**Lecture 1**

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Physical Geography – study of earth’s climate and physical features

 Biogeography – how organisms are distributed across the landscape (why they are where they are)

Abiotic – nonliving elements in an environment

Biotic – living elements in an environment

Badger is in its habitat, called an ecosystem or an ecological system

* Eco- comes from the Greek word *oikos*, which means home
* -ology means “study of”
* Term was coined in the middle 1800s by Haeckel

Single organism

Population (male, female, offspring, multiple generations)

Community (a set of interacting organism in the same habitat)

Ecosystem (abiotic and biotic systems)

Biosphere

* Each community/ecosystem in nature are very different and can vary in space and time
	+ Can’t generalize one community to another without understanding where and when they are

Is climate seasonality?

* Earth is tilted on it’s axis, and occasionally wobbles
* In northern latitudes during summer, we have direct solar radiation while it’s more angled at the poles, so less energy
	+ Also at poles, radiation has to go through more atmosphere, thus poles have much less energy shined upon them and are thus much colder
* Less sun energy comes in at the pole. At the poles, solar radiation needs to go through more layers of atmosphere, thus amount of energy that comes through is much less
	+ This results in both poles being a lot colder than the rest of the earth
* Seasonality occurs when earth on the other side of sun and our southern hemisphere gets more solar radiation
* Weather is the current condition of precipitation and temperature at a certain time point
* Climate is average weather over time
* Seasonality is variation annually
* Climate diagrams were originally proposed to help those with agriculture and it basically summarizes such variation patterns
* When air rises, it cools and can’t maintain as moisture, thus it rains
* Differences in solar radiation across the earth determines patterns of circulation of air
	+ Very hot by equator/middle of the earth because they get a lot of solar radiation
	+ Hot air (which typically contains a lot of moisture) then rises, expands, and subsequently cools as a result of expansion
		- Adiabatic cooling – much like conditioner
	+ When air cools, it can’t hold onto as much moisture and thus rain occurs
	+ When air moves, though, it circles about 30 degrees north and 30 degrees south, where it then comes back to earth
		- Known as Hadley cells
		- Also occurs at 60 degrees north and 60 degrees south, as well as further north and south
* Temperature drives both patterns of circulation and patterns of precipitation
* Wet moist air from tropics typically falls back there; however, at 30 degrees north and south as the air falls, it becomes more dense and warm and actually sucks up moisture, creating drying conditions
	+ Results in stratification of wet and dry conditions, temperatures, and global circulation on earth
* Patterns of air circulation also determines direction of prevailing winds and affects water currents
	+ Air at equator is slower than rotation of earth because it is higher up and has more surface to cover at higher elevation
	+ When wind is blowing towards pole, there’s less surface for the air to cover so it moves faster than earth is spinning
* Wind also affects water current because of the action of wind on waves
	+ Currents in northern and southern hemisphere mimic the direction of the prevailing wind, only being interrupted when they run into continents and turn around
* Topography: shape of land
	+ When air rises, can’t hold as much water and rains
	+ Rain shadow: clouds depleted of all rain so when it passes over mountain, suction occurs so land after is dry

Key things:

Physical geography

Biogeography

Ecosystem (aka ecological systems)

Ecology

Haeckel System

Weather

Climate

Adiabatic cooling – hot air rises and expands. As it expands, it cools so it can’t hold as much moisture. When air comes down towards earth, it becomes more dense and thus heats as it drops, thereby absorbing more moisture

**Lecture 2**

3-8 pages a lecture… should read, yo

Exercises that ask of concepts/assignments… correlation with test questions (based off of?)

* Similar climates across the world that are not connected… Portugal, SF, South Africa, etc
	+ Led to the biome concept, coined by Alexander von Humboldt
	+ Annual precipitation vs average temperature (the plot and the area within the plot) determined largely where animals lived

Rain Forests

* Day length and temperature changes very little, seasons only marked by annual cycles of rain and dry
* Results in rapid speciation and much diversity in organisms
* Leaves lots of room for specialization in very narrow niches
* 6% of earth surface, yet half of all earth’s species
	+ Patch of area the size of a tennis court can contain more species of trees than in the whole US
* Between 5-30 million species in rain forests, however biologists can’t get any more accurate than that
* Stability of rain forest is challenged due to expansion of roads and human urbanization

Grasslands and Savannas

* Grasses replace trees in grasslands and savannas because there’s less water
* More grazers in grasslands and survivors than in the forests

Acquatic Systems

* Littoral (freshwater) and Intertidal (marine/ocean) – zone where plants through in the water (think kind of like a marsh type thing?)
* Limnetic (freshwater) and Pelagic (marine/ocean) – zone that’s too far off the shore for plants to grow, thus most photosynthesis occurs through phytoplankton
* Benthic (in both freshwater and marine/ocean) – bottom zone
* Photic (in both freshwater and marine/ocean) – zone where light reaches
* Aphotic (in both freshwater and marine/ocean) – zone where no light reaches
	+ Abyssal zone exists only in the marine/ocean zone because it’s so dark
	+ The bottom of it also contains hydrathermal vents where there are also organisms living/thriving in their own ecosystems
		- We’re not using enzymes and such from organisms living in hyperthermal vents in many medical and scientific procedures (such as PCR)

What determines where things live in aquatic systems?

