**Why Preserve Biodiversity?**

**I. Functional Value**

**A. Productivity**

**1. Gross Primary Productivity = total amount of glucose produced by plants.**

**2. Net Primary Productivity = GPP – Respiration. So, NPP = amount of new biomass produced by plants. Only this NPP is available for animals to consume, as we harped on before!**

**B. Diversity – Relationships with Productivity**

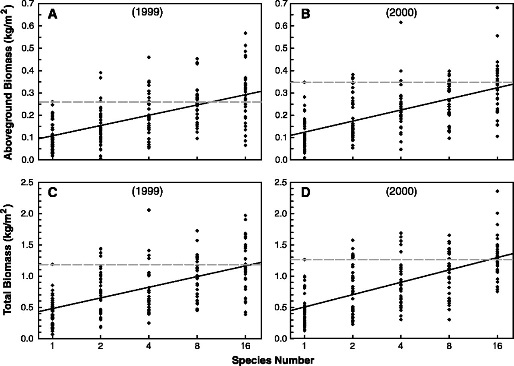
**1. Productivity increases diversity**

**- Quantitative Effect: With more NPP at the base of a trophic pyramid, the trophic pyramid can support more levels…meaning more species of predator. And a consequence of this is that, with more predators, there could be more keystone effects that increase diversity at lower trophic levels.**

**- Qualitative effects: In all likelihood, the increase in NPP is not all the same type of plant material… so the increase in NPP probably also means an increase in the diversity of plants… that differ in qualitative attributes. This would foster specialization and resource partititoning at higher trophic levels, increasing diversity.**

**2. Diversity increases productivity**

**- Actually, with a little thought, this should seem impossible. Suppose we consider ten plant species that differ in their NPP. One will have higher NPP than the others. So, if we want to maximize the NPP of a plant assemblage (let’s say this is a farmer’s field), it would seem that we should plant a monoculture of this most productive species. How can removing individuals of our most productive species, and replacing them with individuals of a less productive species, increase total NPP? We’ll get to this in a moment.**

 **- Tilman et al. (2001). First, let’s consider how diversity can increase productivity randomly – without the forethought and planning of a human farmer who gets to pick and choose their plants. Consider a set of 18 species that vary in NPP (4 species, each, of C4 grasses, C3 grasses, legumes, non-legume forbs; 2 species of woody plants). Now, let’s say that we are going to seed 9 m x 9 m plots, with the species richness set at 1, 2, 4, 8, or 16 species, but the identity of those species determined by a random draw from our species pool of 18. And, suppose we have ~30 replicates of each richness treatment. So, we grow each species alone, and then in random combinations of 2, 4, 8, and 16 species sets. There are three reasons why productivity may increase with diversity:**

**- Sampling Effect: As the number of species increases, there is a greater chance of randomly including the most productive species in the plot. So, with only 2 species, there is only a 2-in-30 chance that a plot will include the most productive species… most plots will NOT, so the average productivity of two-species plots will be low. As diversity increases to 16 species, the probability of including the most productive species in the random draw increases to over 50% (16/30)…so most diverse plots will include the most productive species and, therefore, will have higher productivity. Of course, if this is ALL that is at work, then the productivity of diverse plots will never exceed the productivity of the most productive monoculture.**

**- Niche Complementarity: However, there are more biologically interesting relationships that are possible. First, if the plants are grown at a density at which they compete, then we might expect more competitive inhibition of growth in a monoculture, where all individuals require the same balance of resources. So, reducing the abundance of a productive species, and replacing them with another species that has different niche requirements, might allow both to grow better than they do in monoculture and actually increase total productivity. In this case, a more diverse plot can exceed the production of the most productive monoculture.**

**- Positive Effects: Finally, species may exert positive direct and indirect effects on one another. Legumes, for example, nutrify the soil by increasing the amount of available nitrogen. So, plots that include legumes should have all species do better and thus increase productivity. The greater the diversity, the more likely it is that such beneficial species are included in the plot. This can also cause productivity to increase above the lelve of the most productive monoculture.**

**So, when Tilman did these experiments, he saw that average productivity increased with diversity. This could be caused by any of the three mechanisms. But he also saw that MANY of the polycultures had productivity higher than the most productive monoculture. THESE EVENTS can only be explained by niche complementarity or positive effects. In fact, in both years, AVERAGE NPP of total or aboveground biomass in 16-species plots exceed the NPP for the most productive monoculture. And these were random sets – imagine what a thoughtful farmer could do?**

**Other results from Cedar Creek:**

**Higher diversity plots had lower rates of disease (“Dilution Effect”), higher abundance and diversity of herbivorous and predatory insects (“qualitative effects”), less variation in year to year productivity (greater stability), and stored more carbon in the soil.**

**Well, Indigenous peoples have had a long time trying different combinations. Native Americans grew corn with squash and beans – these three species were called the “three sisters”. The corn is the most productive crop, but total productivity of a field is increased by adding squash that shades the roots and reduces water loss, and by adding beans that add nitrogen to the soil and grow up the corn stalks. However, industrial agriculture shifted to monoculture to increase the ease and speed of harvest of large farms – so there were economies of scale that favored monoculture in the industrial farming age.**

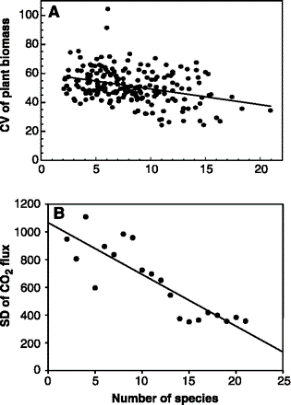
 **- Cutsinger et al. (2006): These same patterns actually occur when you increase genetic diversity, too! Using clones of goldenrod, they demonstrated that productivity increased with increasing clone diversity/plot…in a manner that could not solely be explained by random sampling. In addition, diversity in genetic diversity increased diversity in herbivorous and predatory insects, too.**

