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**Ecology**

This course provides a general introduction to the basics of ecology, including basic definitions and terminology, important abiotic, species-level and inter-species processes, human impacts on ecology and how ecological data is collected and analysed. It is designed to give students an overview of the field, and as such covers many topics and does not go into great detail for any one area. It is therefore ideal for students with limited prior knowledge of ecology and will give a thorough basic grounding in the field.

For the readings that are recommended, we provide a brief overview of why they were chosen and the main messages that we think relate to the course. We do not provide a detailed summary as we would just be repeating the articles, so we recommend that you read them over before teaching, as you may think that other messages are more important or want to highlight different parts to suit your priorities.

***Lecture 1 – Introduction to the structure of the course***

Slide 10 shows the learning objectives for this course. The seven sections (slide 3 – 9) lay out the topics that will be covered to try and meet these objectives. We recommend reading over the entire course before giving this lecture as it will allow you to understand why the course is structured this way and what each of the seven topics involves.

There is no recording for this lecture.

*Reading*

The reading for this lecture covers how and why knowledge is created in ecology.

*Foundations of translational ecology, Enquist et al. (2017) – The Ecological Society of America*

This paper is about making ecology useful for resource managers and decision makers. Basic research and developing our understanding of the natural world is very important. This paper puts the study of ecology into a more practical context, even more so than applied ecology. Researchers and practitioners work together to set priorities for research and co-create knowledge that is useful for land management and conservation.

*British Ecological Society magazine The Niche: “Why researchers should be using local traditional knowledge to estimate biodiversity”*

This demonstrates that knowledge of the natural world is not restricted to scientists, and knowledge generation is not restricted to formal scientific methods. Working with indigenous people can not only improve our knowledge of the natural world, but is also important with regards to equity, social justice and poverty alleviation. Conservation has a chequered history when it comes to its relationship with indigenous communities and the societies of developing countries. Working to redress this balance is important.

***Lecture 2 – Ecology: definitions and taxonomy***

This lecture covers the basic terminology of ecology, and the hierarchy of organisational units that we divide the natural world up into. When discussing these concepts, it is worth noting that there are many exceptions to the rules that demarcate these units, and they are all arguably arbitrary to a certain extent. They are things that humans use to understand the natural world, rather than definitive natural categories.

Habitats and niches (habitat is part of the niche concept) are ways of understanding organism requirements and also the relationships they have with other organisms.

Taxonomy is arguably the most fundamental part of ecology and evolutionary biology. Identifying, describing and naming species allows them to be included in studies of ecology and how they relate to each other.

*Reading*

*Global climate and the distribution of plant biomes – Woodward et al. (2004) - Phil. Trans. R. Soc. Lond. B*

As described above, many biological and ecological categories are arbitrary to a certain extent. Using scientific methods to more accurately define these categories is an important part of modern ecological science. Remote sensing has been used to create a more objective basis for the definition of biomes than the subjective definition that has often been used in the past. The distribution of different tree types is an example of this. This paper also highlights that biomes are not static, and vary due to both climactic change and human actions.

*Two new species of Impatiens (Balsaminaceae) from Putao, Kachin State, northern Myanmar – Bin et al. 2017. Phytotaxa*

An example of work that describes new species

***Lecture 3 – Abiotic controls on organisms***

Abiotic (non-living) aspects of the environment are some of the most important factors that control where organisms can live. They exert selective pressures that drive adaption and evolution, which are the fundamental processes that have given rise to the diversity and distribution of life on earth today.

Temperature, rainfall, are examples of abiotic factors that control where organisms can exist. These describe the ‘fundamental niche’ of an organism. These abiotic conditions can be modified by other organisms. The distribution of abiotic conditions such as temperature are controlled by things including latitude, altitude and other aspects of geography. This geography therefore controls where certain organisms can exist. Finding the abiotic conditions that are important for controlling range limits is an important part of ecology eg. temperature minima for nocturnal lizard *Heteronotia binoei.* When studying the distribution of organisms, this includes both biotic and abiotic range determinants which together form the ‘realised niche’. Mechanistic understanding, such as the activity of lizards under different temperature regimes, is important to understand the fundamental niche.Also important for human economic activity such as coffee growth.

We can see that abiotic conditions are crucial drivers of the life history and distribution of different organisms. These change temporally as well as spatially, with things such as temperature changing with the seasons. Organisms have adapted to this by timing their life events to coincide with these changes, such as deciduous trees shedding leaves, breeding events etc.