* Instead of precipitation and temperature, we consider salinity (amount of salt/freshwater), amount of light received/how far down from surface of water, water flow/wave action
	+ These are different set of physical factors that determines where things live

How do organisms get onto land masses isolated by water (like Hawaiin island)

* Vicariance – idea that organisms are where they are because organisms are attached to piece of land since their conception rather than dispersed there (similar to idea of continental drift/plate tectonics
	+ Movement of plates/continents is rather predictable and there is a known chronology of continental drift which provides 3 hypotheses about the history of organisms
		- Southern hemisphere continents were once all together but have now drifted apart
			* First hypothesized in the early 1900s (1910-1915) but wasn’t accepted by the general public until 1950s
			* Split between Australia and New Zealand is very old, so organisms shared between them is due to dispersal primarily or else from when they used to be together a very long time ago
		- 45 million years ago India crashed into Asia creating the Himilayas
		- 17 million years ago Africa and Europe
		- 6 million years ago South America and North America
* Dispersal is an organism leaving its original habitat and colonizing elsewhere
* Biotic Exchange – when organisms from one continent move onto another continent due to a collision of the two that connects them
* Pattern of plate tectonics and continental drift creates separation between biographic regions and also connects them
* Between Australia and Oriental region lies Wallace’s Line
	+ Organisms between these two areas are very different
	+ Many breaks between biographic regions as a result of history of plate tectonics, with Wallace’s Line being most famous of them
* Phylogeny can be used to date the split between different taxas, but dates that were too recent to be caused/explained by continental drift means that there had to be another reason for the split, namely dispersal
	+ Both dispersal and vicariance is important as a result of this study
* Assassin spider phylogeny coincides with dates predicated by continental drift, and as it turns out these spiders don’t disperse much

Role Humans Play in Altering Kinds Organisms and Where They Are on Earth

* Agriculture
	+ About half of the planet are ecosystems that can be called human dominated
	+ Canals and projects undertaken to move water around the state of California is a big biological issue as it changes the natural ecosystems
		- Example is Kahoolawe Island
			* Was used as a bombing test site during WWII and as a result there’s lots of craters and no trees
			* No vegetation to hold onto moisture, and thus the climate has changed and is now very dry on that island
* Many of earth’s ecosystem, if viewed from space, show a signature from the effects of biology (pattern of ridges and valleys showing erosion, habitats, etc)
	+ This signature could be considered more or less the typography of earth

**Lecture 3**

* Populations are typically distributed in patchy habitats that can be of any size and individuals may move between habitats
* Most interested in how many individuals in population biology, however it’s very difficult to accurately count each and every single one to find the population size
	+ Easier to just estimate the population density for a given area or volume
* Humans recently passed the 7 billion mark
	+ The rate of increase in population has been on a decline since the 1960s
	+ We increase in size every 60-70 years

Classic Birth-Death Model

* If r>0 then population will grow, if r<0 then population will decline
* r does not have to be very big at all in order to increase population size exponentially
* Population Pyramid summarizes the age distribution maps and allows one to quickly tell if population size is changing or not
	+ If population pyramid is very similar to a triangle (broader base, thinner top) it means that the population will continue to expand (Africa, etc)
	+ If the population pyramid looks like a typically bell curve, it means that the population is more or less stagnant (US, Canada)
	+ If the population pyramid looks somewhat like an egg, it means that the population is actually declining in terms of number (Europe)
	+ China’s distribution is different because of the One Child Policy that was implemented, which resulted in a decline in population
		- Such policies show patterns in fluctuations in the population size

Case study: Sea Otters

* Initially there were thousands of sea otters, however they were killed off by humans for their pelts
* Numbers dropped to a few tens, and with management by humans we were able to raise the number to hundreds and now thousands again
* Population has been rising and declining periodically, and now recently on a decline
	+ Thought to be a result of a disease among shellfish that the otters eat

**Lecture 4**

* Life history – pattern of reproduction, mortality, survivorship, and all things an organism does within it lifetime
	+ Time course of events of growth and development
* Exponential growth leads to constant doubling times until something limits growth of the population
* Life table shows the yearly survivorship or fecundity (young produced per female for certain age group) for all the individuals within a cohort (a cohort would be say all the freshmen on campus are within the same cohort)
	+ Sometimes it’s easier to just record all individuals in a population at a given time in order to get the data to create a life table

3 types of survivorship curves:

* For humans: pretty level until old age, in which case it shows a sharp decrease
	+ There is slight decrease towards the beginning due to infant mortality, but once humans survive past the first year, they typically live until old age
	+ Our population is growing at a much faster rate than expected because if you plot it as a log, it should be a straight line however it’s a lot better than a line
* For songbirds: more or less a straight line
* For frogs or other organisms that mass produce eggs: sharp decline right in the beginning because most of the eggs don’t survive past infancy, but after this sharp fall it will be more or less level over time with decrease due to deaths by natural causes
* Such curves can vary within and among species due to environmental factors that affect their ability to survive and thrive
* Based on resources available, organisms allocate certain amounts of energy to various processes that help them live day to day life
	+ Most energy goes towards homeostasis, which helps the individual’s bodily functions going (“keeping the engines running”)
	+ Can then allocate energy towards defense against predators, competitors, growth, reproduction, etc
		- This is known as principle of allocation, or life history trade-offs
		- Similar to not being able to get A’s in every class. Must pick and choose what is most important. For animals, selection acts upon what is chosen as most important

