Chapter One

Ecology – the study of the many interactions in the world around us

- body of knowledge concerning the economy of nature, investigation of the total relations of the animal both to its biotic and abiotic environment

- concept developed by Ernst Haeckel in 1900s

- The study of the interactions of organisms with one another and with their environment

- not “the ecology” (wouldn’t say protect “the physics”)

- not Environmental Science – study of how natural world works

Ecological Systems

Nested hierarchy

- lowest level: look at individual organisms

- biosphere highest level

- organism most fundamental unit of ecology

- organisms interact with the environment that is outside the individual, therefore is lowest level, do not go beneath to organ systems, it is the level at which independent sexual reproduction occurs, natural selection occurs between individuals, etc.

ecosystem – assemblages of organisms together with their physical and chemical environment; a large and complex ecological system; eg) forest, prairie, estuarine ecoystem; all ecosystems are linked in a single biosphere

Levels of Study

Biosphere

- global processes

- includes all environments and organisms on Earth

- exchanges of energy/nutrients by wind/water between ecosystems

Ecosystems

- energy flux and cycling of nutrients

- have no clearly defined boundaries

Communities

- many populations of different kinds living in the same place

- have no clearly defined boundaries

Population

- social system of reproduction, survival, interactions

- population dynamics: density, dispersion, size, composition

- the unit of evolution

Organism

- conditions in which an organism can survive in

- individual’s interactions with biotic and abiotic environment

- individual sexual reproduction

- natural selection

Ecological Roles

Taxonomic Approach (Bio1020 approach)

– roles of individuals in these groups can be quite different even though similarity from ancestors; roles are related to levels

Organism Approach

– emphasizes the way in which an individual’s form, physiology, and behaviour help it to survive in its environment

– seeks to understand why each type of organism is limited to some environments and not others; related organisms different in dif places

Population approach

– is concerned with variation in the numbers of individuals, the sex ratio, the relative sizes of age classes, and the genetic makeup of a population through time

Community Approach

– concerned with understanding the diversity and relative abundances of different kinds of organisms living together in the same place

– focusses on interactions between populationg; limitting and promoting coexistence of species

Ecosystem Approach

– describes organisms and their activities in terms of “currencies,” primarily amounts of energy and various chemical elements essential to life

Function

– organism’s role in the functioning of the ecosystem; occurs because of natural selection; not “purpose”

– ecosystem function reflects the activities of organisms as well as physical and chemical transformations of energy and materials in the soil, atmosphere, and water

Roles change with evolution

– depends on other community members/roles; evolutionary responses include changing roles in order for populations to adapt

Habitat

– conditions of environment (physical and biological conditions)

– Circular: plants define habitat; respond to habitat; alter habitat

Niche (interrelated to habitat)

– organisms’ range of tolerated conditionsand ways of life; role

Conditions of Life: Energy and Nutrients

– photosynthesis: begins energy flow cycles

– nutrients: cycling of energy

Biosphere Approach

– concerned with the largest scale in the hierarchy of ecological systems; movements of air and water, energy and chemical elements

– currents and winds carry the heat and moisture that define the climates at each location on Earth, in turn govern conditions for life

– understand consequences of natural variations in climate

Different Roles in Ecological Systems

-Plants use the energy of sunlight to produce organic matter

-Animals feed on other organisms or the remains

-Fungi are highly effective decomposers

-Protists are single-celled ancestors of more complex life forms

-Bacteria have a wide variety of biochemical mechanisms for energy transformations

-Many types of organisms cooperate in nature

Symbiosis: close physical relationship between two types organisms

Mutualism: positive-positive

Commensalism: positive-unaffected

Parasitism: positive-negative

Patterns and Processes

1. Spatial Variation

2. Temporal Variation

3. Scale

-Includes things like weather patterns, vegetation patterns, climate pattterns.

-Coulees have south-facing slopes that are brown and north-facing slopes that are green in Lethbridge due to amounts of sunlight.

-Scale is the dimension in time or space over which the variation is perceived.

-Temporal variation is perceived as our environment changes over time

-Spatial variation refers to differences place to place: climate, topography, soil type and heterogeneity on smaller scales: plant structure, animal activity, soil content

Basic Principles of Ecological Systems

* + Obey the laws of Physics
  + Dynamic states – balance of ecosystem gains and losses
  + Maintenance requires energy
  + Evolve from very simple principles (such as an individual’s energy) to complex ecosystems

Adaptations: such attributes of structure and function that suit an organism to the conditions of its environment

Human Activities

• Ecological Consequences – Lake Victoria

– Nile Perch

Ecological Research

Scientific Method

- correlation and causation

- experimental manipulations (manipulate system to understand how it

works: is difficult to manipulate in times of climate change

sometimes we make miniatures or microcosms that are easier to

control)

- Science toolkit (lab)

Ecological Research

Ecologists study the natural world by observation and experimentation

Hypotheses

Natural experiment

Microcosm experiment

Mathematical models

Chapter 2

Adaptations to the Physical Environment: Water and Nutrients

Outline:

Properties of Water and Adaptations

Obtaining Water

Osmoregulation

Physical Environment

Niche: Range of conditions that can be tolerated by an organism; organismal roles

Examples of physical factors affecting you right now?

We are always surrounded by biotic and abiotic factors:

(light radiation, temperature, humidity, water, gravity, oxygen, air pressure, water pressure)

In what situations are these factors more extreme?

Adaptations to these factors’ stresses?

**Water**

• Heat

– Conductance

something warms or cools way more easily in water

– Thermal Capacity

takes a lot of energy to change temperature of water a few degrees

max density water is at 4°C; ice is less dense than water

water moderates temperature

• Density & Viscosity

– Gravity

– Drag: can affect the way an organism moves through the water

most organisms live in photosphere of ocean

– Buoyancy

oil droplets in algae and microrganisms

bony fish has mucus, ventilates gills

baracuda are sprinters, different body shape from cruising shark

sharks have large oily livers; slight angle of fins overcomes negative buoyancy; sink in ocean when die; streamlined body; constantly swimming to let water pass through gills

• Nutrients

– Soluble

water is the source of nutrients for all food chains

ions are highly soluble in polar water

water is the “universal solvent” b/c it dissolves so many nutrients

– Advantages?

movement of water brings nutrients to organisms

– Disadvantages?

movement of water can wash nutrients away

• Mineral Content

– Surface Waters: 0.01 - 0.02% by weight

– Oceans: 3.4%

due to hydrological cycle, ocean water evaporates as pure water to the land, in the process of water returning to ocean, minerals are dissolved; hence, more minerals end up in the oceans

Solubility limits

– Ca2+ & CO2

very soluble

– CaCO3

not very soluble, sinks to the bottom of the ocean, forms limestone

limestone doesn’t rise to surface until earthquakes, tectonic shifts

• pH

– pH of water influences environment in and around the water

eg) some organisms are adapted to certain conditions, but may be intolerant to change in pH; some tolerate a range of pH

– H+ and OH- ions

more H+ ions make a liquid acidic

more OH- ions make a liquid basic

– H2CO3

– Heavy metals

– Tailing: mines accellerate the changes in water table

there are metal sulfides in rocks, which react with water to make acid

Water – Physics and biology at a microlevel is also very important

Eg) gecco can crawl up smooth glass b/c each ridge of their toes have thousands of microfibres; tremendous surface area add up london dispersion forces to cling to a surface and hold weight

• Soils

– How do plants get water?

How do organisms deal with conditions around them to survive?

Cohesion/adhesion

Terrestrial plants have their roots in soil; they work on the mircolevel in order to uptake nutrients through the uptake of water

Root hairs have large surface area

– Dissolved nutrients

– NPK

– Matric potential (Water potential)

– Matric potential – Wilting coefficient: -1.5MPa

wilting coefficient is when plant cannot take up water at a pressure

see txt fig 2.9 for water interacting with coarse sand vs. silt

strongest forces occur when water is close up to the solid

(in silt, tight attractive forces bind water to the silt particles)

Soil can be too coarse or too fine for optimal plant-water uptake

• Osmosis

– Solutes

differences in solute concentration cause the movement of water

osmotic pressure builds in non-equilibrial situations

more molecules = higher osmotic pressure

– Osmotic potential

– Root pressure

• Cohesion-tension theory

– Transpiration causes water transportation

Leaves allow evaporation, which sets up a vapour pressure gradient

Water molecules move to where water was lost in the leaves

Lower pressure in the stem xylem draws water up from the roots

• Salt and water balance connected.

– Osmoregulation

eg) alkaline ponds: vegetation is generally sparse close to alkaline ponds

to move water from this pond into a plant requires much solute

eg) mangroves: roots have many larger molecules in roots, results in a higher osmotic pressure; leaves excrete salts to pump salt too many ions out

• Animals

Animals get their nutrients and water from the environment as well, obtains solutes in food and excretes them in urine

– Kidneys

-desert animals can concentrate their urine in order to conserve water

-marine fish diffuse salt through gills

-fresh water fish secrete copious amounts of dilute urine; osmotic gain through gills

-osmotic potential of seawater causes adaptations

-sharks carry large concentrations of urea in blood to equalize the osmotic pressure of the salt water around them

– salt glands

-ocean birds eat fish who are high in solutes; birds secrete excess salt into glands by nasal cavity

– Nitrogen

most commonly formed as ammonia, which is toxic to certain organisms

mammals carry urea which we can maintain for a relative time

in reptiles, uric acid needs to be presipitated out

Ch 3 – Adaptations to the Physical Environment: Light, Energy, Heat

Physical Environment

• Radiation - electromagnetic spectrum

High energy Low Energy

High frequency Low Frequency

Short wavelength Long Wavelength

Ionizing radiation (dangerous) Non-ionizing radiation

Cosmic, gamma, xrays, far UV, near UV, visible, near IR, far IR, microwave, TV, radio

• Light

Light that hits earth’s surface is only a portion of what is filtered through the atmosphere

• Incident Radiation

– Absorbed by Earth ~ 70%

– Reflected back into space~ 30%

• Albedo

– Snow or clouds: high albedo, much is reflected back

– Vegetation: low albedo, much of light is absorbed

“Only a small proportion of the solar radiation that reaches the earth is converted into biological production through photosynthesis.”(Ricklefs pg. 40)

Photosynthetic Pigments

• “The visible portion of the solar spectrum harnessed by photosynthetic organisms is also that portion of the solar spectrum with the greatest irradiance at the earth’s surface.” (Ricklefs pg. 40)

physical aspects of the world have shaped what light gets through; plants have become adapted to this solar spectrum

• Selective

– Absorb / Reflect

pigments like chlorophyll and the carotenoids absorb and reflect dif regions

Chlorophyll reflects green, but absorbs orange-red spectrum

Secondary pigments like carotenoids absorb blue-green and reflect the red

In Autumn, chlorophyll breaks down first with carotenoids left behind

The pigments are complementary to each other

• Aquatic

– Green penetrates water

– water absorbs quite heavily in red, reflects blue most

* Ulva algae absorb blue and red, reflect green, live shallow waters
* Porphyra

Photosynthesis

• Carbon Fixation

– 6CO2 + 6H2O +Energy > C6H12O6 + 6O2

• Photosynthetic pigments

– Electrons released to produce ATP and NADPH

the energy is used in later chemical reactions

Photosynthesis-C3

• Problems

– Rubisco inefficient enzyme

– Initiates reverse reaction

– Water stress

Photosynthesis-C4

• Alternative – Sequester C

Photosynthesis -CAM

• Alternative – Sequester C

store carbon dioxide at night so during day, can close stoma

Photosynthesis

• Reduce heat

– Shade

plants can have microfibre hairs covering leaf to provide shade at micro level

– Boundary Layers

small layer between skin and surrounding air

• Reduce evapouration

– Cost? Guard cells cannot let in carbon dioxide quickly

• Relative Efficiencies

Ratio, gram water lost : g tissue produced

– C3 ~ 300-900:1

– C4 ~ 250-350:1 lose much less water compared to regular plants

– CAM ~ 50:1 highly efficient at retaining water

• Energy Efficiencies

– C3 superior in cool climates

– C4 better in hot climates

• Aquatic systems

already discussed the wavelength of light available in water

– Gas availability in water

carbon dioxide is highly soluble in water, so there is no shortage

in water, CO2 reacts with water to form bicarbonate and carbonic acids

water contains a maximum of 1% oxygen, O2 availability is limiting

– Gas mobility

however, the rate at which CO2 diffuses is the limiting factor

• Flooded roots

Saturated soil or swampland is high temperature, high plant matter, low O2

Oxygen is grabbed in roots above ground that capture soil and take it back to the plant/tree roots

Temperature

• Reactions

– Chemical

– Biochemical

• Upper Limits

~ 45°C Eukaryotes

~ 75°C Thermophiles (heat-loving)

~ 110°C Extremophiles

• Cold

– Ice crystals & cells

– Suppress freezing point

– Suppress ice crystals

organisms increase abundance in glycoproteins to suppress freezing

organisms could also supercool past the point where they should freeze

glycoproteins enable the organism to stop ice crystals spreading

• Range

– Survival

There is a range of temperatures that an organism can survive

Enzyme substrate affinity enables acclimatization in either cool or warm conditions

– Performance

There is an even smaller window in which an organism can thrive

For example, swimming speed of fish in different water temperatures

Thermal Environment

• Exchanges

– Radiation

everything in the universe above 0Kelvin emits radiation

– Conduction

– Convection

if air or water is moving against us, energy emitted from our body is moved by convection

– Evaporation

helps cool skin surface by dissipating thermal energy

• Budgets

Heat budget: heat generated by metabolism and lost by evaporation

metabolism - evaporation +/- convection conduction radiation

Food budget

metabolizable molecules + water + ions

Excretion

nitrogenous wastes + excess water + excess ions

Scale

• Area/Volume – thermal inertia

a small object will cool more quickly than large one according to SA:Volume

Homeostasis

• Negative Feedback

control and regulation of metabolic processes

• Thermoregulation

– Homeothermy vs. Poikilothermy

– Endothermy vs. Ectothermy

– Torpor

• Countercurrent

Chapter 4 Variation in the Environment: Climate, Water and Soil

Outline

• Chapter 4 – Solar Energy – Cyclic Events – Topography – Soils

• Chapter 5 – Terrestrial Biomes – Climatic Determinants – Aquatic Biomes

Elton (1927; Animal Ecology)

• In solving ecological problems we are concerned with what animals do in their capacity as whole, living animals....We have next to study the circumstances in which they do these things, and , most important of all, the limiting factors which prevent them from doing certain other things. By solving these questions it is possible to discover the reasons for the distribution and numbers of animals in nature.