The blue tit, caterpillar and and oak example shows how the effects of abiotic conditions can be mediated by other organisms.

*Reading*

*Inclusion of facilitation into ecological theory – Bruno et al. (2003) TRENDS in Ecology and Evolution*

Shows the importance of including interactions between organisms when doing ecological research. Species do not interact with the abiotic environment in isolation. This work provides a good outline of the theoretical basis of the niche, and the processes that change its size. Introducing theoretical niche models like those in figure 1 can be difficult, and if students have not encountered them before they can take a bit of explaining.

*Mapping the fundamental niche: physiology, climate and the distribution of a nocturnal lizard – Kearney and Porter (2004) – Ecology*

Paper showing the work from the lizard example. The mechanistic vs correlative approaches section is particularly important when discussing fundamental vs realised niche.

***Lecture 4 – Water and Nutrient Cycling***

Functional ecology focuses on the roles that species play in an ecosystem and the flows of matter and energy. Functionalism is an important way of understanding ecology, and the movement of water and nutrients through ecosystems is vital to their maintenance and sustainability. Looking at water and nutrient cycling is also useful because it tends to focus on organisms that can be overlooked, including plants and microbes.

This lecture covers water and some of the most important nutrients for ecosystems, and the processes that facilitate their cycling.

*Reading*

*Nutrient cycling by animals in freshwater ecosystems – Vanni (2002) - Annu. Rev. Ecol. Syst.*

It can be easy to think of nutrient cycling as a primarily abiotic process (precipitation, erosion etc.). However, biotic processes are an integral part of nutrient cycling.

*Global nutrient transport in a world of giants – Doughty et al. (2016) – PNAS*

This paper shows the importance of large animals in nutrient cycling, with phosphorus being an important example. Animals are particularly important for the movement of nutrients across ecosystem boundaries, such as seabirds and anadromous fish from sea to land. The disruption of these processes by declines and extinctions of large species (which are vulnerable to direct killing) is a vital consideration in ecology.

***Lecture 5 - Introduction to Population Ecology***

Populations are one of the fundamental organisations units of ecology. This lecture covers basic definitions and concepts in population ecology and Individual characteristics and processes add up to population level characteristics and processes.

It is often not possible to study entire populations, so ecology studies often focus on a sample and use methods such as mark-recapture to allow for extrapolations.

*Reading*

*Minimum viable population size and population growth rate of freshwater fishes and their relationships with life history traits – Wang et al. (2019) – Scientific reports*

Covers the concept of MVP and how it can be estimated. Importantly, this shows how life history affects the MVP of a particular species, with the important characteristics here identified as age at maturity, age at maturity and fecundity. Life history is therefore very important to consider in conservation, as it may be more difficult to conserve slow-growing and slow-breeding species. Another possible point of discussion is the usefulness of the concept of an MVP in the real-world. Should we be aiming for the minimum possible population size in conservation, or should we be more ambitious than that? A lot of conservation science is focused on small populations, and preventing extinctions, but simply preventing extinction is not the only aim for conservation. Intrinsic values, as well as ecological functions, services and other things all suggest that we should be aiming for population sizes much bigger than the MVP.

*Bird diversity in northern Myanmar and conservation implications – Zhang et al. (2017) – Zoological Research*

Good example of biodiversity survey

***Lecture 6 - Population Ecology 2: processes***

Covers the basic mathematical concepts and equations that describe different types of population growth. It also covers some things that can decrease population growth rate from the potential maximum, including density dependence and Allee effects. Population growth also isn’t constant and can be go in cycles, as well as being dependent on immigration and emigration from sub-populations.

*Reading*

*Trends and status of harbor seal in Washington state: 1978-1999 (Jeffries et al. 2003) – The Journal of Wildlife Management*

An example of how models of population growth can be fitted to real world data to provide evidence for how population dynamics function for different species. Being able to important characteristics such as estimate carrying capacity (K) and maximum net productivity level (MNPL) can be vital to conservation and population management.

***Lecture 7 – Species interactions: competition***

The last two lectures have looked at population ecology, which studies species in isolation and how births, deaths and other processes add up to population level processes. The next few lectures expands beyond this single-species focus and will look at the interactions between species, how we model them and how we understand them. This one will look at competition. There are some simple maths equations that show how changes in the population of one species can affect the population size of another if they compete with each other, using the Lotka-Volterra models of competition. This requires some basic knowledge of differential equations, although a lot of the equation solving requires setting population growth to 0 so it is not too complicated. It is worth ensuring you understand isoclines though and the graphs of these differential equations before delivering the lecture. In simple terms, if two species are competing then the realised carrying capacity will be lower because there are fewer resources available for both species.