Lactic bacteria in cheese makes cheese a certain pH so that it makes it less tolerable to other bacteria, making sure that only certain organisms live in the cheese

* This process can be thought of a purification type process and thus the cheese doesn’t rot

Additive/Arithmetic vs Exponential/Multiplicative Growth

* Malthus thought that populations grow exponentially and double over constant time periods (doubling time is constant so for example it will double every 3 years)
* Additive growth is where a specific number of individuals is added to the population per year

Nt = N0ert

* Allow us to predict the population size at time t

Eventually populations will reach their limit, or carrying capacity (K)

* At some point, populations will reach a limit on the number of individuals that can live within a given environment
	+ Such limitations include abiotic things like number of nesting cavities and safe sites and/or biotic factors, which are imposed by predation, disease, etc
		- Known as logistic growth
* Idea is that there is an intial exponential rise (J part of curve) and it eventually levels off (turning into an S curve)

dN/dT = rN (1-N/K) = N \* (r – rN/K) = r – f(N)

* If N is very small (N<K), then growth rate is the same as what we got from exponential growth
* As N gets closer to K (N=K), then the growth rate or change in population size will decrease and eventually hits 0
* If N>K, then the population growth rate will be negative and the population size will actually decline
* (r – rN/K) eventually sums down to the growth rate of the population
* With competition, the growth rate of species A (rA) = rAmax – f(NA) – f(NB)
	+ rAmax is the growth rate under the best of conditions, however we must account for the damage another species competing against [f(NB)] it does to the growth rate in addition to the damage/parameter that the species in question imposes [f(NA)] upon its own growth rate

r and k-selected Species

* r selected organisms reproduce quickly and often give rise to many offspring at once, and but don’t live very long
* k selected species live a very long time but reproduce less offspring at once

**Lecture 5**

* the human population’s carrying capacity, k, is constantly increasing
	+ leads to the question whether or not it will stop increasing

Life History “Strategies”

* selection and adaptation has shaped the life cycle, favoring those that are more successful
	+ two extremes: little r and K strategy, or r and K selected

r-Selected Organisms

* mature rapidly/has an early reproductive age with a relatively short lifespan
* typically have many offspring at one time with a high offspring mortality rate and low offspring survival rate
* minimal parental care/investment

K-Selected Organisms

* mature more slowly and has a later reproductive age with an overall longer lifespan
* typically have few offspring at same time with low mortality rate and high offspring survival rates
* high parental investment

Density Dependent/Independent Growth Rate

* density independent curves are those that are not dependent upon the population size
* as curve approaches carrying capacity, it begins to level off and this is dependent growth as growth depends on the number of individuals in the region and the number of individuals the habitat can sustain
* K-selected organisms are typically more adapted to deal with competition

Biological Dispersion – how animals are dispersed in nature

* Regular distribution: things are placed in a spaced out manner that is more or less regular or predictable
	+ - Examples include bird territories, farming
* Random distribution: things are placed in a spaced out manner that seems to have absolutely no pattern
	+ - Examples settlement of seeds
* Clumped distribution: things are placed in a spaced out manner that is within clumps that are seemingly random, but are actually not random
	+ Not random because each individual is located in a clump
	+ Distribution of the clumps, however, can be random
		- Examples include habitat patches for checkerspot butterfly

Refinement of Birth-Death (BD) Model

* Inclusion of immigration and emigration, which affects r
* Metapopulation: when there’s a clumped distribution and there’s a population of populations
	+ - Examples include desert bighorn sheep
			* Historical range was very large, but its habitat range has been reduced due to urbanization and colonization by humans that are small and patchy (pretty much a metapopulation)
			* Sheep are moving between these metapopulations
	+ When one such clump population within it disappears or goes extinct over time and is recolonized from other populations, it is considered a rescue effect
* Habitat corridors: ways to conserve species by providing connections between habitats so they can find each other and remain sexually compatible
* Ways to preserve habitats of animals is to limit the amount of our colonization
* Tag animals and using DNA techniques (blood sample, fecal sample) in order to record an accurate number or individuals within a population

Conservation Example: Humpback Whale \*\*\*\*\*\*\* fell asleep here

* In order to identify individual whales, we tag them, check the barnacle symbiosis, etc.
	+ Only 10% of whales have been identified, however we can also use DNA diagnostics by shooting this arrow into their blubber to find out individual whales, how whales are related, and how such populations of whales are connected
	+ Whales spend their winter months in tropical area where they give birth, and in summer months they go to artic where there’s a lot of krill for them to eat

Human Disease Example: Swine Flu

* Different part of the swine flu comes from different animals
* Biggest factor in controlling H1N1 from spreading is controlling spread as people travel all around the world
	+ At airports that have swine flu outbreaks, there are thermal scanners
		- If you’re above a certain temperature, you can be pulled aside to make sure your temperature isn’t a result of having the flu
	+ Contact between people is also monitored so in some countries people wear masks, and contact is much more likely between people aged 14 and under
	+ Super spreader: a person who spreads a disease at a rate much greater than would be expected by chance
* Such pathogens also evolve rapidly so it’s near impossible to complete eradicate it