• Distribution and abundance of organisms

Climate

• Climate vs. Weather

Climate is the longterm environment

Weather is the day-to-day

Solar Radiation

• Photosynthesis

• Heat

• Redistribution

Heat is distributed on a global level, which influences air and water currents

• Seasonality

affected by latitude and polar tilt

Northern hemisphere has less ocean waters than southern = less moderated climates

influences plant and animal life

• Intensity

The same ray of sunlight strikes the Earth’s surface at different angles across the globe according to time of day and axial tilt

When the sun’s rays are striking at 90degrees to the Earth it goes directly through the atmosphere

Differential Heating of the Earth (hotter at equator than near poles)

• Circulation

After striking Earth’s surface, solar energy is re-emitted from the surface and creates convection currents

Dry air from desert carries moisture to forests which let the air rise at high altitudes

Ferrell cells, Hadley cells, and Polar cells exemplify this

• Coriolis effect

While air circulates up-down longitudes north-south; south-north; the Earth is rotating in an east-west direction

• Jet stream

Solar Radiation

• Ocean Currents

Result of the atmosphere and the coriolis effect

– Surface

– Deep

Cool water sinks and then rises in turn, causing the ocean currents to occur in 3D

Highly biological productivity occurs where winds move surface waters away from continental margin and where cooler water currents move past continental coast

• Intertropical convergence

– Precipitation

The sun according to time of year causes radiation to affect the dry and wet seasons

These large simple patterns lead to much more complex climatic conditions

Cyclic Events

• Temperature cycles

– Lakes

Thermocline: rapid change in temperature

Fall: wind turns over nutrients from sediments at lake bottom up, and takes oxygen down to the lower levels of the lake

In winter, less dense water below 4°C floats to the surface where ice forms

The bottom of the lake remains unfrozen year-round; some remain around 4 or 5°C

Spring: nutrient and water turnover due to winds

The early part of summer is highly productive for lakes

• ENSO

El Nino conditions

Southern Pacific oscillations

Warm surface waters cause convection currents above the oceans, it then travels eastward and descends over South America

Every once in a while, this current is reversed due to changes in high/low air pressure; the warm aire travels east and west

• Glaciation

Temperal variation has caused different glacial and interglacial periods

Every 100 thousand years a new period of glaciation occurs

Found this out by O16 an O18 in calcium carbonate in organism foraminifera which corresponds to coldness in its shell: found in the sediments of a 65 meter sample of the North Atlantic ocean bottom

Topography

• Rain Shadow

Foothills and one side of mountain range have large amounts of rainfall

Other side of mountain range is hotter and drier

• Adiabatic cooling – 6-10°C/ 1000m

Difference in way Earth heats and cools

Latitude, elevation, and biome distribution

Soils

Extremely important to terrestrial ecosystem productivity, and are influenced by:

• Climate

• Parent material (underlying bedrock)

• Vegetation (roots in soil, organic material on top of soil)

• Topography (altitude, sun shining)

• Age (developed fertile soil is very old; prairies old soil)

Chapter 5: The Biome Concept in Ecology

Biome

• “One of several categories into which communities and ecosystems can be grouped based on climate and dominant plant forms.” (Ricklefs, glossary)

Biomes are global plant communities, where plants have similar adaptations; however, can be entirely different. For example a cactus from Mexico and a tree from Africa both have spiney stems, but have entirely different evolutionary histories.

What causes biomes?

• Climate determines growth form of plants

(eg) dry areas do not compete for sunlight, but rather for water

whereas tropical rain forests compete for sunlight, not the abundance of water

• History

• Biotic interactions

• Climate can be limiting:

Temperatures range species can live in

Access to water or precipitation

Abundance of sunlight

Biome: Wittaker’s Climate diagram

Annual precipitation vs. Average Temperature

Warm-Wet = Tropical rain forest

Warm-Dry = Subtropical desert

Cold-Dry = Tundra

Cool-moist = Temperate rain forest

Middle temp/mid precip = temperate grasslands, temperate seasonal forests,

Walter’s Climate Diagram

Seasonality in a specific biome/climatic conditions in each month

Mean monthy temperature vs. monthly precipitation

In conditions where water is not limiting, we notice temperature is higher

(eg) tropical forests are warm with lots of precipitation

Seasonal forests vary in temperature and/or precipitation throughout the year

Aquatic Biomes

• Lotic

Flowing rivers and streams

import and export energy and nutrients between water and terrestrial systems

– Allochthonous

– Autochthonous

• Lentic

Standing water

Littoral zone

Limnetic zone

Benthic zone

• Wetlands

highly productive

• Estuaries

form near river deltas, sediments settle out, ample nutrient supply

• Eutrophication

high-feeding system

massive productivity can cause anaerobic conditions

• Marine

Large degree in size

Littoral zone = tidal zone

Photic zone in surface layer

Neritic zone exists just above the continental shelf of shallow water

Oceanic zone where continental shelf drops

Chapter 6: Evolution and Adaptation (to life in varying environments)

Environmental Variation

Scale: the dimension in time or space over which the variation is perceived

Temporal Variation: variation as our environment changes over time (“temporary”)

Spatial Variation: variation as environment differs from place to place (“space”)

Scale

Type: Small Medium Large

• Spatial -Riverbank to -ecosystems -Foothills to plains

river

-Farmer’s field to -regions -Interior mountains

dugout pond to continental coastline

• Temporal -Morning to Afternoon -Season to season -years

-Day to Day -Weeks to months -decades

Humans have modern responses to environmental variation

Animals have many biological adaptations to seasons and environmental variation, whereas humans have technological responses to variation, from agriculture to urbanization

Adaptations

• Examples - Hummingbirds

• “The **organism** is the most fundamental unit of ecology” (Ricklefs pg. 3).

• Organisms are adapted to:

– environments

– variation in environments

Natural Selection

• Conditions:

1. Variation among individuals

2. Inheritance of that variation

3. Selection pressure (differential survival/reproduction)

• Definitions for Variation of:

– Genes

– Alleles

– Genotype

– Phenotype

– Etc: all in textbook

In natural selection, the frequency of a phenotype in the population increases or decreases over time as population undergoes natural selection and evolves.

• Heritability

The total number of individuals that can be accounted for not from environmental conditions but from genetics.

Eg) population geneticists looking at bill size in offspring and parents

Heritability is measured by “ h2 ” – which is higher with more herirability

• Variation

Variation within a population

Frequency distributions

Eg) frequency of phenotype in population vs. range of phenotypic trait values

• Selection

Directional Selection

eg) generation 1: frequency of phenotype in population vs. resistance to cyanide

Those individuals who resist cyanide are favoured

generation 2: the mean has shifted towards those individuals who resist cyanide

Stabilizing selection

Suggests that favoured trait is closer to the mean

Later generations have a closer mean

Disruptive selection

Favoured traits are at the extremes of the population

Later generations diverge into one of the two extremes

Natural Selection Examples

• Darwin’s Finches

different beak sizes developed according to the seed of choice for food

studies conducted during dry seasons:

as seed abundance decreases, populations fall

as seeds become harder, the average beak size increases over time

• Crickets

disruptive selection

crickets who call a lot have high success rate of attracting females

parasitic flies hear the cricket call and drop larvae onto cricket to develop

crickets who do not call neither get infected; nor attract flies

two strong selective pressures

• African estrildid finch – *Pyrenestres ostrinus*

like Darwin’s finches, beak size specialized to eat a smaller range of seeds more successfully

• Peppered moth – *Biston betularia*

lichen-covered trees are white and favour light moths

as coal development caused lichen to die, the dark trees favour black moths

coal factories installed filters, SO2 concentrations decrease, lichen grows again

light coloured moths became equally favoured

Phenotypic Plasticity

• “The genetically based capacity of an individual to respond to environmental variation by changing is form, function, or behaviour.” (Ricklefs glossary)

• Thermal Stress

• Cactus Wren

– behaviour

live in deserts of SW United States, hot environment challenges ability to survive

evaporative cooling: panting releases moisture from lungs, however need to upkeep water

behaviour changes throughout the day:

morning: singing at shrub tops

midmorning: foraging

midday: hiding in middle of shrub

called cactus wren because they nest inside holes in cacti

nests face different directions according to time of year to utilize wind direction and sun elevation to improve success of offspring

– Adaptive?

Reproductive success of wrens in cacti:

45% wrong direction vs. 82% success of nest facing best direction

Phenotypic Plasticity

• Adaptations – On a population level, variation in a feature is due to:

VPhenotype = (VGenotype + VEnvironment) + (VGenotype x VEnvironment)

• Reaction Norm

– within the population, individuals in environment A perform or express themselves differently from environment B

– adaptations to local environment’s prevalent conditions occur

• Acclimatization

– Reversible response

– Shift in physiological tolerances - enzymes

fish in cool and warm waters at certain times of year survive by acclimatizing

– Shift in morphology - skin pigments

• Developmental

– non reversible

can be unique according to individual (eg) permanent burning of surface pigments

can be reversed in population, if not in individuals

can be aquired

• Genotype-Environment Interaction

Additional Examples of Responses

• Storage

• Migration

• Torpor

**Chapter 7: Life Histories and Evolutionary Fitness**

Outline

• Life History Stories

• Trade-offs

• Reaction Norms

• Behaviour

• Environmental Variation

Adaptations to Variable Environment

Morphological and Behavioural

Diversity of Lifestyles

• Life History

Clutch size – litter; number of offspring

Life History Theory

• David Lack – contributor to ecology

look at patterns and proposed hypotheses to describe them

• Clutch size and latitude

migratory birds

• Limits to clutch size

• Reproductive Success

Related to clutch Size – number of offspring

More offspring birds lay; more chance for success

• Provisioning Offspring

Parents can only made so many trips of food

The larger the clutch size, the smaller the provisions of food per nestling

• Cost/Benefit Compromise

Find optimal clutch size for reproductive success

• Natural Selection

• Testable

• Trade-offs

• Time, energy, materials

Allocation and prioritization

Eg) how much biomass goes to leaves, stems, or roots, or protection of seeds

Eg) deer antlers: larger is better attraction for females and conflicts; need to spend enough energy on body muscles and skeleton to back up the antlers

Optimizing

-Conflicting Demands requiring Optimal Solutions

Fecundity(number of offspring per cycle and physical size)

Parity (how many times individual can reproduce: once, twice… many)

Longevity (how much time and energy allocated to life processes > lifespan)

• Survival vs. Fecundity

Number of offspring hatched to number of survival to fledglings

What parents get out of the reproduction investment

Adult survival decreases as fecundity increases

Fecundity curve levels off because of diminishing returns on investment

• Fecundity vs. Fecundity

• Survival vs. Survival

Age at First Reproduction

• Life History

Life span influences the best strategy for sexual maturation

When adult life span is long and few offspring survove, the best strategy is to choose adult survival over fecundity

When adult life span is short and many offspring survive, the best strategy is to choose adult fecundity

Conflict - Survival vs. Fecundity

Graphing optimal solutions

SR = F/SN – S0B/SN

Survival of reproduction risk = (F/S) – (slope x Fecundity)

Slope of the tangent shows the optimal tradeoffs

Conflict - Growth vs. Fecundity

• Life History

Depending on life span, it may be more beneficial to invest in individual growth vs. reproductive efforts

Life History Patterns

• Related to:

– Physical environment; temperature, altitude, etc.

– Biotic environment, food, predators, competitors, etc.

– Other life history factors.

Fast-Slow Continuum

Fast Slow

• (r-selected) (k-selected)

• Short life Long life

• Fast development Slow development

• Many offspring Few offspring/ cycle

• Low parental investment High parental investment

• Colonizers Competitors

• Type III survivorship Type I survivorship

Can be applied to animals and to plants

Relative comparision: a mouse is r-selected compared to an elephant

Life History Patterns in Plants

Toleration of conditions

Competition for resources

Parity

• Semelparous vs. Iteroparous

Acquatic larvae that metamorph into insects:

Mae flies (mate immediately; around one day of life); Dragon flies survive longer

Altricial strategy – young dependent entirely on parents for both food and protection

Precocial strategy – young have some degree of independence

Fecundity vs. Fecundity Investments

• Seed size vs. number

Longevity

• Senescence

longevity can be traded off for other aspects of life history

• Survivorship curves

three different strategies

Type I – individuals are born, and all survive until maturity; after maturity many die; slow development; good competitors

Large, slow, k-selected creatures

(eg) Elephants

Type II – gradual decline

(eg) birds

Type III – high infant mortality rate, consistent survival rate after maturity

Small, fast developing, r-selected organisms (eg) starfish

Life History - Reaction Norm

• Maturation – metamorphosis

Combination of age and size vs. sexual maturation

Trade off of individual size and reproduction

Intermediate size-age reaction norm for maturation

Phenotypic Plasticity

• Reaction Norm

Conflict - Survival

• Chickadees – Starvation vs. Depredation

fat reserves to keep warm

too large of fat reserves makes target for predators

• Chub Minnows – Starvation vs. Depredation

Foraging and Fitness

• Why is this topic included?

Foraging behaviour is a reaction norm; related to fitness in food pursuit

• Search, pursue, handle, consume food

• Proxyforfitness-Energy/Time

• OptimalForagingTheory

Response to Variation

• ExtremeConditions – Seasonality

– Energetic Stress - Avoid vs. Tolerate – Migration, Dormancy, Storage

Migration

• Long-range

Dormancy

• Plants,seeds,insects,vertebrates

• Aestivation, hibernation, insect diapause

Storage

• Internalvs.external

External

• Foodhoarding

Storage

• Greenfinches,Ekman&Hake1990

Experiment

• Temperature

• Food Predictability

Unpredictable foraging

Storage

• Hurly1992;fatvs.hoards

• Variation in food supply

Experiment

Access to food:

– Low Variance vs. High Variance

Ch 8: Sex and Evolution

Outline

• Introduction to sex

• Evolutionofsex

• Sexual Variations

• Sex ratios

• Mating Systems

History of Sex

• “Indeed, sex underlies much of what we see in nature”. (Ricklefs pg. 161)

• Ancestral condition - asexual reproduction

• Sex evolved early and remained

• Many organisms both sexual and asexual

• Secondary evolution of solely asexual reproduction is rare

Anisogamy

• Non-equal gametes

• Allocation of limited resources

Sexual Reproduction

• Peculiar way to treat a genome

• Costly

Costs of Sex

• Gonadal tissues

• Mate attraction - bright colours attract both females and predators

• Competition - deer antlers take energy to form and uphold

• Mating - requires a lot of energy

• Cost of meiosis

– only half of the individuals’ gametes will be expressed in offspring

Offsetting costs

– Hermaphrodism, where an individual has both kinds of gametes

– Paternal Investment - nuptial gift - males could contribute to raising young

Evolution of Sex

• Origin?

• Sex is maintained

– because generates variation in offspring

• Environmental variability:

– Adaptations - Ch. 6

– Reaction norms - Ch. 6 & 7

– Life Histories - Ch. 8

• Recombination

Different allelic combinations are generated in each generation

• Highly variable environment?