***Lecture 8 – Species Interactions: Predation and herbivory***

Continuation of lectures covering inter-species processes. It is worth discussing how a lot of ecological models do help us understand dynamics like these, but they are huge simplifications of reality. Also, conducting experiments in ecological systems is very difficult. The lynx and snowshoe hare system outlined seems to work well for study as lynx in this area feed on few other species and hare are predated by few other species. Therefore the numbers of each species depends heavily on the other and we can study how one affects the other. In other systems, the effects of inter-species interactions do not just affect the two species that are interacting, they can ‘cascade’ through the ecosystem, as with sea otters, sea urchins etc.

*Reading*

*Impact of food and predation on the snowshoe hare cycle (Krebs et al. 1995) – Science*

Gives the results of the experimental manipulation of the snowshoe hare system.

*Evolutionary ecology of plant defences against herbivores (Johnson et al. 2011) – Functional ecology*

Overview of plant defences. This isn’t covered as extensively as predation in the lecture so provides a good summary of this topic for participants.

*Group formation stabilizes predator–prey dynamics (Fryxell et al. 2007) – Nature*

As mentioned in the notes above, ecological models are simplifications of reality. This paper shows how making incorrect assumptions about the system that you are studying can lead to incorrect understanding of a particular system.

***Lecture 9 – Species interactions: parasitism and mutualism***

Continuation of lectures covering inter-species processes. It is worth starting by highlighting the difference between predation/herbivory and parasitism. It is also worth highlighting the difference between a parasite and a parasitoid (A parasite is an organism that lives in or on another species (its host) and benefits by deriving nutrients at the other's expense, resulting in the death of the host. A parasitoid is an insect whose larvae live as parasites that eventually kill their hosts (typically other insects)). It is also worth noting that recent research is showing how mycorrhiza are vital to plant communities and the ecological functioning of soils, and this symbiosis is probably much more important for maintaining ecosystems than has previously been considered.

*Reading*

*The plant immune system (Jones & Dangl 2006) – Nature*

Provides an overview of plant immune systems. This is quite technical but the main take-away is that understanding plant parasites and pathogens, and plants’ responses to them, is vital for the future of agriculture as well as ecology and conservation.

***Lecture 10 – Soil food webs***

The previous three lectures have looked at inter-species interactions that take place between two species (a carnivore eats a herbivore, one species competes with one other etc.). The course begins to expand this beyond these bilateral interactions to show how many species interact with each other simultaneously in an ecosystem. The food webs covered here link back to lecture 4, as energy and nutrients move through these food webs as part of nutrient cycles.

This is quite a long lecture that covers:

* The history of the idea of food webs
* General rules of food web ecology
* Models of food webs and what increases/decreases stability (stability here means how resilient the interactions we see are to change. If a particular ecological network is unstable, small environmental changes may cause large reorganisations of these networks)
* Keystone species which are vital to ecosystem functioning
* How these concepts are applied in studying soil food webs. Soil functioning underpins almost all terrestrial ecosystems so is vital to ecology

*Reading*

The reading covers three things that are crucial to the functioning of ecological food webs and the maintenance of diversity. Dominant species, predation (top-down processes), and plant diversity (bottom-up processes).

*Demystifying dominant species – (Avolio et al. 2019) – New Phytologist*

Defining and identifying dominant species is crucial to ecological understanding and conservation.

*Food web complexity and species diversity – (Paine 1966) – The American Naturalist*

This is an old paper that gives some historical context to the development of ecological understanding of food webs. This focuses on the hypothesis that ‘Local species diversity is directly related to the efficiency with which predators prevent the monopolization of the major environmental requisites by one species’. This means that predation can promote diversity as it controls herbivore numbers, or herbivory promotes diversity as it controls plant numbers. Without this, it may be possible for one species to increase in numbers to a point where it dominates the ecosystem, which decreases diversity. This links to ‘why is the world green and not brown’ slide from the lecture.

