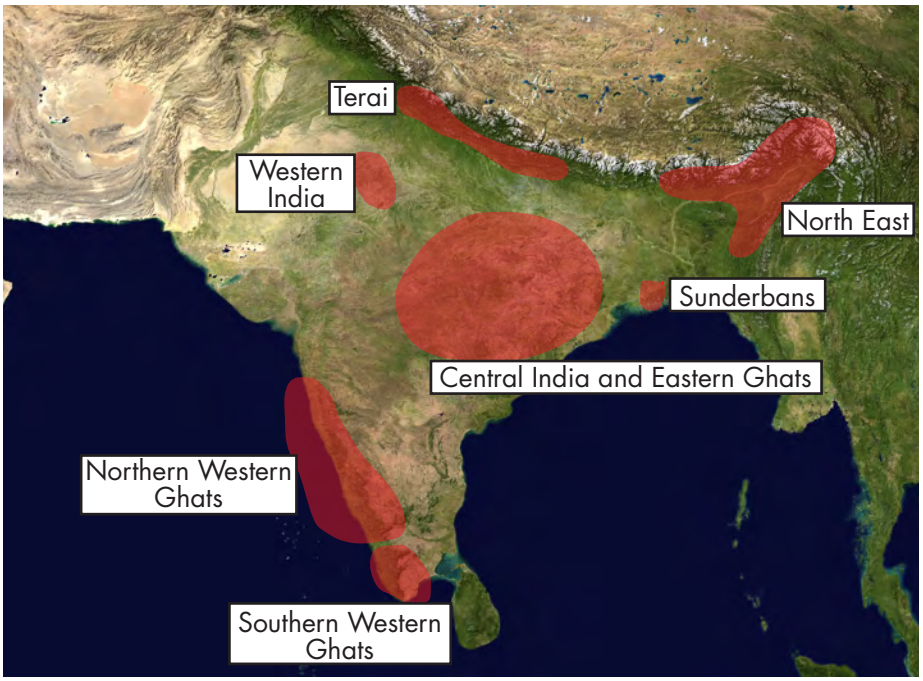


Figure 4. Locations where tiger populations were sampled in India

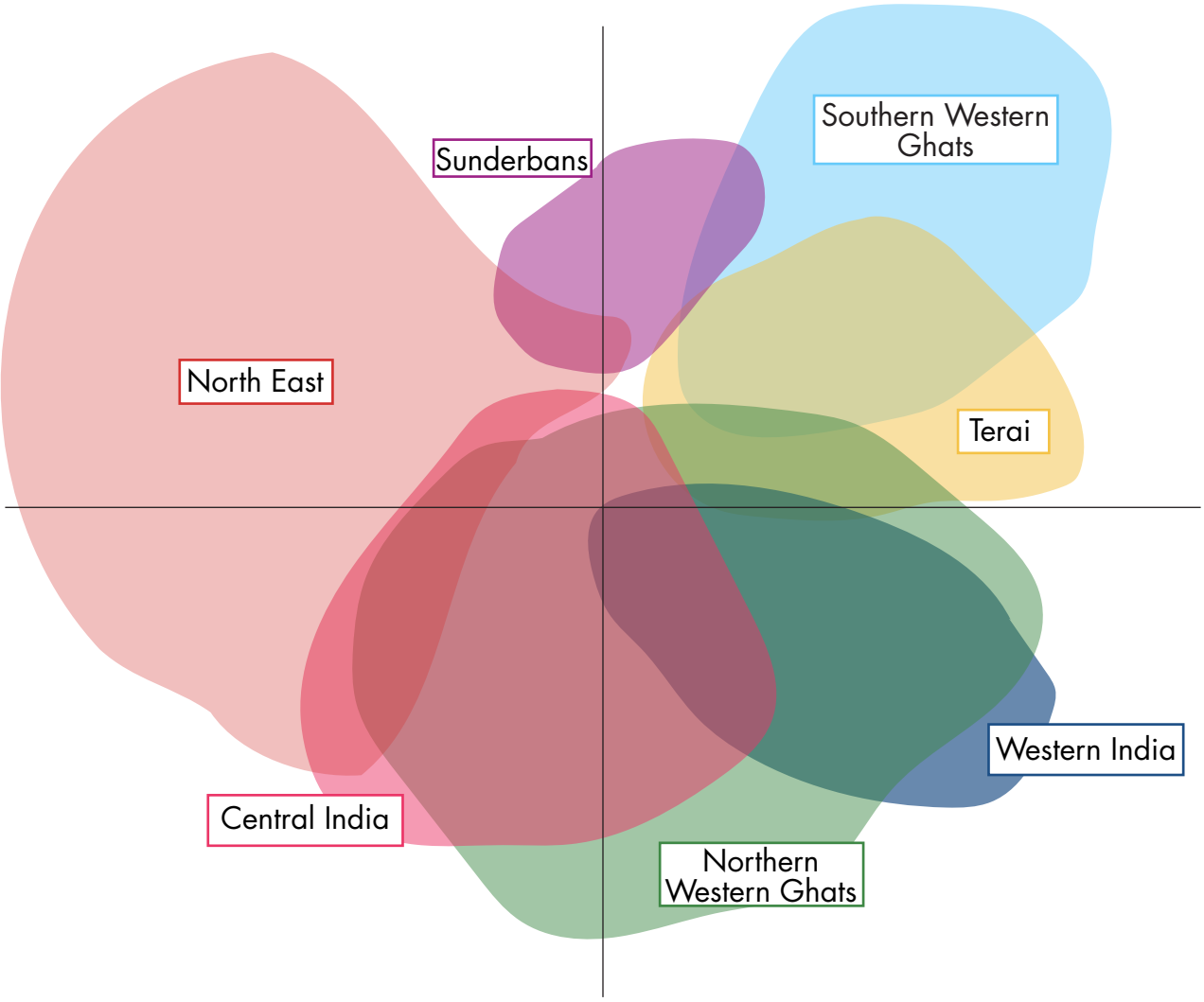


Figure 5. Similarity of genes in tigers from different areas
The bigger the area covered, the more genetic variation there is. Areas where shapes overlap show similar genotypes in the populations.

1. Based on Figure 5, which populations have the most genetic variation? **Describe** how you know.

The North East and Northern Western Ghats poulations have the most genetic variation. The shapes cover the most area in the figure.

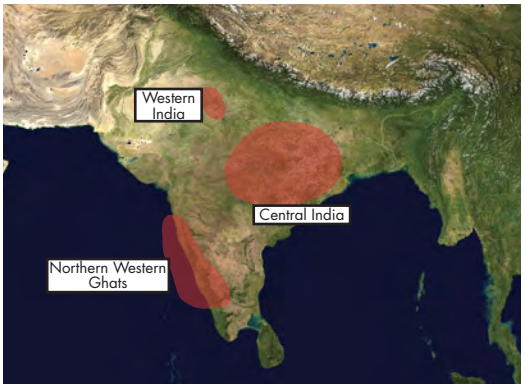
2. Which populations have the most unique genes? **Describe** how you know.

North East, Sunderbans, and Southern Western Ghats populations have the most unique genes. The shapes cover the most area that does not overlap with other areas.

3. **Create** an argument for which populations should be prioritized for protection. Explain why you made these arguments.

Accept well-reasoned arguments. An example of a complete answer includes: I would protect the North East, Sundarbans, and Southern Western Ghats because there are many unique genes and a lot of variation. Students may also select Northern Western Ghats because of its high level of diversity, including a lot of the variation in other spots.

Now we know where there are tiger populations with unique genetics (covering unique areas in Figure 5) and high genetic diversity (covering large areas in Figure 5). We also know that some of the populations are unique. But, should managers try to maintain those unique populations or move some tigers to help them interbreed? Geneticists can use computer models to make predictions about what might happen in different scenarios. Figure 6 shows a computer simulation model for three separate tiger populations. The left graph shows how many tigers need to be in the population over the next decades to not lose any genetic variation. The model tested three possibilities of how to manage tigers. In the first, a few tigers are moved between populations each year so there is some genetic exchange (very low interbreeding). In the second, a moderate number of tigers are moved between populations each year so there is more genetic exchange (moderate interbreeding). In the third, many tigers are moved among populations so there is enough interbreeding to make all the populations genetically similar. The graph on the right shows the number of tigers needed in the Western Ghats population to maintain genetic variation if no tigers from other locations are introduced to interbreed.



