Slide 1 - Hi so in the first lecture one we looked at how what the main human impacts our natural world are and how we can combat them through courage, creating protected areas, but how despite that we're still seeing. High extinction rates high and increasing interest rates on Planet Earth or still seem to be she's disappearing and some of the reasons for that. And so, with that first lecture is mainly based on sort of landscape scale processes so land use change climate change and Protected Area design and placement. So that's kind of considering how we are degrading and transforming areas, and also how we're trying to protect in this lecture we're going to be focusing on particular species, rather than landscapes. And so, going to be looking at what's how species ranges are shifting how conservation is trying to protect particular species And also how we might again have a slightly biased idea of what species need, which is impacting on our conservation efforts.

Slide 2 - So these are learning objectives for this lecture and so we're going to identify factors that are associated with elevated extinction risk, so why a particular some species more vulnerable to extinction than others and we're going to explain the refugee species concept and identify the species that are most likely to be affected by this. This is a concept that try to explain why we have a bias understanding of the biology or particular species and how that impacts on our conservation. I'm going to use a case study to explore how to test that concept of a refugee species. At the end there'll be some materials for an activity to evaluate endangered species myanmar for a conservation risks and design a study to better understand this, for the banteng, which is a wild cow species.

Slide 3 and 4 - So what species are most at risk of extinction and why? So this ties into the last lecture where we were looking at what areas of the world are most at risk of being transformed, and why this time we're going to be thinking about why particular species are at risk of extinction. So these people have looked at this and it found the extinction risk is most acute for the world's largest and smallest vertebrates So here we just love number to read so just animals with a backbone so amphibians, reptiles mammals and birds. There are different reasons why the largest and smallest species are most at risk, so the largest are most threatened by the direct by direct killing by humans so whether this is fishing or hunting or other things like that, and the smallest are more likely to have restricted to geographic ranges which makes them very vulnerable to habitat degradation habitat loss. So if we compare a tiger, which comes up in the activity, to a very small frog which have very different range sizes. Tigers have ranges that span thousands, not individual tigers but tiger populations have ranges that span thousands of miles, and so to completely get rid of that tiger populations habitats. We have to transform a huge area of land so tigers are very threatened by direct killing, and there are also reasons why they are vulnerable to habitat loss. But just for the sake of this example it's unlikely that we it's very difficult to get rid of the whole range of that population because it's been such a huge area. However, if this frog that we're thinking about is endemic to a particular island say and it the entire range of that population only exists over a few square miles and that could be the extent of one farm or a different economic activity. So, by setting up a farm in that area we're getting rid of the habitat for that entire species because it doesn't exist over a large area so it's very easy for humans, then to completely get rid of the habitat for that entire species so that's why these small species which have restricted geographic ranges are very threatened by habitat degradation and habitat loss, so this is just one of vertebrates.

There are huge problems for vertebrates, but the one slightly saving grace, is that we do have quite a lot of knowledge about these species because they tend to receive the most research interest and the most investment. However, for invertebrates plants and fungi they're likely to be affected by similar processes, but we don't know much less about them so it's much more difficult for us to assess what the extinction risks are, and so, not only are we likely to be losing a lot of the species,

we actually aren't really aware of both what we're losing and how to protect it, as well as we are vertebrates.

Slide 5 - So this is just some graphs that show the percentage of different the percentage different taxes are threatened. So, as we can see for some taxa, such as the cartilaginous fishes so that's sharks and rays, and for mammals and reptiles it's these large body of species that are most threatened. So these are the ones that are vulnerable to direct killing by humans so for sharks it's being caught either on purpose or is by capturing fishing the mammals it's poaching, so it can be poaching of elephants of ivory or rhino for rhino horn ,things like that. For reptiles, it can be for food, so we have very large tortoises and snakes that can be hunting for food. Then bony fish is the same so those large bony fish are the ones that are most valuable for fishing so if we think about tuna other species like that. So that's why we have very high percentages of large animals that are threatened because they're threatened by this direct killing. However, for amphibians, the pattern is slightly different and it tends to be those species with small body sizes that are more threatened and that's because those species are very small ranges so are more likely to be affected by habitat degradation and habitat loss, as I said on the previous slide.