*Bottom-up effects of plant diversity on multitrophic interactions in a biodiversity experiment – (Scherber et al. 2010) – Nature*

Covers the importance of plant diversity on food webs and ecological networks. Understandably, plant diversity has a greater impact on lower trophic levels and species that eat plants more often (herbivores), and effects weaken the further away a species is from the plants in the food web (carnivores and other species that do not directly eat or interact with the plants).

***Lecture 11 – Community ecology 1***

Ecosystems are made up of many species interacting with each other. We have been slowly increasing the number of species we have focused on in this course and the complexity involved. Lecture 5 to 10 moved from processes that govern populations of single species, to bilateral inter-species interactions, to food webs showing how matter and energy moves through ecosystems. The next two lectures look at community ecology, and the assemblages of species that live together in ecosystems.

This lecture covers how we estimate the variety of life that inhabits any particular area, how diverse a community or ecosystem is. This includes the various levels it occurs at and the different ways it is estimated. Diversity is affected by many things including area. This is one of the fundamental tenets of conservation, if human activities reduce the amount of area available for wildlife to live in, then diversity will decrease.

Reductions in diversity do not just affect the species that are declining, being extirpated or going extinct, they can also change ecosystem function, although the exact relationships between diversity and function are hard to define. BEF stands for Biodiversity and Ecosystem Function. The last part of this lecture covers experiments and reviews that have linked diversity to function. Functional redundancy exists when more than one species carry out the same function in an area. This means that functional diversity, or diversity of traits, may be more useful for categorising diversity in functional terms than taxonomic diversity.

*Reading*

*Species abundance distribution over time - (Magurran 2007) – Ecology Letters*

The lecture covers the fact that diversity tends to increase as the area sampled increases, this paper points out that the time over which sampling takes place is also important. Generally, the longer the timeframe of sampling, the more species will be found. This is partly due to the fact that many species will not be found in a particular area at all times due to a variety of processes including ecological succession and environmental change.

*The value of biodiversity (Ehrlich & Ehrlich 1992) – Economics of biodiversity loss*

The measurement of diversity and its impact on ecological functioning etc is not only important for ecological understanding but also for conservation and to society. This article gives an overview the different way in which biodiversity is valuable to human society.

***Lecture 12 – Community ecology 2***

This lecture covers succession. Under its original conception, succession was viewed as a directional process and climax communities as stable. Following the creation of new land (volcanic eruption creating an island, sea level fall etc) it was theorised that succession followed a predictable trajectory and the climax community as stable until it was disturbed in some way. However, we now understand ecosystems as much more dynamic. One of the central concepts in modern ecology is that ecosystems are dynamic and constantly changing, covered by the cliché ‘the only constant is change’, and no community is really stable.

Primary succession occurs when places with no life (with the exception of microbes etc) become available for colonisation, which can be lava flows, sea level fall, the movement or sand dunes or the melting of glaciers. Secondary occurs where there is already a biological community of some sort present, can caused by environmental change or the starting or stopping of human activity (agriculture is mentioned at the end of the lecture). Succession is not only affected by abiotic or human processes, but also by other species and the ecological functions that they carry out. Different species occur at different stages of succession depending on their adaptations. Part of this can be understood by r/k selection.

*Reading*

*Holocene isochrone maps and patterns of tree-spreading in the British Isles – (Birks 1989) – Journal of Biogeography*

This gives an example of one of the causes of succession, environmental change. Following the Last Glacial Maximum (in Britain this is dated somewhere between 31,000-16,000 years ago) glaciers retreated towards the poles, opening up more habitat for many species. In the northern hemisphere this means that many species moved northwards, following the retreat of the ice. Different species can move at different speeds due to the way they disperse/disperse their seeds. One way of studying historical movement of plants is by using pollen studies like this one.

*Historical Contingency in Community Assembly: Integrating Niches, Species Pools, and Priority Effects (Fukami 2015) – Annual Review of Ecology, Evolution and Systematics*

As mentioned above, succession is not a completely deterministic and predictable process there are historical contingencies that affect the way it occurs. This paper provides a review of this, and also shows how the effect that species have on the environment alter the niches available for other species and are vital considerations alongside abiotic factors. This kind of historical contingency which can lead to alternative stable states, alternative transient states or compositional cycles show how complex ecology is and why studying it is so difficult!