**Lecture 6**

Types of Species Interactions

* Competition
	+ Negative effect on species 1 and 2
		- Example: interspecific competition could be plants in a rainforest
* Consumer-resource: predation, herbivory, parasitism
	+ Positive effect on one, negative effect on the other
		- Example: predation example is fox eating rabbits, herbivory example is humans eating veggies, parasitism is
		- In predation the prey species die while in parasitism it doesn’t kill the host
* Mutualism
	+ Positive effect on both species 1 and 2
		- Example: pollination
		- Case study: rattle ants and small oakblue butterfly
			* The butterfly larva (the caterpillar) secretes this honeydew liquid which ants like. The caterpillar is able to sense when danger is near, say a spider, and it sends a signal out to the ants and the ants take care of the problem
		- Case study: leaf cutter ants and fungus in Panama
			* Leaf cutter cuts the leaves and feed it to the fungus and the larva feed off the fungus
* Commensalism
	+ Positive effect on species 1, no effect on species 2
		- Example: plant stick to say dog’s fur and later falls off. This benefits the plant because it’s dispersing it’s seeds
* Amensalism
	+ Negative effect on species 1, no effect on species 2

Interspecific Competition

* Gause used different species of Paramecium in different combinations that showed which were better suited for survival
	+ He found that each species of paramecium were occupying different positions in the flasks
		- One was more specialized at the bottom of the flask while the other was more specialized higher up in the flask
			* Concluded that they weren’t competing completely for the same resources in the flask, thus they were able to coexist
		- For the second experiment with extinction, it was because they occupied the same general area and thus competed for the same resources
* When grown on their own, you see a typical S curve and high population growth
* When grown together, one does better than the other but the population growth wasn’t as good as it would have been when compared to the curve where it was grown on its own
	+ Resulted in an equilibrium of population
* Another example with Aurelia and caudatum: caudatum was in the original experiment where it outcompeted another species. In this example, though, it was outcompeted and eventually was wiped out by Aurelia showing how survival is arbitrary depending on the environment and conditions
* Joe Connell’s experiment with barnacles: showed that lower species outcompeted upper species, however the lower species was not as well suited at survival thus it occupied the lower region and this allowed the upper species to continue to thrive
	+ This shows the fundamental and realized niche. Fundamental niche is the where the organisms can grow in the absence of competition and the like, and the realized niche is where one can actually find the species and where it thrives in the real world

Lotka-Volterra Equations

* In cases of predator-prey, the predator gains a benefit from the presence of the prey, so we get rA = rAmax – f(NA) + f(NB) for the predator and rB = rBmax – f(NB) – f(NA) for the prey
	+ Two results from this balance: either there’s a cycle of population growth (possibly sinusoidal) between the two species or extinction
		- Sinusoidal-esque would be the predator species hunts and grows to a larger number, but then there wouldn’t be enough prey for them to survive so their population crashes and this gives the prey species to increase in population, in which case the predator then increases
			* There is a lag time in between the population growth rates between the predator and prey
			* Such an example would be the snowshoe hare and lynx in Canada, wolves and moose in Isle Royale, acorns and mice and ticks
			* Typically, when the prey species is rare, it’s able to escape and hide from its predator and thus it actually does quite well in terms of population growth

**Lecture 7**

* Ecological and evolutionary consequences as a result of interspecific interactions
* Invasion is interaction or spread of organisms into new areas with ecological or economic or health related impact

Resource partitioning: splitting up the available resources in the given area due to specializations that allowed one species to better feed in one region or at one sources in comparison to another species that is able to better feed elsewhere; different species are using different resources in a community

Competitive exclusion: when two or more species compete for the same resource, resulting in one species outcompeting the other

* Two species competing for the same limiting resource cannot coexist

Character Displacement: an evolutionary phenomenon where certain characteristics in species will change over time as a result of competition

* Finches and bees on the Galapagos
	+ On islands where they don’t coexists (only finches present), the finches spent more of its time foraging for nectar and its body size is a lot smaller
	+ On islands where bees and finches coexist, the finches spent significantly less time foraging for nectar (sometimes spending no time at all) and its body size is bigger in order to be able to feed on the nuts and grasses since they need bigger beak sizes
		- As a result of needing bigger beaks, there is selection for bigger birds thus if birds were smaller, they were less fit and died – resulting in a population of birds that were the right size
* Anolis lizards in the Caribbean (better example of resource partitioning \*\*)
	+ Scientists (Schoener) studied where such lizards are found: on the trunks, on the branches, and how far up
		- Those on the branches were bigger and more slender because they can get a better handle on the twigs and branches, resulting in its ability to better support its larger size
		- When two species were somewhat sharing the same resources, they were different sizes – a prime example of resource partitioning
		- Different sizes between the two sexes (mature males are larger than mature females and immature ones)
		- Also dependent upon sunlight and shade
			* All in all this is to reduce competition amongst themselves