We should see sex being most effective in certain variable environments

Biological variability (eg.natural selection on two competing species) has a significant impact on reproduction

• Co-evolution

* Arms race

(eg) snails vs. parasite

• Red Queen hypothesis

If a species doesn’t continue to adapt then they will be left behind

“Around here things are moving so fast, you have to run to stay in place”

– Alice in Wonderland analogy

Evolution of Sex

• Testing the Red Queen (Fig 8.5)

Snails can live in shallow, medium, and deep water

A parasite is adapted to shut down reproductive cycle for own energy

In shallow water, infection rate is high (feces from ducks)

Mostly sexual reproduction in shallow water snails

In deep water, infections are low and snails tend to reproduce asexually

Variations

- Male & Female Function: males, females, and hermaphrodites

• Plants

• Dioecious

- two houses (meaning sexes are separated between two individuals)

• Monoecious

- one individual has both male and female parts

• Monoecious plants

* (eg) in a flower: female and male organs both active at same time

or one part active at one time

* inbreeding can be a “bad” thing – domestic “purebred” animals
* inbreeding in the wild is often completely discouraged, or encouraged
* sometimes a compromise between selfing and outcrossing

• Selfing vs. Outcrossing

* selfing can be discouraged by timing or by arrangement in plant

One or Both Sexes - Hermaphrodism

• Simultaneous

– Earthworms - each individual is putting sperm into the other

– Monoecious plants - both M and F reproductive organs active

• Sequential

– monoecious plants acting as either male or female

– some fish species change sex, F->M, M->F

• Investment -> Fitness: Fig. 8.10 & 8.11

Every point on left curved line shows that the sum between M/F is larger than total

Right concave lines show that it is more beneficial to remain purely either M or F

**Sex Ratio**

Fitness consequences between males and females

• Rare sex has advantage

Difference in number of gender

Either the F/M ratio will oscillate; or stabilize to a genetically determined 50/50

• Biased Sex Ratios

– Local Mate Competition

– Haplodiploidy

In ants males are haploid/female diploid; even if female eggs are not fertilized, they will still develop into male offspring

• Likelihood of survival and success with bias

In birds and mammals we do not see wildly scewed sex ratios:

– Maternal condition

Red Deer can bias their sex ratio

Females in poor condition produce more females

Healthy females produce more males b/c can allocate more energy to their development, which increases son’s future chance of sexual success

– Quality of Offspring

Male Red Deer compete vigorously and only winner mates

Male victor mates with many many females; loser none

**Mating Systems**

Anisogamy

Males exploit female reproductive investment

• Non-equal gametes

• Allocation of limited resources

Mating Systems

• Reproductive Success

– measured as: Genetic contribution to future generations

takes a long time to measure with long-lived animals

– Proxy measure - number of offspring

Male and Female fitness and selection is different

• Male

– Number of mates/fertilizations

– Avoiding cuckoldry - do not invest any energy in offspring that is not theirs

• Female

– Choice - male genetic quality

– Choice - male resource quality

**Mating Systems**

Monogamy and Polygamy (including promiscuity, polygyny, and polyandry)

Monogamy

– Males can contribute to offspring care

However, monogamy is rare in mammals b/c much investment from female

Monogamy is very common in birds

– No alternative - nil Repro Success

Polygamy

(1) Promiscuity

Chance determines which gametes meet

Reproductive Success based on gamete number

– Wind pollination

– Pelagic spawners

(2) Polygyny

Male Reproductive Success

– Matings vs. paternal investment

Males compete

– Mate access

– Territories

Polygyny Threshold Model

-Territory quality of mated male on a higher quality territory exceeds that of an unmated male on a lower quality territory, and thus exceeds the polygyny threshold for female choice

-When territories are more nearly uniform in quality, none exceeds the polygyny threshold and females chose unmated males

(3) Polyandry

One female mating with multiple males and the males are the ones who raise young

– Rare

– Females compete for males; females are the aggressive courter

(eg) spotted sandpiper

**Sexual Selection**

• Selection acting differently on M and F

brightly coloured males have high reproductive success, but are predatory targets

spiders are different in M and F size

sometimes sexual selection and natural selection clash

• Sexual dimorphism

– Sexual function

– Male combat

– Female choice

Female Choice

• Male ornaments - no initial fitness value

• Sexy sons

• Self-perpetuating

Females have a very influential role in reproduction due to their choice

Runaway Sexual Selection

Leks

• Display arena

Proportion of copulations

Handicap Principle

• Females choose trait detrimental to males

• Proof of good genes

Handicap

• Natural Selection vs. Sexual Selection

Rock Ptarmigan

Male Dirt Score vs. Day of the Year

Parasite-mediated Sexual Selection

• Hamilton-Zuk

Chapter 9 Family, Society, and Evolution

Outline

• Social Interactions

• Living In Groups

• Evolution of Sociality

• Cooperative Breeding

• Conflicts

Sociality

• Variation

– Group size: solitary - thousands

– Behaviour: cooperation - deadly enemies

– Timing: occasional - seasonal - constant

– Occasions: reproduction - daily life

• What is responsible for this broad range of social behaviour?

-evolutionary history

-ecological circumstances

Social Behaviour

Direct interaction of any kind among individuals of the same species (Ricklefs glossary).

Organization of Social Interactions

• Competition for resources

• Food, shelter, mates

– Territoriality

– Dominance Hierarchies

Territoriality

Any area defended by one or more individuals against intrusion by others of the same or different species (Ricklefs glossary).

• Intra-specific or inter-specific

intra-specific is much more common

• Size

• Timing

lasting from season to season; year to year; or even lifetime

• Adjustable

• Economic Defensibility

expending energy in order to defend territory;

only want to defend a territory where costs and below benefits.

Optimal is largest difference between benefit-cost.

Brown 1964 costs vs. benefits of defending territory area graph

Myers et al. 1979 density of prey vs. per cent of area defended by Sanderlings

At low density of prey, no point in defending territory; at very high no point defending when there is enough to go around; there is a range where it is beneficial to defend territory

Dominance Hierarchies

The orderly ranking of individuals in a group based on the outcome of aggressive encounters (Ricklefs).

• Pecking order – linear hierarchy

Gray Area

• Lek - territory with no resources

a lek is a place where males defend a patch of ground; best males defend the center area of a lek to establish hierarchy; females attracted to lek

Status - Territories and Hierarchies

• Display, chase, testing, combat

Game Theory

• Outcomes of interacting behavioural decisions

• Symmetrical – even match;

eg) rutting bull moose begin with antler display, then running at one another to feel the other out, finally combat locking antlers and fighting

• Asymmetrical – one opponent is clearly stronger than another; easily solved

Group Living: Benefits and Costs

Animals group together for protection from predators; small birds do not have to keep a constant eye with a larger flock so more time can be committed to foraging; however, there are also more individuals eating, so flight to another patch occurs.

Benefits

• Vigilance

• Kenward 1978

• Selfish herd - dilution of danger

Variation in Spacing

Spacing

(eg) Guppies group together

• Group defense – mobbing – fly off together

• Communal care of offspring

• Learning from experienced individuals

• Cooperative foraging

Costs

• Dilution of resources

• Attract predators

• Parasites and pathogens

• Inequalities or Cheating

Sociality and Ecology

• Jarman1974(dikdik vs. wildebeest)

Small size Large size

Clumped food Dispersed food

Defend territory Nomadic

Group 1-2 Group 100s

Evolution of Social Behaviour

Figure 9.5 Fitness increment of donor vs. recipient of behaviour

Positive and negative interactions

Donor/recipient

+/+ Cooperation

-/+ Altruism – puzzles biologists – why would donor cost itself?

-/- Spitefulness – occurs in humans; seldom in animals

+/- Selfishness

Kin Selection

Altruism could develop from families looking out for members

Coefficient of relatedness (r), shows family ties

Inclusive Fitness

• W. D. Hamilton (1936-2000)

• IBD-Identical By Descent

• Donor action on recipient with allele IBD

Altruistic individuals help others who share the altruistic allele; most likely that these individuals are closely/distantly related

Likelihood of this occurrence can be 50% between siblings

Altruism can be selected for, therefore “evolve” or change frequency

example:

- Belding’s Ground Squirrels like gophers

alarm calls: one individual gives a call when predator is in area to alert others; the caller unintentionally attracts attention to itself

• Predator attack mortality by Paul Sherman

– Caller - 13%

– Non-caller - 5%

- Frequency of alarm calling

• Males - 18% because do not have much investment in colony

• Females with no kin - 18%

• Females with kin - 29% because are caring for sisters with pups

- Is alarm calling adaptive?

- Limit to selfish behaviour

- example: Meerkats

have an incident of guarding which increases with group size

foraging individuals get to decrease their vigilence time

the guard who calls in this case is the safest from predator; because it stands next to the hole; only real cost to guard is lack of forage time

Fig 12.10-11

Cooperative Breeding

• Inclusive fitness in a breeding situation

• Young stay and help their parents raise more offspring

• r = 0.5 is siblings

when r = 0.25 the individuals are half siblings

when r = 0.125 the individuals are cousins

benefit of siblings staying around may include gaining reproductive experience

more offspring are successfully produced when helpers are around

example

• White-fronted Bee Eaters;

• Stephen Emlen

• Silver-backed jackals

• Patricia Moehlman 1986

Eusociality

• Extreme example of inclusive fitness

• Hymenoptera-bees,wasps,ants

• Sterile worker cast-help mother raise young

• Mother-daughter r = 0.5

• Sister-sister r = 0.75

Conflict

Conflicts between related individuals

• Parent-offspring conflict

Investment in current offspring

• Parent-offspring conflict

– Between reproductive bouts

– Between siblings

Lifetime Fitness

Conflicts between unrelated individuals

• Game Theory-ESS-Evolutionarily Stable Strategy

• Frequency Dependent

• Hawk and Dove (aggression vs. peace analogy)

• Cost-Low

Ch. 10 The Distribution and Spatial Structure of Populations

• Introduction to Population Ecology

• Population Distribution/ Dispersion

• Population Structure and Habitat Heterogeneity

• Spatial Models

• Macroecology

Populations

While the organismis the most fundamental unit of ecology, we are now looking at populations which are the fundamental unit of **evolution.**

**Population:**

“The individuals of a particular species that inhabit a particular area”. (Ricklefs)

Why study populations?

-Agro-ecosystems; dynamics of population growth to manage crop growth and livestock

-Pest management for human health and for agriculture

(including mosquitos, grasshoppers, gophers)

-Conservation Biology to help preserve species

-Ecological Services

using the environment for human benefit; (eg) bees are useful pollinators

-understanding population dynamics has practical applications

Population Distribution and Abundance

• We will look at distribution and abundance of plants and animals (organisms)

Population Distribution

• Geographic Range

– Suitable habitat

– Tolerance to physical conditions

– Barriers

Biological activity varies with environmental conditions

There is an optimal range in which the population is maintained across generations

Some variation in the environment causes the population to fail at reproduction although the organisms themselves are tolerant enough to thrive

– Migration

(eg) include both inland and open ocean in range of sockeye salmon

seasonal migrations of herd animals due to grazing

• Heterogeneity

– Patchy

patches of habitat where a population does well

• Ecological Niche

– Fundamental (range of conditions where organism CAN be found)

– Realized (where organism IS found due to predation, competition, or pathogens)

• Ecological niche modeling

Geographic and Ecological space

Map combinations of precipitation and temperature in certain locations; let this space potentially be habitat of organisms, then look to see where organisms actually are; this can be applied to pests accidentally introduced to new regions (eg. weeds)

In Alberta- we introduce species such as game birds and get different results

We look at the optimum of these birds in Europe; then map it in new location and find that the new optimum is much smaller because of harsher range of conditions

Population Structure

Density and dispersion

Age structure

Mating system

Genetic structure

• Habitat Density

– Food availability

within the ranges that a population thrives, and the larger ranges that it can tolerate

– Ideal Freedom Distribution

as you increase quality of resources, you increase the density that can be supported

poor habitat patches are less dense vs. good patches support more individuals

the realized quality of a good patch decreases as its population increases

there is a point where partially filled poor patch is equal to more full good patch

– A population sustains itself by having a neutral or positive growth rate

There is a limit to populations distribution with dispersal

Individuals disperse from area of population increase to area of population decrease

A population can be sustained when negative reproduction rate occurs if other species migrate to that area; compensate intrinsic growth with pop. movement

• Dispersion

– Spacing of individuals

Can be clumped together, randomly spaced around, or spaced away from each other

– Spatial scale

• Random

– Seed dispersal

Can have random plants due to seeds being carried on wind

Animals can carry seeds randomly; relatively even spacing of plants in forests

– Food dispersion

Animals follow where plants are

• Clumped

– Limited dispersal of seeds

Parent plant can only distribute seeds a small distance, causing more to grow near

Ballistic dispersal such as cones exploding in one spot

– Vegetative reproduction

– Animals using specific, rare habitat

(eg) large concentrations of waterfowl in wetlands

• Spaced

– Plants - competition

Even spacing of gyration dispersed seeds

Plants can only survive so close to each other because of limited water access

– Territoriality

Animals defend an equal amount of territory

Spatial scale is important:

If you are looking at a clump closely, you may say they are spaced evenly

However, if you look on a larger scale you see that those even spaces end, and realize that there is a matrix between patches where none of the species live

Spatial Models

• Habitat

– Patches - gene flow inside patches and from one patch to another

– Matrix - empty space between clumps or individuals

– Distance

– Mobility

– Intervening habitat

• Subpopulations

separation can cause limited gene flow between populations

eg) three subpopulations of bull trout in three different rivers

– Framework to understand population features

– Test scenarios

– Abundance and Distribution

• Dispersal

– Lifetime dispersal distance

– Neighbourhood size

– Habitat corridors

Modelled artificially by cutting out patches in forest; connect some by corridors

Spatial Population Models:

where habitat matrix represents unsuitable habitat, and subpopulations occupy patches of suitable habitat

(a) Metapopulation model

Occupied vs. unoccupied patches

(b) Source-sink Model

Source (high quality) patch vs the sink (low quality patch)

Individuals disperse from dense to less dense patches

(c) Landscape Model

The most complex of these models

Also factors into the equation that habitat matrix is heterogeneous

(rivers, landscape, and other habitats dictate true movement paths between the habitable patches)

Macroecology

• Large-scale patterns

– Generalists vs. Specialists

– Density and Body Mass

population density of mice is more that pop dense of elephants

– Energy Equivalence Rule

populations tend to consume the same amount of food per unit of area regardless of the size of individuals. (ie. elephant population and a mouse population would have about the same food requirement per hectare)

Ch. 11 Population Growth and Regulation

• Estimating Population Size

• Demography

• Geometric Population Growth

• Age Structure

• Life Tables

• Exponential Population Growth

Why Study Population Growth? -- Resource management

Estimating Population Size

• Count all individuals

• Sample population

– Relative measures

Eagles observed/hr

Fecal pellets/km trail

– Absolute measures

Density - number/area; or number/volume

• Mark recapture

x = M marked

n N total

sample population N = nM

x

the marked:total ratio should be the same as sample:population

the estimate is going to be close to the mean population

Demography

• The study of the structure and growth rate of populations (Ricklefs glossary).