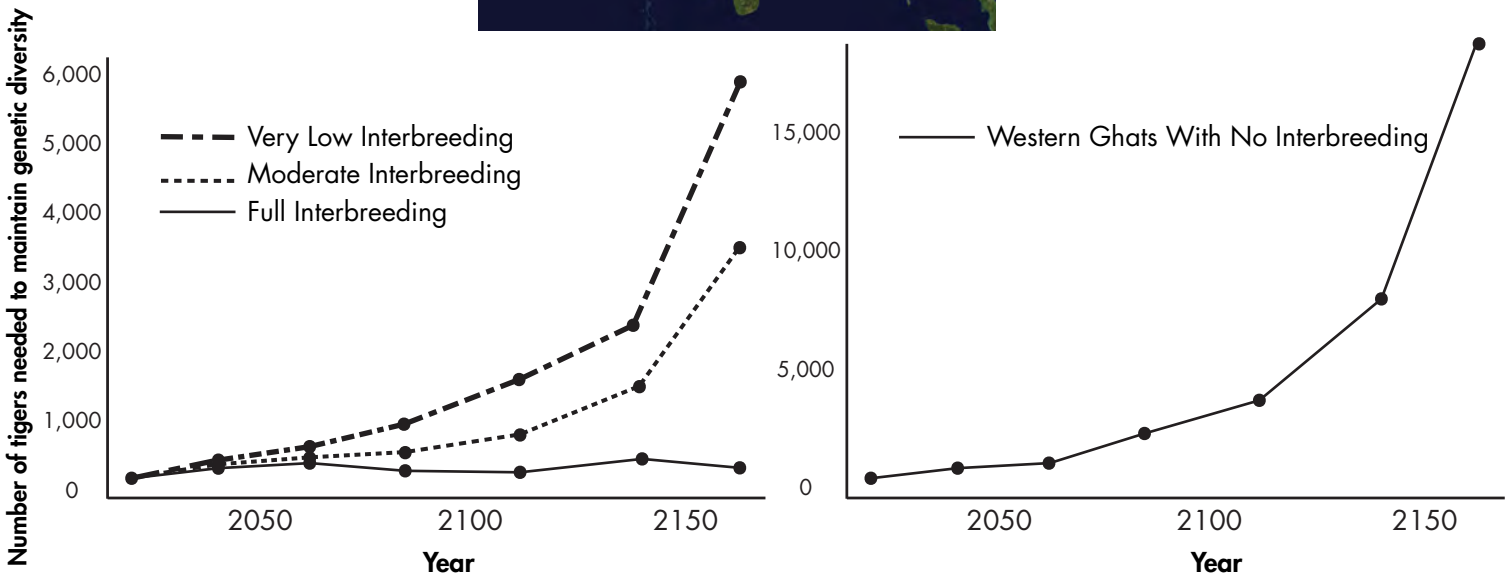


Figure 6. Computer simulation model for three separate tiger populations in India

4. **Describe** what happens to the number of tigers needed in the population to maintain genetic diversity when there is low, medium, or high interbreeding. Use evidence from Figure 6 to support your answer.

The more interbreeding there is, the lower the population size can be to maintain genetic diversity. In the graph, at the highest interbreeding, the population will not have to grow to maintain genetic diversity. But, if there is little interbreeding, the population will need to grow very large after the year 2075. Some students will correctly point out that all three levels of interbreeding maintain the genetic diversity without needing populations to grown until after 2050.

5. The government of India has asked you to help them decide how to manage tigers to ensure that they maintain genetic variation in populations. Should tigers be protected in the areas they live now and never be moved to other locations for interbreeding? Should they move a few tigers every year or should they move many in an attempt to fully connect the populations? **Compose** a recommendation for what they should do to manage tigers. Use the information in the graphs on the previous page to support your recommendation.

This activity would make a very good class discussion. Consider having groups put together their ideas and then have each present their plan. Then, the class can come to a consensus on the best plan. This will allow for corrections to any misconceptions about the graphs. There also may be different reasonable answers. For example, through 2050 the models suggest there is not a lot of need to increase genetic connections of the populations and there may be a desire to manage for unique populations to see what happens. Most students will probably say the safest way to protect genetic diversity is to facilitate a lot of interbreeding.

Below are some news stories about studies on the genetics of tigers in India.

https://india.mongabay.com/2019/09/genetics-shake-up-for-indias-tiger-conservation-plans/

https://www.newindianexpress.com/states/telangana/2019/aug/26/indian-tigers-face-inbreeding-threat-due-to-forest-fragmentation-shows-genetic-study-2024364.html

https://blogs.scientificamerican.com/expeditions/along-the-tiger-s-trail-genetic-studies-aid-conservation/