Consumer-Resource Escalation

* Rubber plant secretes latex that prevents other species from attacking it because if they do, latex will ooze out and will prevent the species from feeding because of the gummy texture and ensues from the latex
	+ Some species developed ways to circumvent such deterrents
		- They’ll cut the vein or create a trench so that the latex can’t come out, and then will proceed to feed away towards the end of the leaf
* Figs and fig wasps (form of mutualism)
	+ Refer to what was learned through Feldman. Same exact example but through an ecological perspective

Invasion Biology

* Invasion: species that is expanding its geographical range and is typically considered bad as it has negative ecological, environmental, and/or health effects
* Probably occurs because it is possible that such invasive species may be able to better survive if none of its predators are present in the new environment
* Facilitation (idea of mutualism): making conditions better for other organisms to invade and survive
	+ ??????????? how is this mutualism? How does the plant benefit?
* Increased dispersal (propagule pressure): if the opportunity for organisms to invade a habitat or establish and be successful is provided, then we change the likelihood an organism will invade a habitat
	+ Similar or identical to ecological release which is an ecological phenomenon where organisms are released from some constraint in their environment, allowing them to expand or occupy a larger niche that they otherwise could not
* Since there’s more opportunity for these species to survive, we expect there to be an increase in their population
	+ Example: Argentine ant, American Chestnut blight, bacteria in our stomachs
		- In Argentina they live in small colonies, however in the US they form supercolonies (aka ants in Berkeley are part of the same colony in San Jose, etc)
		- Chestnut is being wiped out by a fungus. Oak took its place but acorn production of oak is very sporadic. This leads to the mice and tick population fluctuations, and a fluctuation in Lime disease in humans as a result
		- When we take antibiotics, it essentially cleans out our guts. This makes our stomach a prime place for colonization/invasion because there’s no competitors inside the gut, and there’s a serious case of a bad bacteria coming in and colonizing

**Lecture 8**

Ecological Release – evasive species are successful because they are escaping predators/competitors, allowing them to expand their niche and thus “release” themselves from constraints that limit their population. If not because of escaping predator/competitor, perhaps the new habitat is better (i.e. more resources available, etc)

Propagule pressure – the idea that invasive species are successful because they have many opportunities to invade/occupy a new habitat because the more chances, the higher the likelihood of success

Ecological community: a set of interacting species in one place and one time

* Defined by species in them, how they interact, and the habitat structure
* Such communities vary in space and time
* Transect – a way to sample things along a line (lay down a tape measure and record species found outside serpentine outcrop and towards the middle of it
* Serpentine soil is a good way to see the changes in species composition (known as species turnover as certain species are replaced by others as we move through space)
* Species can also turnover in time, a process known as ecological succession
	+ Primary: where species are colonizing open ground for the first time
	+ Secondary: original colonists eventually change the habitat over time, making it more likely that other species will be able to better habitat the ecosystem
		- Example: volcanic explosion clearing the land, glacial moraine (soil underneath a glacier that’s revealed after the glacier melts)
	+ Basically the primary colonizers primer the habitat for future (secondary) colonization by other organisms
		- In glacial moraine example, there’s no nitrogen in the original soil. Of the primary colonizers, some actually fix the soil with nitrogen, making the habitat better for other plants
* Climax communities are those that exist from the beginning to the end (they are primary colonizers but do not get wiped out over time)

Dung Decomposition (succession)

* Male dung beetles roll up balls of dung, of which females will choose and lay eggs in
	+ Such beetles were eventually brought in to take care of the dung

Decomposition of Bodies

* Very predictable: first we see blow flies, then flesh flies, then beetles
* Pigs are often used to simulate the decomposition of the human body because their torsos are roughly the same size as ours

**Lecture 9**

Food webs – network that explains energy flow through the biological community or ecosystem

* Sun gives energy to autotrophs which is given to heterotrophs
* Autotrophs, also known as primary producers, get their energy from the sun
* Heterotrophs are organisms that don’t make their own energy
* Energy flow: sun – primary producers – primary consumers – secondary consumers – tertiary consumers (etc) – decomposers
* Trophic cascade: how feeding at one level cascades down and impacts the feeding at other levels (can also be considered a food chain)
* Omnivores eat both plants and consumers that feed on such plants
	+ Example: elk and wolves in Yellowstone Park
		- Elk eats aspen, which affects many other species, so officials had to cull (kill) the elk
		- Public became outraged so no more culling, except population of elk increased
		- As a result, wolves were reintroduced in order to maintain elk population
		- When wolves were present, the aspen population regenerated
* Keystone species: species that have a disproportionate effect on ecosystem (much like a top down effect)
	+ Example: river otter, California sea otter, seastars in the northwest, tropical fig
* Bottom-up effect is when the lower orders of the food web is more important