**C. Effects on Stability**

**1. Types:**

**- Resistance: ability of a system to withstand disturbance**

**- Resilience: ability of a system to return to its initial state after a disturbance**

**2. Relationships with Diversity**

**- More diverse communities are less susceptible to a single type of disturbance (pathogen, pest, fire, etc.) because there are many species with different niches and characteristics that are unlikely to be sensitive to the same thing. Indeed, as richness increases, communities become less variable in their NPP, and in the respiration of soil biota. Less variable means more stable – With respect to resilience, things may be more complex. A simple system is easier to restore than a complex system with many species… you are unlikely to get it back with the same species composition. Fisheries seem to recover, but rain forests don’t recover to the same state, probably because they are self-regulating and self-determining systems. Rain forests water themselves and also contain most the nutrients in the system. Cut it down and the nutrients leach from the system, and there is less evapotranspiration to the air, and no volatiles to act as condesnation nuclei… so rain declines. With less rain and poorer soils, grasses dominate and the frequency of fires increases… which stalls succession and prevents rainforest regrowth. So thre may be multiple stable states…and once you change a huge area to grassland, it stays grassland.**

**D. Importance**

**- We will need stable, productive food supplies and stable, productive ecosystems to provide constant ecosystem services. Stablility and productivity are both increased by……DIVERSITY. Unfortunately, just when we are placing the greatest demands on our ecosystems, we are causing the 4th great mass extinction event in the planet’s history. Not a good combination.**

**II. Aesthetic Value**

**A. Biophilia**

**Like all organisms, humans evolved as a direct consequence of their intimate interactions with the environment; the environment is still a part of us – it influences who we are, how we think, how we communicate, how we behave, and our mental state. In short, being in contact with the environment, and observant and responsive to it, has been selected for throughout human history. Now, as most members of our species live in manmade environments, we are in danger of losing an appreciation for both the value of nature and our emotional and psychological dependency on it.**

**III. How is Biodiversity Doing?**

**A. Genetic Diversity**

**The genetic diversity of most species is in decline, both as a function of decreased population size but also, for domesticated species, as a consequence of human selection. It is particularly dangerous to our long-term survival to depend not only on a few (3!) species for most of our dietary calories, but to depend on a very small number of genetically homogenous cultivars. While genetic modification has allowed us to create crops that grow faster, with fewer nutrient and less water, and are resistant to pests, it cost lots of money to create such a crop plant. To create another one, that is genetically different, would be almost just as costly – so agricultural companies have preferred to mass produce and sell clones of this one super-plant. The problem, as you now know, is that if the environment changes (and WE are changing it), then there is no guarantee that this cultivar will be able to adapt – and neither will its genetically identical offspring.**

**B. Species Diversity**

**We are losing species at a rate only equaled by the 5 mass extinction events in the Earth’s history. Humans have been nearly as damaging to biodiversity as the meteor that wiped out the dinosaurs. Review the powerpoint to see the quantitative decline that has occurred in many groups of organisms. It has been a global pattern in biodiversity loss—as soon as humans colonized an area, most large animals went extinct. You now know that ‘species’ are the ‘parts’ of nature. How can we expect the biosphere to work like it has—the way that has supported human existence for the life of our species—if we lose all these parts? What IS the biosphere except species???**

**C. Ecosystem Diversity**

**Of course, different species live in different places, and comprise different ecological communities. As species go extinct, the communities they comprise collapse. Within your lifetimes, we have seen old-groeth forest reduced by an area the size of Texas. We have seen Caribbean reefs decline by 50-10%, and coastal mangrove, which protect tropical coasts from storm surge and sea level rise, have been reduced by 35%. It is the biosphere that is responsible for making Earth the way it is – it is the production by photosynthetic organisms, and the transfer of energy through food webs of animals, and the recycling of this energy and matter by decomposers that are truly responsible for making Earth different from Venus and Mars. We can’t live on Venus or Mars, so we are dependent on the biosphere, and all the pieces of which it is composed.**

**IV. Why is Biodiversity Declining?**

**A. Humans Change Habitats**

**All habitat conversion results in a decrease of species. Forests contain the most species, so converting forests to cropland and developed land has had the greatest effect. Fragmentation of habitat, and not just total loss of area, is another driver of extinction for the reasons described in the theory of island biogeography.**

**B. Climate Change**

**Through the burning of fossil fuels, which returns the carbon stored by plants 350 million years ago to the air, we have caused CO2 to increase by 40% in the last 200 years. This is 200 times faster than any change recorded in the fossil record. Although CO2 levels do change naturally, they have never ever changed naturally at this fast rate. And all of the associated predictions are occurring, as well – from melting ice and glaciers, to increase in sea level, to increase in forest fires, to increased rainfall in some areas as the planet heats up.**

**Study Questions (This are pretty superficial questions – I expect you to bring some support for your answers from the lecture material):**

**1) Describe the quantitative and qualitative ways that increased productivity can increase diversity.**

**2) List the three ways that increased diversity can increase productivity. How did Tilman test this idea, and what did he find?**

**4) Define the two types of stability.**

**5) Why might rainforests not return after a huge clearcut? What are “multiple stable states” and how can rainforests and grasslands both be stable ecosystems in the same place?**

**6) What is biophilia? Why should we expect this relationship to occur? Provide evidence for this dependency.**

**7) Why is reduced genetic diversity in crop plants dangerous? Why has it occurred?**

**8) In general, is the extinction rate now unusual? What are the two primary reasons for the rapid decline in species?**

**9) How are earth’s conditions maintained by the biosphere? What is the biosphere made of?**