***Lecture 13 – Ecosystem services 1***

Understanding ecology is not only important for non-human life, but also for human society and economies. One way of conceptualising this is through the concept of ecosystem services (ES), defined as the benefits that people obtain from ecosystems, which can be separated into different categories. Recognising and valuing ES is done to allow for them to be accounted for in decision-making. This has been done in many international agreements such as the CBD, which utilised an ecosystem approach. The Sustainable Development Goals have been developed as a way of integrating human development and environmental sustainability. These approaches are difficult to implement because of difficulties in quantifying ecosystems services and how they change over time. Multifunctionality is one way of integrating ecosystem function and health.

*Reading*

*The natural capital framework for sustainably efficient and equitable decision making – (Bateman & Mace 2020) – Nature sustainability*

Natural capital is one way of understanding and quantifying the benefits that nature and ecosystems provide for humans. As with many new frameworks, different people use the phrase to refer to different things and there is not yet any standardisation of the implementation of the framework. This paper shows a way of valuing natural capital so it be used in decision making and policy development.

*Redefining ecosystem multifunctionality – (Manning et al. 2018) – Nature ecology and evolution*

Provides more detail on the concept of multifunctionality. Again, new frameworks, especially ones that cross traditional disciplinary boundaries, can be ill-defined or be used to refer to different things. This is one effort at defining the concept in a way that is useful for science and decision-making.

***Lecture 14 – Ecosystem services 2: payments***

This lecture covers how and why ecosystem services are valued. Slide 3 brings up a really important point about trade-offs in different services. We will not be able to maximise the production of all of them at the same time. By managing for one service we may decrease the production/value of others.

Why we value nature links to the previous lecture, in that it is difficult to include ecosystem services in economic planning without knowing their value. The benefits of valuing nature are discussed in the presentation but it is also worth discussing potential downsides:

* Would it lead to it being said that nature which has no obvious monetary value to humans is not worth saving?
* Would it allow unsustainable development to be justified if ‘biodiversity offsets’ and similar can be used?
* If we get valuations wrong then could they be used to justify unsustainable developments?
* Does a focus on monetary value (extrinsic motivation) undermine other justifications for conservation (intrinsic motivations)?

The second half of this lecture presents a framework for valuing ecosystem services.

*Reading*

The reading for this lecture provides examples of the different tools that can be used for valuing ecosystem services that are mentioned in the lecture.

*Ecosystem services valuation as a decision-making tool – (WWF 2015)*

The rest of the reading provides examples of how the InVest tool has been used in South America. The ‘Ecosystem Services as Inputs to Decision-Making’ section also provides an overview of the usefulness of ES in decision-making and what is needed to do this at different scales.

*Ecosystem services reinforce Sumatran tiger conservation in land use plans – (Bhagabati et al. 2014) – Biological Conservation*

This work shows how changes in ecosystem service provision can be predicted under different future scenarios, and how this can be done at the same time as predicting impacts on the conservation status of an iconic species. There may be trade offs between ecosystem services and conservation, and actions that maximise an ecosystem service such as carbon sequestration (which could be best served by a monoculture tree plantation for example) may not maximise biodiversity or provide optimal habitat for target species. This work also shows how modelling that predicts changes in the provision of several ecosystem services can be done with time and data constraints.

*ENCA ecosystem service valuation framework and Ecosystem Services Transfer Toolkit*

Two examples of UK-based frameworks for valuing ecosystem services.

Enabling a Natural Capital Approach (ENCA) was designed and is used by the UK government’s Department for Environment Food & Rural Affairs, so is designed for direct use by policy-makers and the government.

Ecosystem Services Transfer Toolkit shows what impact different management interventions will have on different ecosystem services based on the best available evidence, and what that evidence is.

***Lecture 15 – Habitat fragmentation***

Up to this point, the course has covered how ecosystems are structured, what processes drive their organisation and dynamics over time and space, how these things are studied and why they are valuable to human society. The next three lectures will look at how human activities can disrupt these processes and damage ecosystems. This first one looks at habitat fragmentation. Habitat loss removes area that wildlife can inhabit, which leads to lower diversity as covered in the species-area relationships of lecture 11. However, habitat fragmentation has other impacts as well which are covered in this lecture.

*Reading*

*Road networks predict human influence on Amazonian bird communities – (Ahmed et al. 2014) – Proceedings of the Royal Society B*

This work shows that habitat loss and habitat fragmentation (here represented by decreasing ‘roadless volume’). This work shows that although related to habitat loss, habitat fragmentation has independent effects on biodiversity that aren’t captured by metrics of habitat loss such as decreases in tree cover. These independent effects in this case may include disturbance caused by traffic as sell as hunting and other things that are facilitated by access improved by road connections.