Gross Primary Productivity – sun beats down on plant and its energy is absorbed

* Energy is lost through metabolism/heat
	+ Energy leftover available for use to consumers is known as the net primary productivity
	+ Typically only 10% of the energy from one level is available for the next level
	+ Food webs are typically limited to 4-5 levels due to this energy cascade
* Another way to represent this energy cascade is through trophic pyramids, with the higher-ordered organisms towards the top of the pyramid
	+ When it looks like the population pyramids, we must ask whether it’s based on numbers, biomass, or energy
	+ Biomass in open ocean system is a lot different. The second level is actually a lot bigger, but this is because phytoplankton system turns over a lot more quickly, however the energy level is typical
		- End verdict: energy flow and biomass pyramids are not always the same
	+ Primary productivity can be determined by carbon dioxide consumption
* Chicken is most efficient in terms of energy received from consumption of meats, but for potatoes we get almost 100% efficiency, with over 200% efficiency for corn and 400% efficiency for soy
	+ Grass-fed beef is more energy efficient than corn-fed fish
	+ Farmed and “wild” fish are about the same energy-efficiency wise
	+ It can be over 100% efficiency because it’s based on energy we as humans input to grow such crops

Species Diversity in Communities

* Just because a community has a lot more species does not mean it is more diverse than another community with less species
* Species richness is the number of species within a community
* Species evenness takes into account how the number of organisms is distributed among organisms within a community
	+ A community with species distribution of 9-1-1-1 is probably less diverse than one with a species distribution of 4-4-4 even though it has more species because the distribution is not even
* More species result in more biomass: if we add more species, we change the function of the ecosystem and we get more biomass
	+ Sampling – could be just luck or the increased likelihood that we get species within our plot that just so happens to be very productive
	+ Niche complementarity – by adding more types of species, we add more functions that these species can do or perform
		- Research project done by Tilman from Minnesota
		- Different functional groups are known as guilds where organisms within it that makes its living in largely the same way
		- Examples of such groups are C3, C4, grasses, legumes, woody shrubs, etc., that affect the biomass

**Lecture 10**

Plant biomass can be considered as an indicator at how stable a community will be over time

* Possibly with more functional groups, there’s more activity and the community will be more stable
* Restoration ecology: using what we know about ecological systems to restore something back to what was considered natural
	+ Say we had an empty field and wanted restore it to a grassland/prairie
		- Based on the research, it seems best if we introduce many different species/functional groups in order to maximize biomass quickly

River blindness in Africa by Prof. Vince Resh

* Nearly 20 million people are affected by this disease and it usually causes blindness
* When Europeans came to Africa, they wanted to settle by the rivers even though most Africans moved away from rivers in order to avoid the disease
* Insect takes blood sample from human and lays eggs in human skin, often the eye
* Reproduce in the host body and then transported by biting fly
* Resh developed 3 programs to deal with it
	+ Treated residents by getting companies to give free drugs
	+ Controlled the fly population, using potent insecticides
	+ Maintained river diversity because the insecticides can kill other aquatic invertebrates in the river that people and other organisms eat

Patterns of Biodiversity

* One of the major patterns ecologists have seen is that there are more species in the tropics, and there are several models/theories that explain why
	+ Climate stability – back when we had glaciers and ice, it impacted North and South America more than the tropics thus the tropics had more stability and better conditions and species had more time to develop
	+ Energy-productivity – solar radiation is very important in terms of driving patterns for weather and seasonality and such radiation is more intense at the equator; with more energy, perhaps more energy available for energy to cascade through the food web thus leading to more trophic levels
	+ Structural complexity – stratified forests leading to more opportunities and niches for organisms to exploit
	+ Spatial-area (null model) – model without any assumptions
		- Two null models based on how the continents are organized
			* Torborgh at Duke – more spatial area of cover in the tropics
				+ Basically more forests at the equator so more habitats for the species to live in
			* Colwell – mid-domain effect; pencil box analogy; more species in the middle (aka the tropics) and less so on the edges (North and South America)

Diversity is distributed differently in the tropics than in the temperate regions

* Fraction of species shared across geographical distance
* Many species are shared over a large geographical range
* Alpha diversity: species diversity in any one place
* Beta diversity: species diversity from one place to another; how much of the diversity is distributed from one place to another; how does diversity change from place to place
* In the tropics, the diversity is pretty much the same from place to place, which differs from what is seen in North America
	+ Depending on the area, we’d be dealing with either alpha or beta diversity and this is important as it pretty much dictates how our conservation efforts should be

Equilibrium Theory of Island Biogeography (somewhat of a null model; ecological theory)

* 730 bird species in New Guinea
* Islands away from New Guinea shows different numbers of bird species: the closer the more species, the larger the more species
	+ Usually called the equilibrium theory of island biogeography (MacArthur and Wilson)
	+ Easier to colonize big islands that are close, and organisms should go extinct on islands where there’s a lot of species
		- Generally, as the island gets more species, the extinction rates increases due to competition
		- Exceptionally larger islands, however, tend to have lower typical extinction rates since there is more room for the organisms (it still increases with more species, however, just not as drastic)
		- The more diversity on an island, the less likely new organisms will migrate to it and colonize
		- The farther away an island, the less likely organisms will migrate to it colonize it, and thus the more likely ecological niches are vacant and available
		- The closer the island, the more likely species will migrate to and colonize
* Colonization and extinction depends on the number of species on the island
	+ As we increase number of species, extinction rate goes up because more species on island, fewer ecological niches available, more competition, thus more extinction
	+ Larger islands are able to support more species, so the response is more relaxed
	+ As we increase number of species, colonization rate goes down because more niches are filled and thus we can’t add as many species
* To test this, we found mangrove islands that varied in size and distance from mainland
	+ Used a compound to get rid of all arthropods and saw recolonization rate and such over time of these arthropods
		- Mangrove island furthest from mainland was recolonized the slowest
		- Herbivores colonized first, then carnivore insects, then the parasites
* Logging sections of South America resulted in fragmentation of tropical forests
	+ Edge effect: physical and biological factors outside factor influence life at the edge of the fragment (roughly 30% of fragment is influenced by edge effect)
		- Higher temperatures, stronger winds, higher light levels, lower humidity
		- Additionally, species from surrounding habitats often colonize the edges of fragments
		- Smaller the fragment of habitat, the greater the influence of edge effect and thus show the greatest change in forest composition
* Coffee cultivation
	+ There are polyculture and monoculture cultivation, and the polyculture is able to support more life (obviously)
	+ Being near the forest plots, the success of pollination increases
	+ Hand pollination in polyculture because they’re too far away to be pollinated by bees and other stuff
	+ “ecosystem service”