Slide 6 - And again, this isn't rather looking at body size, this is looking at range size and we can see that small Rangers increase vulnerability, so the generally the smaller species range is the more threatened, it is because it's more vulnerable to these habitat loss and habitat degradation. It does vary a bit, so those animals with a very large ranges have very large body sizes so they're the ones that are affected by direct killing. It just because there's a correlation between body size and range size so there's one very large ranges are probably dominated by whales and other large marine mammals and fish and that are have been threatened by whaling and fishing and other direct killing.

Slide 7 - And it's not only body size and range size that can make species vulnerable and to extinction, there are other characteristics that play as well, so if we look at pollution, for example, it tends to be freshwater species and also amphibians, are very vulnerable to this. So pollution can affect any ecosystem, but freshwater ecosystems in terms of the flow of certain chemicals. Say that a farmer sprays his field with fertilizer or pesticide when it rains some of those chemicals will be washed off those fields and they end up in streams and rivers and eventually into the sea and so those virtual ecosystems are considered downstream of those terrestrial ecosystems, because they're receiving the runoff. Therefore freshwater species are often more affected by pollution, because they receive a greater concentration of it, because a large area of farmland, for example, is washing into that fresh water ecosystem and creating high concentrations of these pollutants. It's not only those ecosystem characteristics that makes species vulnerable, but it can be the characteristics of the species themselves. So amphibians, have permeable skins, which allows them to conduct gas exchange, of course, their skins and but because apparently well, they can also be vulnerable to pollution, because those chemicals can get cross their skins and affect them more seriously than, for example a mammal say or a fish that has a less permeable skin. So there are certain ecosystem and species level characteristics that make particular species, more or less vulnerable to a driver of declines, such as pollution.

Slide 8 - Another example, of this is diseases which can be important local drivers of local biodiversity decline. And this is particularly important, not only for the natural world now, but also for humans in light of the Covid pandemic, which is thought to have jumped from a different species of some sort into humans, so it's a zoonotic disease. There is very good evidence now the that the more we degrade the natural world, the more likely diseases are to jump across species boundaries

into humans and so it's likely that we're going to see more of these diseases and more of these pandemics in the future because of our impacts on the natural world. And, but again if we think about what makes species vulnerable to extinctions amphibians, can be more vulnerable to diseases than other species, it depends on the disease, obviously, but amphibians, are quite vulnerable to particular diseases again because of amphibian skins. So the chytrid fungus which causes the disease called chytridiomycosis has caused the decline of many amphibians species because it can affect them because of their permeable skins.Obviously different diseases affect different species but we have to consider the vulnerabilities of the species when we're conserving them.

Slide 9 - So we're going to continue to talk about what makes certain species vulnerable to extinction a budget for we do one papers i'm going to talk about uses this term, the anthropocene. So this ties into what we're looking at in the last lecture where we were thinking about how human impacts are having serious effects on the natural world around the globe now so, even if we haven't converted an area directly an area of land directly, climate change and other things are having impacts everywhere globally around the world. And, in light of this, and the recognition that humans are now one of the primary drivers of global environmental change, and it is also now almost guaranteed that this is going to leave some sort of geological signature in the rock record, whether or not that is things like plastics and other things, getting into the rock record and being preserved and whether or not it's radioactive materials from a nuclear testing whether or not there's going to be particular signatures leftover in the rocks which that most certainly will be. Not only is human activity affecting things globally it's also going to leave a geological scale record of that to some extent, and so a recognition of this has been proposed that we're entering a new geological era, called the Anthropocene which is likely to be dominated by the impacts that humans are having on the planet. And some of the there was a lot been lots of proposals of how where this where the start of this geological era should be. Whether or not it should be the start of the Industrial Revolution and the increases in global CO2 and atmospheric levels, whether or not it should be around the 1940s, when there was a spike of radioactive materials in the rock record because of nuclear testing. There's been lots and lots of different proposals another one is the global decrease in CO levels that happened hundreds of years ago now when Europeans colonized the Americas and lead to huge declines in the human population, thereby diseases and other things, and that lead to a decrease in global CO2 emissions, whether or not that has less a record in the rocks and that could be used as a marker for the anthropocene.