*Creation of forest edges has a global impact on forest vertebrates – (Pfeifer et al. 207) – Nature*

This work shows the importance of edge effects on forest vertebrates, and that a large majority are affected by these. However, the effect does depend on the traits of the species in question. This includes body size, the effect of which varies across taxa, with smaller-bodied amphibians, larger reptiles and medium-sized non-volant mammals (mammals that can’t fly) more strongly affected. This shows how important it is for planning to take account of edge effects. Along with the previous paper, there is evidence that by merely measuring remaining habitat and no taking fragmentation and edge effects into account, we may be overestimating the amount of suitable habitat remaining.

*Ecosystem decay exacerbates biodiversity loss with habitat loss – (Chase et al. 2020) – Nature*

This work also shows that habitat loss does not just impact species by reducing the area for them to inhabit. If this was the only effect that habitat loss had, the reduction in diversity would be proportional to the loss of area. Instead, small and more isolated habitat patches experience other changes, and a breakdown of ecological processes, termed ‘ecosystem decay’. ‘Ecosystem decay’ needs to be included in conservation and land-use planning.

*A large-scale forest fragmentation experiment: the Stability of Altered Forest Ecosystems Project – (Ewers et al. 2011) – Philosophical transactions of the Royal Society B*

*Movement of Moths Through Riparian Reserves Within Oil Palm Plantations – (Gray et al. 2019) – Frontiers in Forests and Global Change*

*Land-use change is associated with a significant loss of freshwater fish species and functional richness in Sabah, Malaysia – (Wilkinson et al. 2018) – Biological Conservation*

These papers cover the design of the SAFE project experiment and some of its important results and findings. Studying large-scale habitat fragmentation is difficult, especially experimentally. SAFE is a great example of how this can happen and the challenges involved.

Some species may not be able to move through fragmented habitats, and the prevention of dispersal and migration may negatively impact species of conservation concern, such as the moths discussed here. Riparian reserves (those around rivers) provide important migration routes and connectivity through human-dominated and fragmented landscapes, as is shown for moths.

The freshwater fish study shows how important it is to protect primary habitat for some taxa, as any form of logging or land use change decreased species richness and functional richness, but these decreases were not made worse by more severe logging. This suggests that the only way to protect the diversity of freshwater fish in this ecosystem is to protect primary forest, and that in the case of protecting this diversity there is no acceptable level of land use change.

There is another document accompanying the materials for this lecture which contains links to other examples of tools to value ecosystem services.

***Lecture 16 – Invasive species***

This lecture covers another disruption to ecosystems and ecological function. Invasive species are species which have been moved to a new area by human activity, and become damaging to the new ecosystem. Humans have moved species about on purpose, as sources of food, pets or for agricultural pest control, or accidentally as stowaways on ships etc. These mechanisms are outlined in the second half of the lecture.

It is important to note that not all species that are introduced to a new area are automatically invasive. The first part of the lecture sets out the conditions that define whether species are invasive, what characteristics increase the probability that a species becomes invasive and why introduced species can breed quickly and perform better in new ecosystems.

Invasive species are not only important for conservation, but they also cause a lot of expensive damage to human economic activity.

Methods of controlling invasive species and preventing species movement are outlined at the end of the lecture.

*Reading*

*Invaders, weeds and the risk from genetically manipulated organisms – (Williamson 1993) – Experientia*

This research provides evidence for the tens rule set out in slide 4 of the lecture. This is quite old work but shows the importance of considering the characteristics that might make species more likely to become invasive, for conservation but also for economic activity such as the genetic modification of crops. This allows for more effective planning to prevent us introducing invasive species or creating them through genetic modification.

*Why Alien Invaders Succeed: Support for the Escape-from-Enemy Hypothesis – (Wolfe 2002) – The American Naturalist*

The paper referenced on slide 9 that provides evidence for the escape-from-enemy hypothesis and considers parasitism and herbivory.

*Release from parasites as natural enemies: increased performance of a globally introduced marine crab – (Torcin et al. 2002) – Biological invasions*

The paper references on slide 11 that provides evidence for the escape-from-enemy hypothesis and considers parasitism.