**Lecture 11**

Ecosystem Processes

* Incoming solar radiation and reflected solar radiation as a result of albeto, or amount of reflected energy (amount of energy that comes in through radiation is balanced by amount that is reflected and lost to space)
	+ Of incoming radiation, 23% is reflected through atmosphere and 8% through surface, making earth visible from space
	+ Rest is absorbed by gases in the atmosphere and surface of earth, heating up and re-emitting the energy which is either absorbed by the atmosphere or lost to space
		- This energy absorbed by gases heats up and sends back to surface and the cycle continues
		- 69% of solar radiation energy is basically lost to space
		- Greenhouse effect is the effect of gases in the atmosphere absorbing the energy radiated by the sun (carbon dioxide, methane, water vapor, and nitrous oxides
		- Earth is 34 degrees C warmer than it would be because of the greenhouse effect
* Open ocean has less net primary productivity (amount of energy available to pass down) per meter squared, but if we multiply through by the amount of surface area of the earth represented by aquatic systems, it’s roughly the same as the earth
	+ As a percentage of the earth’s NPP, it’s 25% because it’s so big area-wise
* NPP in aquatic oceans is based on availability of nutrients rather than temperature and precipitation as seen in terrestrial ecosystems
* Upwelling – currents that bring nutrient rich water to the surfaces (bottom-up process)

El Nino

* Wave height and temperature height varies greatly during el nino (30 cm and 5 degrees)
* Patterns of precipitation changes as a result of el nino

Earth is an open system for energy, but closed system for matter

* Autotrophs – takes in carbon dioxide, nitrogen, potassium, and phosphorous
* Sedimentation – results in organic compounds that humans use for fossil fuels
	+ Examples include erosion, burning of fossil fuels, etc
		- Such chemicals go back to inorganic forms found in the soil, water, etc.
* Leaching – taking elements out of a solid states via water and having it flow through a water system

Global Hydrological Cycle

* Water redistributes heat
* Evaporation and precipitation of water drives the cycling over the globe
* Transpiration is water loss from plants
* Water that falls on land ends back in the ocean through rivers, etc.
* Fresh water ecosystems: spring and fall turnover
	+ Water is dense-ist at 4 degrees
	+ During winter, ice on top, but bottom of the ocean is warmest
	+ As water warms up, it moves up top and there results in a turnover, which cycles the nutrients

Annual Patterns

* Snow typically runs off mountains and enters our water system
* With less snow, there’s less runoff so water supply decreases
* Migratory birds follow certain routes but without water at their rest stop, they die
* Local hydrological patterns can have large impacts
	+ Heat in central valley pulls in the cool air to the Bay area
	+ Higher air flows, or jet currents, move sometimes
		- As jet currents are offshores, it keeps fog offshores and there’s a higher pressure region in the central valley
		- As jet currents move onshore, low pressure region in central valley which pulls the fog in
* Redwoods get their water from both fog and rainfall
	+ Can tell based on the hydrogen isotopes found in the plants

**Lecture 12**

Nitrogen Cycle

* N2 is most abundant gas in atmosphere (78% of air we breathe) but is often in short supply in biological communities
* Most organisms cannot use N2 gas because the two nitrogen atoms are connected by a triple bond that doesn’t easily break
* Nitrogen fixers can break triple bond in N2 gas in a process called nitrogen fixation
* Microbes convert N2 into ammonium, then other microbes convert this into nitrite and nitrate, which is used to produce nitrogen containing organic molecules
* Nitrogen can be leached out of soil by water and carried off into lakes
* Denitrification is the process with which some organisms take nitrate, nitrite, ammonium, etc. back into N2 so it can go back into the atmosphere
* Too much nitrogen can be bad because phytoplankton can take this nitrogen and reproduce rapidly through a process called eutrophication
* Eutrophication is the bloom of phytoplankton growth as a response to additional nutrients, resulting in a dead zone due to lack of oxygen
	+ Consequence of too much nitrogen in the system so plants do extremely well and use up all the oxygen so everything else dies
	+ Phytoplankton reproduce so quickly that consumers can’t keep up by eating them
	+ Phytoplankton population consumes oxygen during respiration and decomposers use up oxygen while they process the dead phytoplankton bodies
	+ Oxygen level in water drop drastically, and many aquatic organisms like fish crustaceans can’t survive on low oxygen
		- This results in a dead zone devoid of life