Slide 10 - But, regardless of which one would pick a lot of these this is now kind of dozens of measures of human impact of the natural world that are showing huge increases so there's this area, called the great acceleration around where we see a great increase in the rate of a lot of these measures, so whether or not its carbon dioxide in the atmosphere or other greenhouse gases. Whether or not its temperature ocean acidification or the impact we're having on the natural world such as tropical forests lost or domestication of land. And then the last one that terrorist terrestrial biosphere degradation we're seeing a lot of these indicators massively increasing around 1950. And this is just providing evidence that we're having a pervasive impact around the world, we are activities are not only altering the natural world on a global scale, it will also be recorded in in the geological record in the future in the far future so that's just to try and explain what this term, the anthropocene means because it used here in this paper which i'm going to talk about.

Slide 11 - And so we talked about what characteristics make particular species vulnerable to extinction, whether or not that is because their habitat is vulnerable, so freshwater fish are vulnerable to pollution, or because they have particular characteristics that make them vulnerable to threats, so amphibians are vulnerable to pollution and disease, or whether or not they have they are

vulnerable to direct killing by humans, because they're economically valuable for food or for other resources such as tusks in elephants, or small range which makes them vulnerable to habitat loss.

But in in combination we're losing species at a rapid rate. It's not only the fact that species go extinct that's important it's also the decrease in the abundance of animals, so, even if we're not going extinct, the fact that we're losing a lot of these animals is important for ecosystems globally because certain species carry out things, called ecosystem functions. So, for example, I study mega herbivores and these are really important for the distribution of nutrients and ecosystems, so they eat plants in a particular area here then move and defecate somewhere else and it's moving nutrients from place to place. So they're really important for this nutrient transfer around and ecosystems they're also important for maintaining complexity in particular ecosystems so by grazing and trampling. They convert what may be closed canopy forest so very thick forest into places that have a mosaic of habitat some more open areas with some closed areas and things like that. So particular species have important functions within ecosystem so, even if a particular species hasn't gone extinct globally, the fact that we're losing a higher number of these individuals reduces those processes and that occur on a day to day basis, and what that means is that we kind of get feedback loops of impact so by say we lose a mega herbivore in a particular area and we lose their their grazing and browsing and trampling processes, so it converts that area into more closed kind of the forest and then we may lose some of the species that were adapted those more open areas. So it's not just the extinction of species that have a particular focus species that is important, it has a knock on impact for the ecosystems that's important.

Slide 12 and 13 - And are there, particular ecosystems, as well as particular species are there, particular ecosystems that are vulnerable to these extinctions and then to the knock on impacts of those others extinctions. And so, this paper here looks at declines of megafauna around the world, so megafauna are large species. Large species that here defined as a species that are over 100 kilograms in weight. And as we can see on the previous slide and this slide we're getting greater rates of deformation in tropical forests and that is partly because it's the tropical areas that have, as I said in the previous lecture tropical areas that have the highest diversity and abundance of species. And so what that means is that they're kind of there are more, not only do they have this high diversity, but also very vulnerable to habitat loss, and they also have a higher number of megafauna species, so these large species that are vulnerable to direct killing. So as we can see the top here there's the number of megafauna species, which is much higher in Africa and Southeast Asia than in other parts of the world. There are many hypotheses why there are more megaherbivore species in Africa than elsewhere. And one of the hypotheses is that because they evolved with early hominids early humans, for a long time and they became adapted to the presence of humans. And there are other theories as well, but there's a very strong correlation between the movement of humans around the globe thousands of years ago and the extinction of large bodied species. So when humans arrived in North America, for example, around that same time large bodies species sites go extinct so it's thought to be that humans contributed to the extinction of these large body of species. Because humans evolved in Africa, it may be that, megaherbivore species were adapted to the presence of humans over a longer period of time they managed to survive into the present day, there are lots of other theories as well, so if you're interested in that then, then please look it up, but that's just one of the theories as to why many more megafauna species exist in Africa and elsewhere. So the number of megafauna species, the fact that it's higher in the tropics means that there's more species more megaherbivore species that are vulnerable to becoming threatened. So there's a greater concentration of these megafauna species in the tropics and these megaherbivores species are the ones that are vulnerable to direct killed by humans. So, therefore, there is a greater number of both declining and threatening megafauna species in these tropical areas. As we can see