• Humans- babyboomers, generationX etc:

– Consumer behaviour

– Health care

– Insurance

• Resources:

– Expected future harvests

Geometric Population Growth

• “Populations grow by multiplication rather than addition” (Ricklefs)

• Discrete reproductive bouts

Geometric Population Growth

• Nt+1 = Nt + Births - Deaths + Immigrants - Emigrants

Simplify by ignoring I and E

• Nt+1 = Nt + Births - Deaths

• Nt+1= NtB - NtD

B and D are average per capita rates • Nt+1=Nt(B-D) 🡪 • Nt+1 = Nt λ

Geometric Population Growth – N(t) – population N at any time: Nt+1 =Nt λ

• N1 =N0 λ

• N2 = N0 λ x λ

• N3 = N0 λ x λ x λ

Nt = N0 λt

Geometric Population Growth

• Nt+1 = Nt + Births - Deaths + Immigrants - Emigrants

**Nt = N0 λt**

**Nt+1 = Nt λ**

where **λ = Nt+1/Nt**

Age Structure

• B, D & λ: average per capita rates

• Is this fair?

• Frequency distribution

Life Tables

• Cohort Life Tables show:

* age, numbers alive, survival rate, mortality rate, exponential mortality rate, death rate, expectation of further life (etc.).
* annual environmental variation not taken into account
* must be able to know the age of the animal to know this: eg) growth rings in trees, horns in goats, skulls of prey

Life History Studies

The Influence of Age and Time on Fecundity

Now we can look at environmental variation that has caused mortality rates

Exponential Population Growth

• How do we describe increase for a smooth growth curve?

• Geometric – ΔN is a function of time

* Nt+1 = Nt λ
* N(t) = N(0) λt

• Exponential- make Δt very small – ΔN instantaneous

– ΔN/Δt = bN - dN: per capita rates

– ΔN/Δt=(b-d)N; [let r = b-d]

– ΔN/ Δt = rN

– When Δt=0; represent as a derivative of N vs. t

– dN/ dt = rN

• dN/dt = rmN

• rm - Malthusian parameter

• Instantaneous rate of increase

• Per capita tendency for an individual to affect the population

N(t) = N(0)ert

Part Two: Ch 11 – Population Growth and Regulation

• Doubling time

• Regulation

• Density dependence

• Applications - yield

• Density independence

Exponential Population Growth

Expectations

• Geometric

– Nt+1 = Ntλ

– Nt = N0λt

• Exponential

– dN/dt = rN

– Nt = N0ert

Doubling Time

• t2 = [loge2]/[logeλ]

= ln2 / lnλ

• Field vole example - text

λ = 24

t2 = ln2 / ln24

t2 = 0.69/3.18

t2 = 0.22 years

doubling time is 79 days in field voles

Doubling Time – Growth of Money

• t2 = [loge2]/r

• Rule of Thumb for money

Doubling time = 70/ annual interest rate

• $1,000investedat10%interest

• 7 years - $2,000

• 14 years - $4,000

• 21 years - $8,000

• 28 years - $16,000

• 35 years - $32,000

• 42 years - $64,000

• 49 years - $128,000

• 56 years - $256,000

• 63 years - $512,000

Population Growth

• Introduce organisms to new habitats

• European Starlings

– by 1918 Starlings were introduced to New York city

– now found across North America without natural predators or pathogens

– outcompeting native species

• Gypsy Moth

– exponential population growth across Eastern Canada and United States

• Scotts Pine

* plant pollen accumulation rate

• Whooping crane rehabilitation growth

Regulation

• Introduce organisms to new habitats

• Reindeer

– populations cannot grow exponentially forever

– populations growth will level off or crash after a time of exp growth

– lack of resources cannot support

• Yeast, paramecia, and barnacle populations also grow exponentially

Logistic Growth Curve

• If you take a look at the logistic curve compared to the exponential curve you see a difference in change of population size in relation to time

• K – the carrying capacity of the environment

• N(t) = K/(1+e-r(t-i))

• dN/dt = rN(1-N/K)

Example:

K = 200 and N = 20 1 – N/K = 1 – 20/200 = 0.9

K = 200 and N = 180 1 – N/K = 1 – 180/200 = 0.1

Density Dependent Regulation

• Adjust r – which is the rate at which the population is growing

as population is more dense, reproduction decreases

where r is negative, the population is decreasing in size

We infer that density affects the rate of reproductive increase

• Density dependent factors influence birthrate and deathrates and can prevent a population from growing to its biotic potential

• with crowding, death rates (d) increase and birth rates (b) decrease

• Equilibrial Carrying Capacity (K) will occur when the population stops growing and therefore B and D are equal

How can r be adjusted with outside influences?

• More predators, more death, lower carrying capacity, lower population size

conisder this in a static situation where there is an equilibrium of B and D

• More food, raised birthrate, lower death rate, more food supports more individuals and raises the carrying capacity

Examples: population altering b and d rates in insects

• number of progeny formed per day in different density of adults in container

• offspring per day has a negative slope as population density increases

Example: birds

• young fledglings per female decreases (negative slope) as number of breeding females increases

• percentage of surviving juveniles in autumn decreases with number of adults

Example: mammals

• range quality of surroundings from poor to good / relates to population density

• percentage pregnant females decreases as range quality increases/ more density

• Death rate - functional predator response

wolf functional response of killing rate vs. moose density

Example: plants

• size vs density

at large density, the plants are smaller with plant dry weight (grams)

• Self-thinning curve

Average dry weight per plant decreases as number of surviving plants increases

• If many trees are crowded, they are thinner and smaller; fewer trees can grow much larger and thicker

Density Dependent Regulation

• Positive (inverse) Density Dependence

• Allee Effect

as you increase the spawners, you increase recruitment, and you see positively increasing reproduction effect in the herring populations until a point where density dependence factors kick in and even with high spawning density, not as many recruits are made

MSY: Maximum Sustainable Yield

• harvest and recovery of a population

• MSY is at the inflection point of the graph or maximum slope of the population increase in a logistic growth curve (where K🡪 K/2)

Density Independent factors

• B and D rates are not related to density of a population

Population size vs time is the graph of growth

Many invertebrate populations are affected by abiotic factors and are controlled thusly

• Negative feedback does not occur here as it did in density-dependent  
There is no “corrective” factor

• Environmental factors

-weather: snow accumulation, drought

• Density Independent Effects are NOT regulation

**Ch 12 Temporal and Spatial Dynamics of Populations**

Altruistic Regulation

-for the good of the species

-individuals limit reproduction to maximize lifetime fitness and survival

Metapopulations

Spatial and Temporal Dynamics:

Patches of suitable habitat

Matrix of unsuitable habitat

Population Fluctuations

Even regulated populations fluctuate

Counter to regulation?   
Regulation does not imply constant K

No intent to regulate at K

Little long term data to monitor fluctuations in population

Regulation

Introduce organisms to new habitats

Rate (b or d) in altered to regulate K

Yeast

Paramecia and Barnacles

Causes of Population Fluctuations

• Variation in environmental factors

– Direct or indirect effects

• Feedback features of density dependent regulation

• Temporal Scale of Sheep

• Fluctuations minor - 2 x

• Body size larger

• Iteroparous

very easy for the population to recover

greater capacity for homeostasis: better resist physiological effects of change

Temporal Scale Phytoplankton

• Fluctuations major - 1000 x

• Small size

• b & d high

Temporal Scale

dN/dt = rN(1-N/K)

• Life histories

– K-selected (Slow) vs. r-selected (Fast)

– Parental care

Elephants (Kselected) take care of young a long time vs. mice (r-selected)

Magnitude of Variation

• Not necessarily independent of each other

If populations are out of phase, the two species could be in competition

Temporal Patterns

Periodic Fluctuations

Some populations cycle with regularity

Small mammals exhibit this temporal pattern

Lemmings populations become intensely dense and must disperse

Lemmings go from very few to very many in a 4 year cycle

Predator-Prey fluctuations

Lynx and hare driving a cycle of population size

Recruitment Events

Large amount of reproduction and survival in offspring

Many fish surviving one year creates an age cohort that may echo in later years

Trees: drought opened up forest allowing shade-intolerant plants

Pines cannot re-establish themselves in the forest

Beech trees are shade-tolerant and survive well

Causes of Temporal Patterns

• Periodic environmental factors (Hypothesis 1)

– Few physical phenomena have regular patterns

– Examples?

• Feedback delays in regulation (Hypothesis 2)

Metapopulations

• Anthropogenic fragmentation

– spacial separation from humans or natural causes

– Forest, prairie, and other regions split up

– causes fragmentation into patches

• Population dynamics

– subpopulations

– each subpopulation occupies a patch at a certain density

• Extinction & colonization events

• Extreme migration or little migration

Levins Model

A simple equilibrium model for metapopulations

We look at portion of occupied patches

“e” extinction per patch and “c” colonization are per capita rates

Metapopulations - Levins Model

• p – fraction of suitable habitat patches occupied

• e – probability that a subpopulation will go extinct

• ep – extinction rate

• c – probability that a patch will send colonizers

• p – fraction of suitable habitat patches occupied

• 1-p – fraction of patches empty

• cp(1-p) – colonization rate

• Stable N - balance extinction & colonization

Metapopulations - Levins Model: ^

p = 1 – e / c

if e = 0; probability of extinction is zero

then p = 1 and all patches are occupied

if e = c; prob extinction = prob colonization

then p = 0 and overall patches will become extinct

or if p=1 then all 100% of patches must become colonized

if e < c

then p will have a portion of occupied sustainable patches

the more patches that have individuals, the more probability of colonizers leaving the patch; however, the more patches have individuals, the less colonization is because patches are already colonized

Species with fragmented habitat have a larger probability of extinction

-The approximate carrying capacity of these small fragments has interesting population dynamics as individuals colonize patches

-There should be factors that cause extinction or cause more likely colonization

-patch area and patch isolation

unoccupied patches are small islands, smaller size greater extinction rate

largest area patches close to other subpopulatins have highest occupied rate

Metapopulations - Levins Model

• Assumptions

– Patches equal in size and quality (e and c)

– Patches equal in providing colonizers

– e independent of local sub-populations

(population dynamics are asynchronous)

1) Patches equal in size and quality (e and c)

– Size affects extinction

– Size and quality affect N, which affects extinction

Think of a coin toss: heads the pop extinct, tails survives

One individual has a 50-50 chance of survival

The probability of flipping many heads in a row to extinct all is tiny

Statistically, as you increase pop size, chance of extinction becomes small

• Violations of assumptions have been incorporated into Metapopulation Models

Ch. 14 Species Interactions

• Outline

– Species Interactions

– Evolutionary Responses

– Parasitism

– Herbivory

– Indirect Interactions

– Mutualisms

Energy and Nutrients

“The **organism** is the most fundamental unit of ecology” (Ricklefs pg. 3).

• Photosynthesis – Energy flow

• Nutrients – Cycling

• It’s all about Energy!

Species Interactions

Effects on Species 1

|  |  |
| --- | --- |
| Mutualism | Consumer – Resource |
| Consumer – Resource | Competition |
| Commensalism | Amensalism  (eg) Bison herds stepping on insects or outcompeting them |

+ -

Effect on Species 2   
N/A - +

+ -

Species Interactions

• Consumer-Resource

One individual taking biomass from other organisms

– Predator

kill prey immediately and consume

– Parasite - Host

does so over a period of time

– Parasitoid

offspring are parasites that develop inside host before emerging and killing the host

– Herbivore

consume plant organisms

– Detritivore

consumers of dead organic material

Timing and Intimacy

-short and casual vs. long and intimate relationships

-low probability of death of resource organisms

short eg) grazers and browsers

long eg) parasites and many arthropod herbivores

-high probability of death of resource organisms

short eg) Predators – including seed predators

long eg) parasitoids

Evolutionary Responses

• Consumer-Resource

– Strong selection pressure

Natural selection of healthy prey escaping the predators

Wolves preying on the sick and old shapes the prey population

Adaptations for Defense

Eg) porcupine quills

Eg) dinosaur: triceratops horns for defense

Eg) skunk

Parasitism

• Association

– Transient

mosquitoes

– Prolonged

tapeworm

• Arms Race

– Virulence and Restraint

More spores produced, larger proportion infected, but may not be sustainable

Parasite: As density is decreased, infection rate is lowered in the culture

There is an optimal amount of virulence in parasites for reproductive success

If too many parasites are infecting a host, the host could die too early

Horizontal Transmission:

* from living host to living host
* from dead host or spore bank in sediment
* life cycle with two or more host species

Vertical Transmission:

* from mother to offspring

Parasitism

• Life Cycles

– injestion, produce cysts in digestive tracts, offspring excreted in feces, contamination causes injection by another mammal

– Primary host is a predator who consumes the parasite from the secondary host where the parasite embedds itself in the muscle/meat of prey animal

– Malaria

-mosquito who feeds from diseased mammal injects gametocyte which infects the mosquito’s salivary glands

-mosquitos infect human with sprorzoites into bloodstream

-malaria migrates to human liver

Species Interactions

• Consumer-Resource

– Parasitism variations

– Dodder (plant)

grows around another plant and taps into host plant’s tissues

parasitic plant takes biomass from another species

Herbivory

• Arms Races

– Physical Defenses

eg) thorns

– Chemical Defenses

eg)ooze out dangerous toxins

– Primary Compounds refer to those in plant metabolism

– Secondary compounds

• Nitrogenous compounds

• Terpenoids

• Phenolics

• Tannins

Wines, spices, flavouring or plants are caused by secondary compounds

• Arms Races

– Digestive Defenses

Indigestible by herbivores:

– Cellulose

– Lignin

• Ecological Effects

• Arms Races

– Grazers

– Protruding teeth vs. Basal meristems

– Hypsodont teeth vs. silica

Herbivory

• Defenses

– Constitutive

– Inducible

Indirect Interactions

• Food Chains & Webs

Competition

Consumer

Resource

+

-

Mutualism

• Trophic

– obtain energy together: feeding relationship

– bacteria in stomach help metabolism/digestion

– Ruminants & Microbes

• Dispersive

– Plants & Pollinators (disperse pollen in return for consuming nectar)

– Animals and Seeds

• Defensive

– one recieves food or shelter in return for defending partner from consumers

– shrimp and small fish eat parasites from skin and gills of larger fish

– Ants & Acacias

– Dan Janzen

Ch. 15 Dynamics of Consumer-Resource Interactions

• Outline

– Consumer-Resource Effects

– Population Cycles

– Lotka-Volterra Model

– Cycle Stabilization

– Alternative Stable States

– SIR model

Consumer-Resource Effects

• Population regulation

– Assumes C-R populations seriously influence each other

(birth rate / death rate; population size vs time)

• Resource Population Responses

– Krebs et al. 1995, 2001

– 1km2 plots

Control (field of rodent population with natural food and predators)

Manipulated Fields: - Predators; + Food; -Predators + Food

Population Cycles

• Aside from the environmental influences on populations, other regulatory factors such as predators can strongly influence a prey population and vice versa

• Predator Prey Interactions?