Carbon Cycle

* Cycled through earth’s organisms, soil, atmosphere, and oceans
* Most carbon is found in fossil fuels and rocks and atmosphere contains very little carbon in the form of carbon dioxide and methane
* Most carbon available to organisms on land is in the soil
	+ During respiration, organisms release carbon dioxide to atmosphere
	+ In photosynthesis, plants take in carbon dioxide from atmosphere for gross primary production
* Rate of which carbon dioxide dissolves in ocean slightly exceeds rate at which it outgases
	+ Some of the dissolved carbon dioxide is converted into organic compounds by phytoplankton like diatoms, most of which is recycled through trophic interactions of most organisms
	+ Some of carbon dioxide is transformed into insoluble carbonate compounds, making ocean more likely to take in more carbon dioxide from atmosphere
* During winter, metabolism exceeds photosynthesis so increase in carbon dioxide
* In summer, photosynthesis exceeds metabolism so decrease in carbon dioxide in atmosphere due to increased intake
* Considered a greenhouse gas, is transparent to visible light which warms surface of earth
* Warm surface emits infrared radiation back towards space, but is absorbed by other greenhouse gases which warms up and emits more infrared radiation
* Methane increase through livestock production, rice cultivation, and water storage in reservoirs because microbes break down organic compounds anaerobically to produce it

Ozone

* Upper atmosphere
* Filters UV light
* Ozone holes around antartica and also thinning of layer in US and Australia
* Leads to pollution and respiratory diseases in lower level of atmosphere

Sulfur

* Important in proteins
* Mainly from volcanoes
* Contributes to acid precipitation

Phosphorous

* Important in DNA and fertilizers
* Used in laundry soaps and was a fear that it would lead to eutrophication due to runoff
* Also found in animal waste

Iron (not tested)

* Limited in oceans
* Chlorophyll synthesis, animal enzymes

Iodine, Selenium, Colbalt (important in plants, but again not tested)

Greenhouse gases: carbon dioxide, methane, ozone, water vapor

* We’re adding a lot more greenhouse gases, and as a result there are now warming trends (the average temperature has been increasing)
* Various models and there are disagreements with regards to exact values, but climate is warming/temperature is increasing
* Global warming is not predicted to be even around the earth
	+ At tropics/equator and poles, should get warmer than other places on earth
* Also predicted change in precipitation
	+ Wet areas of earth will get wetter and dry areas of earth will get drier
		- Exceptions are Australia and far north
	+ Basically, more extremes in weather
		- For example, not necessarily more tornados in the US but rather more extreme tornados/an increase in intensity of tornado storms

**Lecture 13**

Biomes in Arctic Region

* Ice, tundra, boreal forest
	+ Forest is encroaching on tundra as climate warms
	+ More broadleaf plants vs needle (small leaves and evergreens) because of albeto
	+ Albeto: ice and white snow reflects light back into the atmosphere, warming up the area
* Most ice in the Arctic melted last year, and thought to have mixing water and a resulting large effect on biota mixing through the water

David Ackerly – how quickly will landscape change and how quickly can plants adapt in response

* In mountainous regions, species don’t need to move as fast to combat climate change in comparison to species in the central valley region
	+ Depending on elevation, where temperature can change rapidly over a small geographical scale, organisms won’t have to move as much
* Climate won’t be as affected on the coast because of the cooling properties of the oceans
* Different areas are experiencing different rates of temperature rise
* Flooded grasslands and savannas will change quite quickly, however biomes such as tropical and temperate forests won’t change as drastically
* Tropical forests and temperate forests won’t change as much as the savannas would
* Easier for organisms to go up and down mountains than move to other places

Heat and Malaria

* Malaria is a protist that’s carried around by mosquitos and is one of the major health problems in the world
* Mosquito carrying malaria bites human, transmit it, the plasmodium reproduces inside human, another mosquito bites humans and picks up protist again, bites another human and cycle repeats
* Occurrence of malaria corresponds to temperature because it’s based on where the mosquitoes live
	+ As climate is expected to warm, malaria may become more prominent in other areas of the world

Heat and Health in Cities

* Because of concrete and asphalt in cities absorbing radiation, the heat in cities is greater than heat in rural areas and parks
	+ Known as a heat island
* Earth can only stand so much disturbance before systems collapse
* Berkeley Initiative for Global Change Biology looked at a number of different factors and determined which were important enough to cause a major shift in how the ecosystem functions/works
	+ State shifts – ecological transitions
* Eventually will reach tipping point where community changes so much that there’s no way to recover from it

Ecosystems Processes that Humans are Involved in

* Fragmentation
* Disruption of neighboring areas – when we fragment areas, we also have an impact on neighboring area that may still be in good shape (edge effect)
* Transforming landscapes
* Accumulated impacts from human activity (eutrophication due to runoff)
* Changes in atmosphere (global warming, ocean acidification)
* Replacement of conifers in northern latitude (pine beetles, shift to broad-leafed trees)
* Loss of biodiversity
* Ice melting (glaciers and polar regions)
* Such drivers force the ecosystem into a new state