the number of threatened megaphone species actually highest in Southeast Asia and that's likely due to the demand for the body parts of particular species in traditional East Asian medicine and so rhino horn tiger bones things like that are often used in this traditional East Asian medicine traditional Chinese medicine. And so that's why there's been a lot of direct killing of these malformed species in that in Southeast Asia and whether available in in countries, including Myanmar, Korea and those places. And so the demand, which is quite close to that for traditional Chinese medicine, which is quite close geographically has driven a lot of declines of these megafauna species that's why there's a lot of those threatened megafauna species in Southeast Asia. As I was saying it's the fact that the particular species characteristics makes them vulnerable to extinction and to declines caused by humans, and that has knock-on impacts, for their ecosystems, so these tropical ecosystems, therefore, will be losing the megaherbivore species there that the other species have evolved in conjunction with and they're losing these ecosystem functions and that has knock on impacts for the ecosystem as a whole. So tropical ecosystems are having a bad time because not only are they being converted on a large scale, as we saw in the previous lecture they're also experienced this defaunation which has very important knock on impacts for the ecosystem as a whole.

Slide 14 and 15 - And so now we've looked at what characteristics make species vulnerable we're going to have a look at refugee species. And so, if due to habitat loss habitat degradation and we cause species to retreat into relatively small parts of their native ranges. When a species is undisturbed it will live across its native range, but the habitat suitability won't be even across that whole range certain places, will be more suitable than others. And then populations in the less useful areas are maintained by movement of species of individuals from the highly suitable areas to those less suitable areas but because that can be this dispersal of individuals, it maintains populations in areas of relatively low quality habitat. However, if we disturb those dynamics if we transform parts of that range it can push those species, just to inhabit small areas of that nature range and there's no guarantee that those places will represent suitable habitat for that species. And it may be that they have to exist in modified ecosystems that represent quite low quality habitat. If that occurred before their native range was properly described and studied, we can assume that we can often assume wrongly, that the places that we are not that we now find the represent suitable habitat that they would kind of that species is meant to just inhabit that area. It could be that that could be wrong, it could just be because we weren't able to study them before that declined across their whole native range. So an example of this, the European bison, which is currently mostly conserved in forest areas, however it's physiology it's morphology and things like that the adaptations of his teeth suggested it's a grazer, so it should be eating grass, however, there is very little grass in the forest areas where we coding conserve the species. Instead it's assume that it's a browser so it's trees and whilst in the short term, it may be able to survive in this forest habitat It may be that it's range always included areas of forest, it may represent generally low quality habitat for this particular species and therefore, in the long term viability of those populations may be compromised if they can't maintain high survival rates and high fecundity rates based on suitable habitat. If they're not getting the nutrition they require, the nutrition they were adapted to from grasses it may be that in the long term at least, the declines, and even extinctions of these refugee species. They're called refugee species because it's analogous to human refugees that are displaced from their place of origin and forced to move to other places. So that's that's why it's called the refugee species.

Slide 16 and 17 - So, as well the European bison another example of this, which is based on a lot of work done in my lab group is the cape mountain zebras which we actually talked about in the first lecture So this is a species that lives down in South Africa, so there are three zebra species across Africa. There's the plains zebra which inhibits those green areas on the map at the top there there's the Grevy's zebra which has a much smaller range in the blue areas on the bottom left.