***Lecture 17 – Climate change***

This lecture covers another disruption to ecosystems and ecological function in climate change. The climate has constantly changed over the history of the world, but modern day climate change that is caused by humans is different as it is happening much more quickly, and synergistically with other threats to the natural world and ecological disruptions. The International Panel on Climate Change (IPCC) synthesises all the available evidence and produces reports that show how the climate has changed and predict how it will continue to do so in the future under different scenarios of fossil fuel use. These different scenarios are called Representative Concentration Pathways or RCPs (slide 12). These predictions include large amount of uncertainty which comes from different sources.

Human-caused climate change interacts with natural variations in the climate such as the El Nino/La Nina cycle.

Climate change is not just increases in temperature, but has other effects including ocean acidification, ice sheets melting and sea level rise. Climate change will shift species’ bioclimatic envelopes, the environmental conditions that they are adapted to. Many species may not be able to disperse or their habitat may disappear entirely, including polar habitats such as the tundra. Ocean acidification will also negatively impact marine organisms that make shells or other structures out of calcium carbonate, including corals. Corals are also affected by increasing temperatures, as anomalously high temperatures cause them to expel symbiotic algae, leading to bleaching and death.

*Reading*

*Climate Change 2014 Synthesis Report – IPCC*

IPCC’s 2014 report that presented the best available evidence for changes that had been observed, their causes, predictions for future changes under different scenarios and what can be done to reduce future change and adapt to that change which is inevitable.

*Impacts of 1.5°C of Global Warming on Natural and Human Systems - IPCC*

The 2016 Paris Agreement adopted at the 26th UN climate change Conference of the Parties (COP26) committed signatories to try and limit global warming to 1.5°C. This report shows what impact this level of warming would have around the world.

*Climate change and the permafrost carbon feedback – (Schuur et al. 2015) – Nature*

One of the worrying things about climate change is the possibility of positive feedback cycles. These occur when climate changes results in something that causes further climate change. The example here is that increasing temperatures melts permafrost, which causes the release of carbon dioxide and methane, which contributes to further climate change, melting more permafrost etc. This is discussed in this paper. Another example is melting ice. Increasing temperatures melt sea ice, which means there is less ice to reflect sunlight back out of the atmosphere. Water is much less reflective than ice, so absorbs more energy from the sun’s radiation than ice. This leads to further warming, melting more ice etc.

***Lecture 18 – Experimental design***

The last three lectures cover how ecological data is obtained and analysed. This lecture covers the design of ecological experiments, from the research question to data analysis.

*Reading*

*Soil multifunctionality and drought resistance are determined by plant structural traits in restoring grassland – (Fry et al. 2018) – Ecology*

This is the example of the ecological experimental design presented in the lecture, and shows how such an experiment is formally written up and published in a scientific journal.

***Lecture 19 – Descriptive statistics***

This is the first of two lectures that give a brief overview of how ecological data is analysed. The lecture begins with some simple definitions of different types of data and the difference between precision and accuracy. After data has been collected, the first round of analysis is composed of descriptive statistics that show what the data looks like before more detailed analysis can be conducted.

*Reading*

*Maths skills for biologists*

This document gives some more detail about planning ecological studies, descriptive statistics, measures of diversity as well as statistical tests and data presentation (graphs) that are covered in the next lecture.

***Lecture 20 – Inferential statistics***

Inferential statistics go further than the statistics covered in the previous lecture in that they do not just describe the dataset in question, they use statistics to infer things about the dataset ie whether there are correlations between particular variables or whether variation in a dependent variable can be explained by other variables.

This lecture covers the rules of probability that underlie all the tests described (including p values), different types of errors that can occur, and which test to use with different types of data. Error types link to p values because the statistical tests described provide a probability of a type 1 error occurring, where a type 1 error is a false positive when a researcher incorrectly rejects a true null hypothesis. When discussing parametric and non-parametric test it is important to mention that all statistical tests rely on certain assumptions, and it is vital to know what these are, ensure they are met when conducting analyses and use alternative tests if they are not.

*Reading*

*What a p-value tells you about statistical significance*

Gives more information about the probability that statistical tests are based on and p values.

*What are Type I and Type II Errors?*

Gives more information on these two types of error.

*Test of association: which one is the most appropriate for my study? – (Gonzalez-Chica et al. 2015) - EPIDEMIOLOGY AND BIOSTATISTICS APPLIED TO DERMATOLOGY*

A more detailed practical guide to help researchers choose the most appropriate test and analysis procedure for a particular study depending on the research question and the type of data.