– Predators and Prey drive each others population size

– Prey Time delays

4yr cycle - 1yr delay for predators to recruit

rodents and birds of prey

– Predator Time delays

10yr cycle - 2yr delay accounts for time for young to reach sexual maturity

lynx and snowshoe hare

• Predator Prey Interactions?

– Test - Island

can control predator species and number of predator individuals on island

cannot control avian predators

Peaks of hare densities on the island and the mainland tend to coincide, but the hare populations remained higher on the island due to fewer mammalian predators

• Host-Pathogen Interactions

– Peaks every two years reflect the time required for the population to produce enough susceptible infants to sustain an outbreak of measels in London, England

– Low stages: most adults had measels at infancy and so are immune; not enough susceptible children because had measels during the past bout

– Outbreak occurs in babies and young toddlers who have never built up an immunity to measels

• Laboratory Study

– Oranges with prey mites (herbivorous on oranges) and Predator Mites

– Could not sustain populations because both became extinct

– Discovered that Vaseline was a critical factor

Vaseline protected the prey for a time, allowing them to disperse to other oranges and therefore maintain the population

Dynamic Population Model results where population size cycles in a few weeks: to be expected for small invertebrates

– Host-prey populations cycle out of phase

Lotka-Volterra Model

• Prey (V for victim)

– dV/dt = rV - cVP

– dV/dt = 0 P = r/c where r is the rate of increase

and c is the efficiency of predator hunts

Few predators, few prey = many losses

rV is population increase

cVP is population decrease

dV/dt is equal to zero when the rate of population increase is a function of the capture efficiency

• Predator (P)

– dP/dt = acVP - dP

– dP/dt = 0 V = d/ac Where a is the metabolic efficiency for

reproduction from nutrition

dP is the loss of predators: dependent on population density and death rate

dP/dt is equal to zero when the rate of increase (BirthRate dependent on “c” capture efficiency of predator parents; and on “a” efficiency of reproduction) is equal to the deathrate or rate of predator decrease

• Stability?

– dV/dt and dP/dt = 0

Number of Predators (P) vs. Number of Prey (V)

If predator population is high, prey population size decreases and vice versa

Prey isocline: where population size of the prey species is not changing and is stable at dV/dt = 0

Predator population is stable as isocline of dP/dt = 0

More predators causes prey decrease

Less predaotrs causes prey increase

• Joint Population Trajectory

– One stable point or,

– Continuous cycle

dP/dt = 0

|  |  |
| --- | --- |
| < | < |
| > | > |

Number of Predators (P)  
r/c

dV/dt = 0

d/ac

Number of Prey (V)

Populations respond accordingly

The point where the equilibrium isoclines for predator and prey cross is the joint equilibrium point

Cycle Stabilization

• Functional Response

– C. S. Holling

– Predator satiation

as prey population increases, each individual predator can eat more, up to a point where the predator is always full to capacity

Three types of functional response curves

Two graphs: Number of Prey consumed per predatory against prey density

Proportion of prey consumed per predator vs prey density

Type I – constant increasing slope

Proportion of prey consumed per predator is a constant no matter prey density

Each predator consumes a constant proportion of the prey population regardless of the prey density

Type II

Predation rate decreases as predator satiation sets and upper limit on food consumption

Type III

This is an odd response curve, starting low response, increasing response, then leveling off decreasing response

This has to do with the way the predators hunt

Sometimes the predator disregards a less common prey type = search image

Predation rate decreases at low as well as high prey densities

Cycle Stabilization

• Functional Response

– Predator satiation

– Type III

– Search image

Example: the predatory beetle and their prey mayflies

Mayflies in diet vs. mayflies in environment = predator result

-Low mayflies in environment: the proportion of mayfly larvae in the diet was lower than expected by chance when the mayflies were uncommon

-High mayfly density: more mayflies in the beetle’s diet than expected when mayflies are common

-Straight line is the expected or hypothetical line where predator would exhibit no preference from mayflies to other prey

• Numerical Response

– Predator population growth

– Immigration

Cycle Stabilization

Why do cycles end? Sometimes populations reach K because:

• Predator

– Alternative foods

Predator population can hunt other species

Prey species A populations are driven low, the predators decrease and begin to hunt another prey species B to sustain predator population size

• Prey

– Refuges

Allows prey populations to recover sooner than would usually

Alternative Stable States

• Insect outbreaks

There could be two types of equilibrium

– Consumer-imposed equilibrium

– Resource-imposed equilibrium

Example: bark beetles

Insect outbreak results from movement between the two equal states:

Bad weather kills the consumer (predator)

Bark beetles refuge and escape predator and population size increases to the carrying capacity of food in the forest because are not limited by predators

SIR Model

• Pathogens & Hosts

– Transmission rate (P)

– Recovery rate

Pathogens (predator) and Host (prey)

S – susceptible individuals

I – infected individuals

R – recovered and cannot be reinfected for period of time because of immunity

It is the product of S and P is high, an outbreak can occur

Graph begins with 0 infected individuals and 100 susceptible

Infection rate increases:

converting individuals from susceptible > infected > recovered

Example:  
 Epidemiologists working on the statistics of H1N1 flu in people

**Chapter 16 Competition**

• Outline

– Resources

– Competitive Exclusion

– Models

– Asymmetric Competition

– Habitat Productivity

– Exploitation vs. Interference

– Consumer Effects

Competition

• Community Ecology

– Coexistence

• “Use or defense of a resource by one individual that reduces the availability of that resource to other individuals, whether of the same species (intraspecific competition) or other species (interspecific competition)” (Ricklefs glossary).

Resources

• Intraspecific competition assumed

• Self-thinning

• Interspecific competition

• A.G. Tansley

– realized each area will have different microhabitats

– did an experiment to demonstrate

– *Galium*

two species which each grow better in different soils

Competition for resources examples

Essentials: food, water, sunlight

Reproduction: competition for mates (animals)

competition for pollinators (plants)

space: shelter from elements and predators

space: territory or niche to inhabit

Resources

• Non-renewable

– space

– habitat/niche only is available when individual occupying that space dies

• Renewable

– Influence by consumer (predator affects prey population)

– None (one-way interaction: the rate decomposers produce nutrients has influence on plants; but plants uptaking nutrients won’t influence decomp.s)

– Direct (two predators on the same prey species)

– Indirect (Balean whale eats krill vs. Sperm whale eats squid eats krill)

Minimun resources

• Liebig’s law of the minimum

– Limiting resource

– being limited by one resource and another resource are not independent on each other but do interact

Peace & Grubb

– *Impatiens parviflora*

how this plant responds to different types of resource limitations

fertilizer treatments and light intesity where varied

- nitrogen and phosphorus were synergistic in promoting plant growth

– synergy

synergisms can be positive or negative

when two resources together enhance the growth of a consumer population

Competitive Exclusion

G.F. Gause

• later came up with idea of ecological niche

• test tubes of paramecia which both require the same resources

• population density: grown separately both species thrived

grown in a mixed culture the one species died out

one outcompetes the other

• Coexistence vs. competition

• “Two or more species cannot coexist indefinitely on the same limiting resource”. (Ricklefs glossary)

Competitive Exclusion

• dN/dt = rN(K-N)

K

• dN1/dt = r1N1 (K1 - N1 - a1,2 N2)

K1

• dN2/dt = r2N2 (K2 - N2 - a2,1N1)

K2

• dN/dt = rN(K-N)/K or (1/N)dN/dt = r(K-N)/K

Competitive Exclusion

• r - Intrinsic rate of increase vs. N - population density

– modified by K1, N1, N2

rate of increase of a species1 (r1) decreases as population density (N1) increases

Coexistence if each equation equals zero, meaning values of a is less than one

Interspecific competition is less than intraspecific competition

• dN1/dt = r1N1 (K1 - N1 - a1,2N2)

K1

• dN2/dt = r2N2 (K2 - N2 - a2,1N1)

K2

• Coexist if:

– a < 1

– interspecific effects < intraspecific effects

Competitive Exclusion

• Multiple resources

– we never really look at competition for just one resource (eg. phosphorus)

• Dave Tilman

– Diatoms *Asterionella* and *Cyclotella* competing for two resources

silicon : phosphorus

1. at high Si/P ratios, *Ast* excluded *Cyc*
2. At intermediate Si/P rations, the two species coexist
3. At low Si/P ratios, *Cyc* outcompeted *Ast*

Asymmetric Competition

• Advantage due to different resources or factors

(eg) nutrient availability vs stress tolerance and competition

two species of barnacles on verticle profile of a shoreline

One “C” lives in the upper intertidal zone

The other “B” spends its time underwater at lower tides

B outcompetes for overall area

If B is removed from lower zones, C moves down

It C is removed from upper zones, B does not change

Therefore, C can live all along verticle shore, but B cannot

Habitat Productivity

• Should nutrients supplements not eliminate plant competition?

Their competition is complex

• When is plant competition more intense?

When nutrients are low or high?

• H1 (Grubb & Tilman) Low nutrients = more intense competition for nutrients than high nutrient conditions would be

• H2 (Grime & Keddy) High nutrients = more intense competition for water, sunlight, and territorty space than low nutrient conditions

• Evidence?

Both do occur

- Plants probably do most nutrient competition below ground in low nutrient situations. In this case, the plants are far apart on the surface and have complex root systems.

- Plants compete more above ground when nutrient levels are high because the soil can support more plants so they live closer together and try to compete for sunglight to not be shaded by the other plants around in close proximity

Habitat Productivity

• Should nutrients supplements not eliminate plant competition?

– Nancy Emery (Purdue Univ.)

– Stress tolerance vs. nutrients

Increasing physical stress by soil salinity and anoxial

Lower and upper borders are set by competition

• Exploitation - scramble for resources

– Indirect - ability to exploit shared resources

(eg) little girls scrambling for marbles on the floor

(eg) Red Robins and shrews both eat the same food; because of their lifestyles they never see one another or interact directly, but compete indirectly

• Interference

– Direct - defending resources

(eg) little boys fighting to grab marbles on the floor

(eg) yellow-headed blackbirds displace the red-headed blackbirds

– Intra- and Inter-specific

– allelopathy

plant competition

operated through chemicals

(eg) Oak leaves contain chemical compounds that limit/inhibit seed germination of other plant species

(eg) Eukalyptis leaves have many natural oils that burn easily

Eukalyptis trees recover better from fire than seedlings

If the trees’ leaves fall and concentrate fire around the tree, it will outcompete the seedlings by survival

Consumer Effects

• Robert Paine

• At high predator numbers the three tadpole species grew equaly well

• In the absence of predators, certain tadpoles dominate the ponds to nearly eliminate H

• Voles and plants

Meadow voles can be excluded from certain patches = better plant growth

The biomass of food plants was much greater in the plots from which voles were excluded

**Ch. 17: Evolution of Species Interactions**

Outline– Introduction

– Predation & Adaptations

– Antagonists - mutual adaptations

– Genotype-Genotype interactions

– Stable States

– Competitive ability

– Reciprocal evolutionary responses

Introduction

• Ch 15 - Predation

• Ch 16 - Competition

• Ch 17 - Evolution of species interactions

• Physical Environment vs. Biological Environment

• Coevolution: “The reciprocal evolution in two or more interacting species of adaptations selected by their interaction.”

– Reciprocal

– Diffuse

– Coexistence or Exclusion

– “... net outcome of their interaction is a steady state. Alternatively, when one of the antagonists cannot evolve fast enough, it may be driven to extinction.”

• Coevolution: How can we possibly study this?

We study adaptations by comparing different populations

Experiment/Studies: different environments give different responses

Correlations

If our results show a correlation we verify hypothesis

Predation & Adaptations

• Animal colours under different selection pressures

• Crypsis:

– camouflage where prey animal blends into its surrounding

– moths on tree bark, insects looking like twigs or leaves, camelion

• Warning colouration

– aposematism

– brightly coloured caterpillars, moths, monarch butterflies

• Mimicry

– Batesian

moths that look like monarch butterflies

tropical mantis and moth with black and yellow wasp coloration

Frequency-dependent population: hawk-dove relationship

model-mimick (if too many mimicks, the wasp is at a disadvantage)

– Müllerian

different species of toxic butterflies convergently have the same coloration to alert predators that “all black-yellow-orange butterflies are toxic”

Antagonists

• Mutual Adaptations

– Genetic Model

– Arms Race or Red Queen

– Charles Mode

– resistance and virulence

r- not resistant v- not virulent

R- Resistant V- Virulent

RV if most are resistant and virulent, there is no longer a benefit because nothing left to infect; let down the cost of virulence; then do not need resistance: end up with rv again

– r,v 🡪 r,V 🡪 R,V 🡪 R,v 🡪 r,v

If this is modelled, we see population cycles (like the lynx-hare model)

– Genotypes cycle similar to predator and prey

Antagonists

• Mutual Adaptations

– Observations of specializations

– Heliconius butterflies and passionflowers

Passionflowers are vines that have incorporated toxins into its tissues to deter herbivory; ancient and long-lived specialization in this plant when look at evolutionary phylogenies

• David Pimentel

see if can get these adaptation systems to work in a lab environment

– Part 1

– Wasps 

the wasps infect the fly pupae by parasitizing

-one cage: remove the flies so prevent evolution: wasp population does well

-second cage: both wasp and fly progeny remain in cage; opportunity for evolution; eventually fly pupae can resist the wasp;

-New cage with fly population from second cage: the wasp population remained low, while the fly population remained relatively high and constant

Genotype - Genotype Interactions

• Foundation of Coevolution

– myxomatosis

Rabbit population exploding in Australia

People had to introduce the myxoma virus to the Australian rabbits

The first epidemic killed nearly one hundred percent of the infected rabbits; however later epidemics killed less percent of the surviving population

The virulence selected for resistance in the rabbit population

Now, people must continually engage in this interaction to keep the rabbit populations of Australia under control

– Rust strains & wheat varieties

Differences in genotypes of rust depend on differences in genotypes of wheat and vice versa.

Could never completely get rid of the rust

Two options: select the wheat which is resistant or try to treat infected wheat

Either way, still have problems with resistance-virulence cycles

We have good information on genotypic variation of the host wheat

– Scale insects and pine trees

these insects infect a pine tree along the pine needles

different trees have different levels of resistance

Scale insects transferred to different branch on the same tree survive well because they are adapted to that tree’s genotype

Those transferred to other trees exhibit poor survival

We infer that the insects get around the resistance of one particular genotype of a tree and not another

However, the tree will become infected after several generations of scale insects; genetic turnover of the tree is much slower (longterm reproduction) than the insects (frequent reproduction

Can large K selected organisms ever get away from small R selected pathogens? -- Not likely

Stable States

• Consumers & Resources

– Selection intensity differs

– Rate of evolution

selection for change relative to rate of exploitation (rate of predation)

blue line(resource): selection on resource populations to reduce exploitation by consumers increases as exploitation increases

red line (predator): selection pressure on the consumer population to increase consumption of a resource population decreases at higher levels of exploitation. Negative selection pressure may favour switching to alternative resource population.