Slide 18 – We have the cape mountain zebra which lives down in the Cape region of South Africa. So the dark grey area represents the historical range of the species, so it would have existed across a large area of the Cape of South Africa previously. This species is now confined to these black dots here, which represent nature reserves in South Africa. So, as you can see it's gone from quite a large historic range to small, isolated populations and so it's the potential this species represents a refugee species. So a large scale population declines followed by recovery. There are now around 4800 individuals in more than 75 subpopulations and so it's been pushed into these relatively small, isolated parts of its previous range. One of the other worrying things, it's not just about habitat suitability, is that it's gone through this population bottleneck. And so, this means that there was at one point a very small population size and lots of the current population is descended from that small one founder population, which may mean that it's has problems with its genetic variation going forward. But we're not going to talk about that now we're just going to talk about the refugee species aspect. So the areas in this map represent some of the reserves where this species is now found. For this work, the first thing we did was to assess the habitat quality of these different results, based on the availability of grass. As we said in the first lecture the coastal renosterveld, which is the one of the habitat types in this part of South Africa, probably represents a very suitable habitat type to this animal because it has high amounts of grass. Its morphology and physiology and other things suggested it's a grazer which eats grass, therefore, it needs to have high levels of grass, to be able to be healthy and for populations to sustain themselves. So the vegetation index here is based on the availability of grass in these different nature reserves so poor quality habitat in yellow reserves have low grass. Green reserves have high quality habitat with high amounts of grass.

Slide 20 - And there are lots of suggestions that the amount of grass has very important impacts on. different measures of habitats of population performance, so one is the population growth rate so as we can see as vegetation index increases as more there's more grass in these areas. Population growth rate increases, the same with the density of individuals, so how many individuals per unit area and also the foal to mare ratio. This is the ratio of how many female adults are in the population compared to how many young there are so it's an indication how well the population is breathing and performing. So if they are more foals, then the population is doing well. So all of these measures of publishing performance correlate with this vegetation index so generally the more grass, the better these populations doing.

Slide 21 - As well as just comparing these things directly, we can also use fecal sampling, which is what I do with black rhinos, to look at diet quality and also the impacts that diet quality has on the physiology of these animals. So we're using the physiology as a connection between measures of habitat quality, the amount of grass, to the population performance. Can we find indicators that show that the low grass low amounts of palatable grass are causing problems for individual health which then add up to the population performance.

Slide 22 - So corticosterone is a hormone that indicates stress in mammals and through the fecal sampling, we can measure the level of this stress hormone from individuals, and then we can see whether or not is low quality habitat areas or what be assumed to be low quality habitat are causing these animals to be stressed, and maybe that stress means that they cannot breed and survive as well and it has these cumulative impacts that mean that the populations are performing well. As we

can see there's a negative correlation between the amount of stress hormone found in fecal samples and the vegetation index. So basically the more grass, there is the less stress these individuals are and the better the population can survive and breed and perform into the future, so the better it is for conservation. So this is a great example of a potential refugee species. In the past, these animals were all across this cape region in South Africa and now confined to these quite small, isolated areas, some of these areas don't have high amounts of grass. These areas of low grass, are these yellow areas, maybe have low habitat suitability. And it may be the populations that managed to survive they're not because the habitat suitable but because those were areas of low threat, so perhaps they were an inaccessible, so people couldn't access them to hunt zebra or maybe there was other reasons why they managed to hang on in these places. However, if we just assume that because we find there now those places a suitable habitat we're not getting the whole picture and we may be trying to conserve this species in the wrong places. So this is actually a very interesting example of the refugee species because it might be that the refugee concept has been internalized into the name of the species so mountainous high altitude areas in South Africa tend to be places with less grass. They have other vegetation species, so it may be that we think we're supposed to conserve these species in mountainous areas because that's often what we find them, however that's incorrect and it's actually in more lowland places with more grass availability, are the places where we should we can serving this species. This is an example of a potential refugee species and the work that we can do to try and identify whether or not these animals are refugees.

Slide 23 - So in summary animals with large and small body sizes are most vulnerable as are those with small ranges. There are also other characteristics that can make species vulnerable to particular threats. The anthropocene is associated with global declines and defaunation. However, this is spatially differentiated and we're tending to get more declines, especially if megafauna in tropical areas, partly because tropical forests are one of the biomes that are experiencing high rates of habitat loss, but also because those areas very diverse, so if there's more species there to begin with, as the potential for greater numbers of species to both the client and go extinct. So we have to think about that one we're prioritizing our conservation actions so potentially tropical forests could be very high priority for conservation. Refugee species of those have been pushed out to their optimal or good habitats and as a potential the refugee species are more common than we realize.

Slide 24 and 25 - So there are two activities to do. There are some information sheets that have information on particular species from Myanmar from the IUCN redlist which outline the species characteristics, the threats they face and the reasons for decline. And what i'd like to do is to read these information sheets and try and identify characteristics that would make these particular species vulnerable to land use change or other threats. So do they have a very small range size? Do they have very specialist diets? Are there particular things that bring them into conflict with people? Would they be valuable for hunting or the other human and economic activities? Are the species likely to be refugees, have they been pushed to have preferred habitats and why? And so, go through those information sheets and highlight or underline things that you think would make these two species vulnerable to particular threats.

Slide 26 - Once you've done that the second part activities design a study to try and understand banteng ecology, so this animal here, which is a wild cow native to Southeast Asia. Go through the information sheets identify the knowledge gaps that exist about banteng ecology. And then I want you to try and identify how you would measure their health and reproduction and how you could use historical information to study habitat preferences. There's another sheet that goes along with this activity that gives you a general outline of the studies that you would you want to design so walks through identifying what are the knowledge gaps that you can identify, then how we tackle

these knowledge gaps and what the desired outcomes of this study would be. And you also have a budget for this, it would be $10,000. So alongside that i'd like to come up with a rough budget of what you would spend this money on if you were awarded it.

Slide 27 - So as part of this there's different ways of studying a shy species so banteng live in forest habitat, which makes them quite hard to study. So, how would you study this shy species, if you can't go and directly observed them was different ways of doing it. One is to set up camera traps So these are cameras that are remotely triggered so when something moves past and they take a photo and you can then use that to try and estimate population sizes, depending on the markings that different animals have. So if you just set up a camera and just count the number of individuals that go that it takes too long, you might get the same individual over and over again, so you can use specialist software or you can do manually to try and identify either patterns on the individuals or different things that show you distinct individuals. You can also use tracking so you can go out and find the tracks of particular species and which you can use to identify how many individuals are in a group or you can find the tracks and identify and observe them directly. You can use things like hare traps, and so this often goes along with genetic techniques, so you set up velcro on trees that you know these animals are going to be walking past and it catches bits of hair as animals brush past and then you can then either by the morphology of the hair or genetics to identify what species the hair belongs to and you can use that to try and get an idea of how many individuals there are. This is similar camera trap, how many individuals there are. You can also use fecal sampling which we talked about with it in the case of the cape mountain zebra which is not only as useful for identifying which species that are present by what the dog looks like you can also use it to identify what they're eating and look at their stress hormones, to try and give an idea of what habitat preferences this species has. So if you can identify their diet what they're eating and an indicator of health, such as the stress hormones that we talked about, then you can have an idea which habitat types what diets are beneficial for these animals.

Slide 28 - So this is the general plan that I would like you to come up come up with for the activity so can't with your aims and research questions. Think about the methods that you want to use and then come up with a budget of timeline and desired outcomes and also have a think about whether or not this general plan that you come up with can be applied to other species and what other species, it would be useful for in Southeast Asia. Okay, so that's in my lecture and we've got one more on monitoring population dynamics of particular species and then there's this short coding activity to go along with that i'll be running through as a recording Thank you very much.