Can have coextistence of predator-prey

We can transfer this information to competition

Competitive Ability

• Indirect selection

– through resource exploitation

– two species can influence each other by both consuming the same resources

• Under selection

Living together in competition causes intense selection pressure on both species; on average both species can be maintained by one will dominate eventually

• *Drosophila*

Over time *D. nebulosa vs. D. serrata* both survive together

If we take *D.n* from this competitive environment and introduce it to a naïve *D.s* population; we see that *D.n* does better

Likewise, D.s from the competitive environment does better than naïve *D.n*

• David Pimentel

– When populations get small

Selection is different depending on size of population

-If housefly population is large and blowfly is small, then the housefly is more influenced intraspecifically by competing with other houseflies than with blowflies.

-The blowfly population feels stronger interspecific selection from the many houseflies.

-If the experienced blowflies are introduced to naïve houseflies in equal number, the blowflies dominate and outcompete the housefly

• Character displacement

– Sympatric

range of overlap

Character traits of two closely related species differ more where they are sympatric than where they are allopatric

– Allopatric

– David Lack

reproduction is restrained for the good of the individual

Reciprocal Evolutionary Responses

• May Barenbaum

• Yucca & Yucca Moth

– Obligate mutualism

-Appears a long history of interaction

Entirely dependent on each other

One only reproduces when the other is present

-Yucca Moths pollinate the Yucca plants

-Without the flowers, the Yucca Moth larvae cannot survive anywhere but on the Yucca flowers

It turns out that this relationship is relatively new in evolutionary terms

There were ancestral relationships and ancestral parasitism

Mutualism evolved

Ch. 18 Community Structure

Complexity of Communities

• Intensity of interactions

– Why are these species coexisting?

– Why not other species?

– What happens to predator prey dynamics if additional factors are added?

– What is the effect of competition between populations?

– Why is the community stable to disruptions?

– Why does this community contain more species?

• We are trying to understand the ecological factors that control these responses.

• Community

* An assemblage of species that occur together in the same place.
* An association of interacting populations, usually defined by the nature of their interaction or the place in which they live.

• What is the “Same Place”?

– Boundaries

– Landforms; ecozones

– Arbitrary borders

History of Community Concepts

• H. A. Gleason (1882 – 1975)

– Individualistic concept

– Natural selection - maximize fitness of individuals of each species

– Species live where they can; which is important to the structure of communities

• F. E. Clements (1874 – 1945)

– Holistic concept

“Whole” system

A community was composed of species and their environment interacting

– Community analogy:

Organism - interactions between parts

– Coevolution between species

Table 1. Community Concepts

|  |  |  |
| --- | --- | --- |
| **Concept** | **Open Community** | **Closed Community** |
| **Proponent** | Gleason | Clements |
| **Organization** | Individualistic | Holistic |
| **Boundaries** | Diffuse | Distinct (ecotones) |
| **Species Ranges** | Independent | Coincident |
| **Coevolution** | Uncommon | Prominent |
| **Interactions** | Abiotic | Biotic |

Community Concepts

• Evidence?

– Robert Whittaker; 1920 - 1980

– Physical factor gradients

– Soil moisture, temperature, light, etc.

Closed communities:

Ecotones are regions of rapid replacement of species along a gradient.

Open communities:

Species are distributed independently with respect to one another.

• Distinct Boundaries?

• Yes - physical/chemical transitions

examples -Lethbridge coulee river valley vs. upper land prairie

-lower to higher altitude changes vegetation from forest to subalpine

-within the forest different tree species due to soil chemistry

concentration of elements in the soil determine the plants that make up each community

• No - smooth transitions

• Problems

– Scale

– Emphasis on plant data

– Co-evolution - Biotic factors!

– Community structure and function

Food Webs

• Food Chains

– Primary Producer

– Primary Consumer

– Secondary Consumer

– Tertiary Consumer

– Quaternary Consumer

• Many connections occur in a food web

Competition; Interactions between predator-prey

Food Web

• Robert Paine

– Keystone species

certain species, which are crucial to the community

eg) krill in marine Antarctic food webs

– Keystone Consumer

beetles which feed on golden rod keep golden rod from spreading in the community, which outcompetes plants

– Richardson’s Ground Squirrel

keystone species

gophers

burrow in the soil; turnover of soil nutrients; provide burrows for others; prey animals for coyotes and hawks

• Characterize interactions

Biomass

Atomic energies

Relative sizes of populations within a community

(eg) Predator species G relies mostly on species F, although also feed on E

Predator species H feeds mostly on E and D but also feeds on B (omnivore)

Consumers F, E, and D all feed on B; Consumer F also eats A

Only D eats producer C

This shows that C is not as important, therefore not a keystone species

Predator H is a keystone consumer

Primary Producer B is a keystone species

Predator G Predator H

Consumer F Consumer E Consumer D

Primary A Primary B Primary producer C

Stability

• Constancy: resistance to change in the face of an outside influence or disturbance

In subsets of the community, the populations are in relative control

Seemingly related to trophic levels

• Resilience: ability to return to a stable state after a disturbance

-Experiment:

extended the rainy season by watering the plots

saw an influx of plant productivity with more water

experimental plot reaches capacity and decreased total productivity

-Insight into Climate Change:

Temperatures, precipitation, and length of seasons can have dramatic effects on populations of communities

• Alternative Stable States

Seemingly different stable population sizes

Carrying capacity could be set be food or by predators or both

Trophic Cascades

• Control

– Bottom-up

When a trophic level size is determined by amount of food available or size of lower trophic level

– Top-down

When a trophic level size is determined by intensity of predation or when a higher trophic level dictates the size of a lower level

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tertiary Consumer |  |  |  | X |
| Secondary Consumer | X | X | X | X |
| Primary Consumer | X | X | X | X |
| Producer | X | X | X | X |

• Evidence?

– Microcosm

– Field

algae vs. zooplankton

increase nutrients to increase algal production

we see a positive relationship

number of algae increases, so number of zooplankton increases

larger zooplankton population can support higher trophic levels

suggest a bottom-up effect

A lake without fish has fish introduced

Fish prey on zooplankton

Smaller zooplankton population means less algae consumption

Increase in algae

Top-down effect

• Indirect Effects

Freshwater aquatic community vs. terrestrial community

When plant dies, its nutrients will go into the water

Nutrients help water plants and algae, which feed insects and amphibians

Insects and amphibians leave water and live in terrestrial communities

Introduction of fish in pond has a positive effect on St. John’s Wort on the shore

Flies, Butterflies, and bees are affected by competition with dragonflies

Fish eat dragonfly larvae

Fewer dragonflies means less interference with pollinators

More pollination supports growth of St. John’s Wort plant

Conclusion: presence of fish endorses plant growth

Ch 19 Community Development

Primary Succession

• Bog succession

Concepts

• Community

– Structure

– Function

– Time

• Community Development

– Why do communities change?

– Why do communities stay the same?

– What aspects of communities change?

• Perturbation

• Disturbance – Many species – Fire – Flood – Dune blowout – Ice scour – -> Recovery to stability

• Succession

– “A regular sequence of changes in the species composition of a community in a newly formed or disturbed habitat that progresses to a stable state.” (Ricklefs glossary)

• Sere

– “A series of stages of community change leading toward a stable state.” (Ricklefs glossary)

– Different seres can lead to same endpoint.

– Multiple paths to same climax community

• Climax Community

“The endpoint of a successional sequence, or sere; a community that has reached a steady state under a particular set of environmental conditions.” (Ricklefs glossary)

Primary Succession

• Definition

– “Succession in a newly formed or exposed habitat devoid of life.” (Ricklefs glossary)

• Krakatau 1883

Secondary Succession

• “Succession in a habitat that has been disturbed, but in which some aspects of the community remain.” (Ricklefs glossary)

Primary & Secondary Succession

• Some gradation

– Intensity vs. size

Patterns & Mechanisms

• Why? - No purpose

• Adaptations to habitats

• Species Replacement

• Mechanisms

– Facilitation

– Interference

– Tolerance

Patterns & Mechanisms

• Facilitation

– A species increases the probability that a different species will establish

– Alder - N-fixing symbiotic bacteria

– Surfgrass - Teresa Turner

Patterns & Mechanisms

• Inhibition

– Species prevent colonization by others

– Predation, competition

* Sousa
* Looked at recolonization of a community in a patch
* Limpet and algae – predation
* Algal competition
* Self-inhibition is common in early stages of succession
  + Decaying horseweed roots stunt the growth of horseweed seedlings; so the species is self-limiting in a sere

Inhibition can create a **priority effect** when the outcome of an interaction between two species depends on which becomes established first.

Tolerance

* ability to tolerate physical conditions

eg) lichen on rock

* few biological interactions
* early colonizer species
* in a sere, establishment of a species showing tolerance is not influenced by its interactions with other species, but depends only on its dispersal ability and its tolerance of the physical conditions of the environment; once established, species are then subject to interactions with other species etc.

Complex interactions

* mycorrhizae

fungal species that lives in soil

can either help gardens grow or act as parasites

Combination of plants and fungi from the same area show the strongest effects, both positive and negative

In some cases even the direction of the effect depended on whether the two species came from the same or different areas

Temporal Patterns

* initial stages: rapid turnover of species
* later stages: slow turnover
* western grasslands:

if disturb soil, 20-40 yrs will be secondary/back to original

soil chemistry itself will take 100yrs to get back to normal

* Glacier Bay Alaska

Climax community

* limits set by climate
  + temperature, rain, energy
* progression toward:

-higher biomass

-more nutrients in plant biomass not necessarily in the soil itself

* characterized by:

-negligible species turnover

-cannot be invaded

Structure vs. Composition

-Structure – increasing complexity

-Species – may still change somewhat

Diversity

Landscape Scale

* Most diverse at intermediate stages of succession
  + Not total dominance by a few species
* Heterogeneity
  + Disturbance

Climax Community Reality

* Clements claimed there were 14 terrestrial communities in North America
* Recent research: subtle differences in each community
* Scale issue:

There could be 14 communities on a large scale

The smaller scale/ finer more specific scale we see differences

External Influences

* Lodgepole pines and fire
* Unlike other trees, where seeds in cones are released when fall turns cones dry; lodgepole pinecones do not fall annually
* Lodgepole pines bank their cones year to year; covered in resin
* Fire causes lodgepole pinecones to release seeds

Prairie-forest edge

* influenced by fire
* bison grazing will nip of samplings
* when bison and fire are not present, samplings continue to grow

Species Characteristics

* Colonizers vs. competitors
* Life history features
* Survivorship

Applications

• Resource Exploitation

• Fisheries

• Forestry

– Clearcut

– Selective

Chapter 20 Biodiversity

* Species Richness, Abundance, Diversity
* Community Membership
* Niche
* Patterns and Process
* Equilibrium

Biodiversity

-definition – Ricklef’s glossary

“Variation among organisms and eclogical systems at all levels, including genetic variation, morphological and functional variation, taxonomic uniqueness, and endemism, as well as variation in ecosystem structure and function.”

-biodviersity is more than just species

-the same species can have a wide range, with many variations in different parts of the range of the species

Species Richness

* the number of species in an area

Species Abundance

* The number of individuals of each species
  + Relative abundance
* Population size
* Example: Fig 20.2 text explanation lacking
  + Yaxis: Relative abundance (%) representation of community
    - Few species that are very common
    - Below 1% is where there are many many species with smaller population sizes in the community
  + Xaxis: as number of individuals in quadrats divided by total individuals of different species

Species Diversity

* Both richness and abundance
* Shannon-Weiner Index
* Simpson’s Index
  + Gamma = Sum of pi2

Index increase with:

* + Species richness
  + Abundance events

Example:

Species: A B C

90 9 1 🡪uneven distribution, lower index

30 40 30 🡪 this one will have higher Simpsons Index

Species Richness

* Species-Area Relationships
  + S = cA2
  + Number of species is equal to a constant times A2
  + Log(S) = log(c) + 2log(A)
  + Y = slope + xaxis coordinate
* Scale
  + Figure
    - Slopes change depending on species scales
    - Depends on range of where you are recruiting, small scale has fewer species, large scale contains many species
    - At local scales, sample size influences species richness, and the slope is relatively high
    - At regional scales, the slope remains constant as samples incorporation an increasing variety of habitat types

Scales

* Species Diversity (richness)
  + Local – alpha: homogeneous habitat
  + Regional – gamma: across habitats
    - Should be larger species diversity/richness around world
    - Some occaisions when alpha is close to gamma
    - Species can be generalists or specialized
  + Species turnover across habitats = beta
  + Sorensen similarity = C / [(S1+S2)/2]
    - Decrease with distance
    - Distance versus Ln(sorensen-similarity)
    - The more rapid turnover in the north-south direction in both regions reflects the steeper climate gradient in that direction
    - Species turnover also in east-west patterns

Community Membership

* Why are these species not others?
* Alberta Breeding Bird Atlas
  + Does not include species that move through territory (migration)
  + 10x10km grids, 212 species seen N of Taber
  + Why only ~69 breeding species in river valley?
* How can we account for species richness?
* Outcome vs. Process
* Weiher and Keddy
  + 20 species of wetland plants
  + microcosm- large tub experiment

water depth, litter, fertility variables

* + 5 years of survey of the 20 species
  + found increase in biomass
    - biomass was less in fertilized and more in fertilized soil
    - both situations increase biomass
  + decrease in species
    - number of species decreases as years pass after planting
    - number of species in fertile plots even lower than the not fertilized; in this fertility treatment perhaps there was a larger bloom in the fertilized plot so that successful species outcompeted others
  + filters
    - orginal species pool 🡪 germination/competition 🡪 realized species pool = 14 🡪 division to high water and no high water etc.

Community Membership

Niche

* Fundamental and Realized Niche
  + Areas of competition condense a fundamental niche to a realized one
  + Some species can join a pool and some cannot

Trade-off

* Local species vs.
* Abundance,
* Niche breadth

As the size of the regional species pool increases, average species abundances and numbers of habitats occupied by species in local communities decrease, while local species richness increases

- suggesting that increase of species causes an increase in competition so that the population size is smaller

Ecological Release

-if have large regional diversity/small local diversity from competition

now go to an island with few species = less competition

then, the species that are present can have larger populations

niche can be broadened to support larger population size without limitations

Resource Gradient

-look at idea of coexistence

Niche coexistence

Model of simplistic/one factor

* Resource partitioning
* Species packing
* Resource gradient
* The gradient of resources can influence how many species can be packed into a community; recall that two species cannot live on the same limiting resource
* How to increase species population size?
  + If the gradient is made longer
  + Species becomes more generalist – more resource sharing
  + Species become more specialist – more packing with narrow niche

Two dimensions in a model of Niche coexistence

-Soil chemistry samples taken to get idea of the ranges of nutrients that affect plants

-Calcium and Organic Matter

-under what combination of calcium and organic matter do we find a particular plant to grow? We find a range of organic matter, as well as a range of calcium

-two species in the same forest then have different niches

-we find that if species should overlap in conditions, we also find that in reality the complexity of different nutrient combinations results in very little overlap

example:

-bats

-differences in ear size (reliance on sonar)

depends on food source

bats can eat insects, fruit, frogs, or fish

-differences in wing size (maneuverability)

bats in forests that prey on insects need more maneuvering

than bats looking for fruit in the plains

example:

streams in Mexico

species of fish

headwater springs: eat mostly detritus as move downstream, begin to eat algae

river mouths: most complex system where fish can eat different species

Patterns and Processes

-Latitude

-bivalve

-we see species richness is low in Arctic and Antarctic, but very high diversity at equator

-Hypotheses

-Physical

-Temperature

(not surprising, high latitude temperatures less hospitable)

-Precipitation

central north America dry, as south get moister and more diversity

Energy input (temperature) or water (precipitation) can have an influence on biodiversity. Sometimes one will have more influence than the other. Another view is to put the conditions together. For the most part, between birds, mammals, reptiles, and amphibians, we see a positive correlation as potential evaporation/transpiration increases, so do number of species.

-Hypotheses

-Habitat Heterogeneity

-as habitat becomes more diverse, more niches allow more species to occupy

-topography creates habitats

-complexity of habitat structure

grassland, marshes, desert, shrubland, forest

we could see productivity and number of bird species are related in habitat complexity

-foliage height diversity: the more diverse the more bird species

Hypothesis

-Dispersal

-for example, in a peninsula, species richness decreases as move away from the mainland because with extinction, habitat can only be re-colonized from the mainland direction down the peninsula

-Disturbance

-plant diversity could correspond to mammal diversity

-gophers: burrows disturb ground

plant species levels are highest at intermediate soil disturbance

-Predation and Herbivory

-if look at taxonomic distribution, most species are insects

-is it possible that insects drive plant diversity? We see some evidence of this in the tropics.

-any seedling in a particular tree is subject to its leaves being eaten

-survival of the tree is higher with further dispersal from the parent tree because the parent tree attracts insects

Equilibrium Theory

-Islands

- Equilibrium Theory of Island Biogeography

- MacArthur and Wilson

- Species diversity on islands is a combination of colonization and extinction

- rate of colonization vs. number of species

few species on an island = high colonization rate

as species on island grow and become established, fewer can colonize

extinction rate increases with larger number of individuals

extinction is low when there are fewer species - lower competition

-Island Size

- Small islands support fewer species than large islands

- dictates where the equilibrium lies

text book does not include:

- colonization rate ought to be greater in large islands

-Island Distance

- a near island must be colonized more easily

-lower number of species on far islands

-Continents

Large time scale that includes speciation

Number of species on continent increases – more potential for divergence

Gain of species through speciation and loss of species through extinction would theoretically also reach an equilibrium of number of species

**Chapter 21 History, Biogeography & Biodiversity**

• Outline

– Adaptation vs. Phylogenetics

– History of the Earth

– Continental Drift

– Biogeographic Regions

– Changes of Climate

– Convergence

– Local vs. Regional Effects

Communities

• Structure and Dynamics – Spatial and Temporal

• Biodiversity - species richness – Patterns and process

• History and Biogeography – Geological & Evolutionary time

**Communities** (Fig 21.23)

**Additions**

Continental Migrations Colonization Resource Partitioning

Speciation Habitat Selection

Regional Diversity Local Community

**Losses**

Species Exchange Disease Competition

Mass Extinctions Bottleneck Predation

*Geological Time Ecological Time*

Adaptations & Phylogenetics

• What conditions for evolution?

• Phylogenetic inertia

eg) kangaroos: the mammalians of Australia are mostly marsupials

bring along individual phylogenic history into their lifestyle and reproduction

even though live in similar niches to other mammals

Biogeography

• Regional Histories

• Spatial patterns in evolution, speciation, extinction

• Communities:

– recent adaptations

– history

All three time scales play a role in every community

History of the Earth

• 4.5 Billion Years

• Life – 3.8 Bya first forms

• Prokaryotes – first known life form

• Eukaryotes – developed later

• 590 Mya, abundant fossilization (calcium carbonate shells preserve easily)

• Radiations

• Fossils – snapshots in time; realtively rare

• Polartity – time

Deeper strata are older layers

Continental Drift

• Plate tectonics

About 250 Mya, most of the earth’s land masses were joined together in a single giant continent called Pangeae. By 150 Mya, Pangeae had separated into two landmasses, Laurasian and Gondwana, then Gondwana split.. etc

• Climate

Continents: where they were with respect to latitude has changed dramatically as well ~400 Mya

•Dispersal

Species Distributions

Formation and loss of landbridges from continental drift

• Vicariance

Ancestral Taxonomic group

– separated by some physical reason (eg. mountain formation)

Biogeographic Regions

• Alfred Russel Wallace 1823-1913

(contemporary of Charles Darwin)

– Zoogeographic Regions

Nearctic (N.Am)

Neotropic (S.Am)

Paleartctic (Europe, N Af, N Asia, Middle East)

Afrotropic (Africa)

Indomalaya

Australasia

• Patterns

– Isolation

– Connections

• American Interchange

(migration between North and South America eg. mammoths, sloths, deer, possums)

Changes in Climate

• Long-term - Continental Drift

• Medium-term - Glaciations

• Pleistocene - Ice age, 2Mya

• Alternate warming & cooling

• Retreats & Migrations

• Plant Pollen

Catastrophes

• Mass extinctions

Catastrophes

• Asteroid struck Yucatan

• 10km diameter; 25km/sec

• Tidal waves; fires

Meteorites

Catastrophes

• Asteroid struck Yucatan

• Tidal waves; fires

• Plant production halted

• Birds and mammals not affected?

• Dinosaurs lost over 1000s of years

• Implications - evolutionary radiations

KT – Censoic-Tertiary transition

Convergence: Form & Function

• Different regions, similar environments

Examples:

• European woodpecker, Hawaiian seedril, cactus wren

• Red Squirrels

European not closely related to the North American

However, these squirrels converged to a very similar form

• Eutherians vs. Marsupial

Mice: rodent mouse (eutherian/placental mammal) vs. marsupial mouse

• Other examples:

In Africa and South America we see similar grazers

Wolves: Gray Wolf and Tasmanian Wolf not at all phylogenically related, both exhibit canine bahaviour and converged to similar niches in different continents

• Convergence & Divergence

Both are seen within and between groups

Two species in the same community are probably not related to one another; Closely related species diverge and live in different ecological niches

Distantly related species converge to same morphology and share a niche

Species Richness

• Regional Processes vs. Local Ecological Processes

• Regional vs. Local Test

Glaciation could have caused species to be pushed down from North America to South America; when Glaciers receded S.Am species recolonized N.Am

Glaciation would also have caused genera loss in Europe; after glaciation they could have reinvaded from Africa (if could make it across Mediterranean Sea) and from Asia. This is called tropical invasion.

Biodiversity can be caused by the continental and climatic changes in the history of the Earth

Species Richness - Multiple Effects

• 1) tropical invasion

• 2) habitat diversity

• 3) speciation

• 4) extinctions

• 5) recolonizations

Chapter 22 Energy in the Ecosystem

• Outline

– Overview

– Thermodynamics

– Energy Input & Assimilation

– Primary Production

– Ecosystem Variation

– Trophic Pyramids

– Energy Flow Rates

• Photosynthesis – Energy flow

• Nutrients – Cycling

• It’s all about Energy!

• Basic Principles of Ecologial Systems – Obey the laws of physics – Dynamic states – Maintenance requires energy

• Evolve – Very simple principles -> complex ecosystems

Thermodynamics

• First Law

– Energy can be transformed, but not created or destroyed

• Second Law

– Energy transformations lead to increased entropy

Energy Input & Assimilation

• Incident Radiation

– Absorbed ~ 70%

– Reflected ~ 30%

“Only a small proportion of the solar radiation that reaches the earth is converted into biological production through photosynthesis.”(Ricklefs pg. 40)

• Photosynthesis

• Carbon Fixation

– 6CO2 + 6H2O +Energy 🡪 C6H12O6 + 6O2

• Photosynthetic pigments 39kJ light energy per gram of C assimilated

Energy Input & Assimilation

• Primary Production

– NPP = GPP - R

net primary production equals gross primary production minus respiration

– Foundation for all ecosystems

• Measurements

Photosynthesis can be measured by CO2 into plant and O2 out

Water is not a good measurement for photosynthesis because other things affect water intake

• Measurements of Energy Input and Assimilation in Plants

– Terrestrial

A. Net uptake in light (net primary production) measured by net CO2 uptake

net CO2 uptake is output from respiration and intake for respiration

B. Net release of CO2 in the dark gives respiration

Gross Primary Production = Gross CO2 uptake = A + B

– Aquatic

easier to look at oxygen to measure

• Harvest Biomass

• AANP

– Annual Aboveground Net Production

**Primary Production**

The following factors affect primary production -- the production of plants

• Light

light intensity affects primary production

• Solar Constant

– 1,366 W/m2

the amount of this energy that actually gets to the earth surface is much less:

• Ground

– 500 W/m2

• Saturation Point

– 30 - 40 W/m2

• Compensation Point

– 1 - 2 W/m2

the point at which the GPP = respiratory production; net photosynthesis = 0.

• Light

– Forest Canopy

has an impact on the ground level species competing for sunlight

– Grassland Canopy

• Photosynthetic Efficiency of Ecosystem

% sunlight 🡪 NPP during growing season

~ 1 - 2% (if no other serious limiting factors)

sunlight has an affect on primary production

Most light is reflected or absorbed by photosynthetic plant pigments

• Temperature

If temperature is high, photosynthesis increases (think tropics) but respiration also increases

• NPP 🡪 with temperature to optimum

– Temperate ~ 16oC is the optimum temperature for respiration/photosynthesis

– Tropical up to 38oC

Water

• Water use efficiency

– g plant dry matter produced per kg water transpired

(transpired - not input by precipitation)

Generally up to 2 g/kg (two grams of plant per kilogram of water)

– Max 4 - 6 g/kg in drought tolerant plants

Seemingly inefficient! Seems like a lot of water for this

– Agriculture?

Irrigation is using about 90% of water allocation in Southern Alberta

We are starting to reach practical limits

• Nutrients

– Nutrient use efficiency (NUE)

– Terrestrial

how much dry matter is produced in relation to nitrogen assimilation in soil

the highest NUE is about 200:1 for nitrogen and 4000:1 to phosphorus

this tells us that nitrogen is a limiting nutrient in terrestrial ecosystem

– Freshwater Ecosystems

phosphorus tends to be limiting

look at chrolophyll (relates to plant mass in water) versus nutrients in water

• Growing Season

A longer growing season will obviously produce more matter annually

NPP increases towards the equator

Relates to total number of days in a year that plants can photosynthesize

Ecosystem Variation affects Primary Production

• Latitude

– Factors?

– Temperature

– Precipitation

• Evapotranspiration

• Comparisons

– Patterns?

Terrestrial:

Temperature and Precipitation help primary production

Nutrients in a temperate area are mostly in soil; in tropics a larger proportion of the nutrients is actually in the biomass; so in the tropics slash and burn agriculture is unproductive after one or two years when the crops use up all nutrients in the soil

Aquatic:

shallow waters such as algal beds and reefs are able to turnover nutrients

open ocean cannot cycle nutrients because it is too deep

estuaries are highly productive

Trophic Pyramids

• Odum’s Energy Flow

Egestion: \* not in text \* large amount of food in indigestible (eg. cellulose) and is never assimilated into the body

Input of energy to organism 🡪 Assimilation 🡪 Organism Production 🡪 energy that is available to the next trophic level

Loss: Egestion, excretion, respiration

• Assimilation Efficiency

– Assimilation/Ingestion

– Herbivores - seed: 80%

– Herbivores - grazers/browsers: 30 - 40%

can be low efficiency because they cannot digest cellulose and lignin

– Herbivores - new growth: 60 - 70%

flush of new leaves that comes out in spring

– Carnivores: 60 - 90%

animal tissue is more digestible, so wolf eating deer tissue is efficient

wide range, consider owl eating mouse: regurgitates pellet of bone/hair

• Net Production Efficiency

These values are very low

– Production/Assimilation

– Birds: 1%

– Small Mammals: up to 6%

– Most mammals: ~ 2.5%

– Reptiles & Amphibians: ~ 50%

highly efficient; think temperature/ thermoregulation

have a huge advantage for energy, save energy because don’t produce it

– Most insects: ~ 40%

– Sedentary aquatic inverts: up to 75%

Trophic Pyramids

• Terminology

– Primary Producer

most energy is available at this level

– Primary Consumer

– Secondary Consumer

– Tertiary Consumer

– Quaternary Consumer

• 10% rule – Implications?

If you want to maintain a large population of large whales, then a low trophic level is required for food because there is more available energy

There is only so much energy available; can only have so many large animals

Thought Question

Big fleas have little fleas upon their backs to bite ‘em, and little fleas have lesser fleas and so ad infinitum. Discuss.

As you move up the food change there is less energy available

Cannot go “ad infinitum” because there is not enough energy for there to exist a further predator to prey on our current top predators

Trophic Pyramids

• Implications?

Indicator Species:

high level carnivores

• Herbivore vs. Detritus Food Chains

– Parallel

– Energy Flow

– Nutrient Cycling!

Energy Flow Rates

• Varies by ecosystem

how long is energy present (stored in biomass) before it cycles on?

• Inverse - Residence Time

in years

– RT = Energy stored in biomass (kJ per m2)

– Net productivity (kJ per m2 per year)

• Residence Time – Patterns?

Forests have long residence time

C-C bonds in woody material stores energy in their biomass

Trees can live a long time

Cultivated land has short residence time

Chapter 23: Pathways of Elements in the Ecosystem

– Ecosystem Models

– Water

– Carbon

– Nitrogen

– Phosphorus

– Sulfur

– Microorganisms

Introduction

• Incident Radiation

– Absorbed ~ 70%

– Reflected ~ 30%

“Only a small proportion of the solar radiation that reaches the earth is converted into biological production through photosynthesis.”(Ricklefs pg. 40)

• Trophic Pyramids and Food Chains/Webs

• Biomass

– Energy

– Nutrients

• Food Chains/Webs

– Living & Non-living

• Nutrient Cycling

Macronutients: carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur,

potassium, calcium, magnesium

Micronutrients: zinc, selenium – only needed in small amounts

Proteins, fats, carbohydrates

• Biogeochemical Cycles

– Ecosystem Pathways

– Nutrient Regeneration

• Assimilatory Processes

– “Referring to a biochemical transformation that results in the reduction of an element into an organic form and hence its gain by the organic compartment of the ecosystem.”

• Dissimilatory Processes

– “Referring to a biochemical transformation that results in the oxidation of the organic form of an element and hence its loss from the organic compartment of the ecosystem.”(Ricklefs)

• Coupled transformations

– Organisms or environment

– Linked transformations

energy is lost at each trophic level

Ecosystem Models

• Compartments

- Biological Processes:

Organic compartment: autotrophs, microbes, detritus, animals

Inorganic compartment: atmosphere, soil, water, sediments

- Geological ProcessesL

Inaccessible organic compounds

(elements are locked up in rock; rate at which mineral is released is slow)

• Fluxes

biological processes (fine-scale time) move more quickly than geologic processes

Water

• Hydrologic Cycle

¼ of solar energy that hits the earth drives evaporation

• Teratons

– 1012 metric tons

Carbon

• Photosynthesis & Respiration

– Solar Energy

– GigaTons (109)

– 31yr. res. time

– Local Scale

• Ocean & Atmosphere

• Atmosphere

– 5yr. res. time

• Precipitation of Carbonates

– Calcium Carbonate

– CaCO3

– Low solubility

• Methanogenesis

– Anaerobic conditions - archaebacteria

– CH4

• Atmospheric CO2

Levels change over time

• Grassland Productivity

– Morgan et al. 2004

enclosed area with more concentrated carbon results in higher plant productivity in certain grass species; however, the added production is more indigestible to cattle = carbon cycle is complex! Can’t make assumptions

Nitrogen

• Local Scale

-plants get nitrogen from soil as ammonium ions, or in the form of nitrates

-nitrites can become stable nitrogen oxide or molecular nitrogen; N2 is atmospheric nitrogen that must be fixed in order for plants to use it

• Global Scale (Geologic time)

-nitrogen is taking out of and put back into the atmosphere

-humans make more nitrogen runoff causing dead zones in aquatic systems

Phosphorus

• Simple (GT)

– Trivial atmospheric component

– No oxidation-reductions

– PO43-

• Lakes

\*see textbook Fig 23.16 – spring and fall overturn of phosphorus; settles on bottom

Sulfur

• Complex – GT

• Sulfides

• H2SO4

Microorganisms (Bacteria)

• Heterotrophs

– Reduced organic C for energy

• Autotrophs

– Assimilate C into organic material from CO2 (chemoautotrophs are different)

• Photoautotrophs

– Light energy; aeorbic; H2O as electron donor

Biosphere depends on solar energy

Photosynthesis drives processes of life

• Chemoautotrophs

– Energy - aerobic oxidation of CH4, H, H2S, etc.

• Thermal Vents

– Bacteria

–H2S 🡪 SO42- + Energy

Chapter 24 Nutrient Regeneration in Terrestrial

• Outline: Aquatic Ecosystems

– Weathering

– Soil

– Micorrhizae

– Pathways

– Climate

– Aquatic Regeneration

– Stratification

– Oxygen Depletion

– Shallow Waters

– Deep Ocean Waters

Weathering

• Nutrient Cycling

Bedrock and soil materials release inorganic soil nutrients

lost in groundwater and stream runoff;

uptake into plant biomass;

plant detritus degrades inorganic nutrients back into soil

• Outputs

– leaching

• Inputs

– Weathering

– Particle settling

– Precipitation

– N fixation

• Hubbard Brook

• Watersheds

– Inputs & Outputs

Trees are sampled for water content

The water collects into a stream, which is gauged in a test experiment

• Weathering

~ 10% annual plant uptake

plants pick up nutrients released by weathering

approximate equilibrium between nutrient uptake from weathering vs.

spring runoff and leaching

Soil

• Decomposition

– Limiting step

• 4 mechanisms in forest

– Leaching, Large detritivores, Fungi, and Bacteria

Mycorrhizae

• Mutualism

Form close associations with roots of plants and increase the surface area of plant roots so that plants have more access to nutrients

Mycorrhizae stimulate growth at low phosphate conditions, but not at high phosphate concentrations, at which point other nutrients become limiting.

Plants provide carbon compounds for mycorrhizae

* Ectomycorrhizae
  + Do not penetrate the cells of the plants
* Arbuscular mycorrhizae

Pathways

• Detritus Cycle

organic soil matter 🡪 decomposed into monomers 🡪 uptake by microorganisms to build up polymers (but when die the polymers are decomposed back to monomers) 🡪 plants access nitrogen (ammonium and nitrates) from soil as well as compete with microorganisms for organic monomers 🡪 when plants die, depolymerization is the rate-limiting step in decomposition

• Soil Depth

-the above activities are different according to soil depth

-by the depth in the soil, can find whole pine needles on top litter, and more organic parts in the middle, and more minerals at lower depth in soil (towards the humus)

Climate

• Decomposition Rate

– Temperate vs. Tropic

In different areas of the world, percent of phosphorus is more in either plant biomass or in soil

In tropic areas, moist = faster decomposition = faster plant uptake

Nutrients in tropics are more found in the plant biomass

Nutrients in soil is higher in temperate regions

Climate

• Tropics

– Eutrophic soils

remember a eutrophic lake is a highly productive lake

temperate forests have much soil nutrients

– Oligotrophic soils

remember a oligotrophic lake not productive lake

oligotrophic soils in tropics

poor soil nutrients

• Agriculture

– Slash and burn

throwing away nutrients because all plant biomass was burned

– Carbon loss in cultivate soils

Tropics lose carbon from soil at ten times the rate that temperate does

Canada Venezuela Brazil

Original C soil content Kg/m2 8.8 5.1 3.4

Rate of loss %/year 1% 11% 9%

• Nutrient Budgets

movement of nutrients into and out of watersheds

• Hubbard Brook

– Deforested a watershed

What happens when trees are taken out of a watershed?

How bad is the clear-cutting process on nutrients in the soil?

When not a lot of biomass is present to take up water and nutrients, there is a huge loss of nutrients in runoff and leaching

Example, increase outflow of nitrates by 20 times without trees

Regeneration

Terrestrial Regeneration

– Near plant roots

Decomposition is largely aerobic and occurs in soil litter near plants

– Aerobic

Aquatic Regeneration

– Far from Plants & Algae

Decomposition occurs at ocean bottom, and can occur far from plants/algae

– Anaerobic

– Primary productivity is highest in shallow waters or areas of upwelling

• Liao & Lean

– Bay of Quinte, ON

– Limnocorrals

used thin corrals that extend to bottom of lake to measure nitrogen uptake

Nitrogen (ug/L/day)June 5Sept 5

Phytoplankton Uptake 18.5 129 shows nutrient circulation Grazing – herbivores 9.7 27

Sedimentation 2.6 63

Stratification

• Thermocline

Over summer, productivity drops above the termocline

Spring and fall turnover enables the top of the lake to regain productivity

• Ocean Currents

– mixing

– upwells

-When two masses of water come together, they can increase productivity because each mass has different dissolves components

-When the two systems meet, some of the mixed water may enter the stratified water mass, carrying nutrients that stimulate production

-In the stratified water mass, production is low because nutrients in the surface waters have been depleted

-peak productivity occurs at the thermocline

Oxygen Depletion

Lakes

• Thermocline

– Anaerobic

– Solubility

• Hypolimnion

lower levels contain bacteria that are decomposing matter which lowers the oxygen levels and creates anaerobic conditions in the lake

• after spring turnover ends, bacterial respiration gradually depletes the oxygen

Shallow Waters

• Productivity

– David Schindler

Are the oilsands in Alberta polluting the Athabasca River?

Schindler demonstrated that there are problems in water quality

– CN vs. CNP treatment

What is the greatest limiting nutrient in the aquatic system?

Schindler constructed a curtain between two sides of a lake

After 5 years, found that phosphorus is the main limiting factor

Also means that phosphorus pollution can cause eutrophication

• Eutrophication

– Pollution

– point source: sewage

– Pollution

– non-point source

leaching of nutrients into river from many points along river

* Agriculture
  + Biggest impact on aquatic system eutrophication

• Hypoxic Zones

Dead Zones

Agricultural runoff from USA into the Mississippi watershed into the Gulf of Mexico causes huge algal bloom and huge depletion of oxygen in the water

• Estuaries & Salt Marshes

– Export 50% of NPP (net primary production) into ocean

* Downstream flow
* Surges of water from tides
* Nutrients from upriver
* Most productive aquatic systems

Deep Ocean Waters

• Nutrients in surface layers

Alfred Redfield – Redfield Ratio

• Average Phytoplankton nutrient ratio

N:P – 16:1

Probably the required ratio of nitrogen to phosphorus for optimal productivity

Updated C:N:P ration is 100:16:1

Iron in the open ocean

• Iron and carbon sequestration

– Iron (Fe) is limited in open ocean far from shore

• Martin experiment. 1980s

– Fe tripled productivity

suggests that in that ocean area, iron is the limiting nutrient in phytoplankton

• Coale et al. experiment 2004

– increase productivity, independent of Si

• Other consequences?

People are reluctant to take this experiment on a large scale because we are unsure of the consequences of tampering with the ocean ecosystem

Final Exam

• Aiming for: – Tues. Dec. 14th - Fri. Dec. 17th

• Chapters – 17 - 26 (not 27)

• Similar Format

– Multiple Choice or True/False (1)

– Distinguish Between or Explain (2)

– Essay or Figure Essay (5)

**Chapter 25 Landscape Ecology**

• Outline

– Introduction

– Landscape Mosaics

– Habitat Fragmentation

– Habitat Corridors

Final Exam

• Aiming for: – Tues. Dec. 14th - Sat. Dec. 18th

• Lectures – 17 - 26

• Chapters – 18 - 26

• Similar Format

– Multiple Choice or True/False (1)

– Distinguish Between or Explain (2)

– Essay or Figure Essay (5)

Introduction

• Landscape Ecology

– “The study of the composition of landscapes and the spatial arrangements of habitats within them, and of how those patterns onfluence individuals, populations, communities, and ecossystems at different spatial scales.” (Ricklefs glossary)

• Landscape Context

– “The quality and spatial arrangement of the habitat types in a habitat matrix.” (Ricklefs glossary)

Landscape Mosaics

• Habitat Heterogeneity

– Yellowstone fires

• Ecosystem Engineers

– Beavers

Habitat Fragmentation

• Habitat Patches & Matrix

• Effects

– decrease habitat area   
– increase patchiness

– increase edge/ perimeter

– decrease patch size

– increase patch isolation

• Findlay & Houlahan 1997

– Wetland biodiversity

– Patch size

– Habitat diversity

There is a positive relationship between number of species and size of patch, which makes sense as diversity increases with larger size, housing more niches

– Extinction

– Colonization

• Prairie

Highways fragment smaller habitats

Creates matrix between patches dangerous

• Predators and Nest Parasites

roundheaded cowbirds: leave their eggs in the nests of other birds

prairie species are often adapted to cowbird eggs and reject the cowbird, only want to raise own young and not waste energy on young not own

out east, the warblers will raise a cowbird as its own, negative species impact

Habitat Corridors

• If habitats are in patches, it is more beneficial to have corridors to promote movement and genetic exchange between patches

• Dispersal

– Migration

– Colonization

• Habitat Matrix

– Metapopulation

Large healthy subpopulations makes the metapopulation much more stable

– Werner et al. 2007

• Stepping Stones

– Rivers

– Riparian Habitat

Birds from Northern Alberta have a habitat in much water

Migration requires that these birds rest in “stepping stone” river valleys as they move across Southern Alberta and on

**Chapter 26 Biodiversity, Extinction, Conservation**

• Outline

– Human Population

– Biodiversity Value

– Extinctions

– Conservation

Human Population

• 6.8 billion people are on the planet

• 35% of terrestrial land on earth is in agriculture

• 35-40% of terrestrial NPP (net primary production)

– Use/abuse of resources:

mining, using resources faster than are regenerated

– Pollution & disturbance

– Loss of species & ecosystems

• Ecological principles

Demographics: pre-agricultural, to pre-industrial, to post-industrial society

We saw a situation of stability where Birth and Death rates are the same

With technology, the death rate drops

Birth rate is higher than the death rate, causing population to grow

Biodiversity Value

• Extinction – a species is gone from the planet and cannot return

• Extirpation – disappearance of a population of species from a range but exists elsewhere, and has chance of reintroduction of the species to the area

• Intrinsic value

argument that biodiversity has intrinsic value

(instances where a spider is just as important as a panda)

• Self-interest

– Recreation

– Pharmaceuticals

– Food

– Commodities

• Ecological goods

- Renewable resources

- harvesting wild or domesticated animals from a healthy biological system

• Ecological services

- functions and processes in ecosystems provide a lot of value to humans

• Grasslands

– Carbon storage

– Water regulation

– Water filtration (water being cleaned as it moves through the soil)

– Erosion control

– Soil formation

– Waste treatment

– Pollination

– Pest control

Biodiversity Value

• Reliability – Tilman & Downing 1997

plots of ground in a prairie area with controlled number of plants per plot

variation in amount of species

biomass remaining after drought vs. plant species richness before drought

the larger species richness before drought resulted in more biomass after

• Maintaining biodiversity maintains ecological stability

Extinction

• Mass extinctions

• Background extinctions

– Fossil record; species longevity 1-10 My

~ 1 extinction/year to be expected

We must look at what the rate is from human activity

• Anthropogenic

– Past 400 years there have been 700 vertebrate species lost - documented

Shows us that human activity has at least doubled natural extinction rate

• Causes of Species Loss

1. Habitat loss
2. Small populations
3. Exotic species
4. Over-exploitation
5. Pollution

• Habitat - 76% of USA endangered species are endangered because of habitat loss

• Deforestation Country % Change/year

– Canada +0.1

– USA +0.3

– Nicaragua -2.5

– Panama -2.2

– Paraguay -2.6

– Brazil -0.5

Freedman 2004

Think if Brazil is cutting half a percent of forests each year: exponential decay

Canada is almost at the point where there is more cutting than planting

• Habitat: Brazil Atlantic coastal forests

Many species require old-growth forests

The new-growth forests are unsuitable to many organisms, causing extirpation

• Habitat - Prairies - remaining native grassland

– Canada - 25% agriculture

– Alberta - 40% land dedicated to agriculture

Because of agriculture, extirpations occur

• Habitat: Prairies - native grassland - extirpations

– Bison (restricted to domestic farms and parks)

– Wolf

– Grizzly (no longer on prairies, now restricted to mountain areas)

– Swift Fox

– Prairie Dog (different species from Richardson Ground Squirrel gopher)

– Black-footed Ferret

– Burrowing Owl (on its way down, only few hundred left)

– Ferruginous Hawk

• Cumulative Impacts

• Small Populations

– Stochastic Effects

– Habitat Fragments cause small populations, which are susceptible to extirpation because it is not as stable, more influenced by weather, natural distances, and predator introduction

• Genetic Bottlenecks

– N. Elephant Seals

~20 individuals 1890, now >30,000

– No detectable genetic diversity

– Cheetah - no detectable diversity

Extinction and Extirpation by Exotic Species

• Exotic Species

– Natural species exchanges

– Biogeography

• Anthropogenic - Islands

– New Zealand

aside from bats, had no mammalian predators

many birds nested on the ground

introduction of cats and rats devastated bird species

– Hawaii

introduced plants and animals

• Lakes

– Anglers - bait fish accidentally introduced by fishers

– Anglers - game fish, adding species want to hunt into a lake

• Exotic Species examples in N Am from Europe

– Purple loosestrife

– Knapweed

– Leafy Spurge

– Starlings

• Over-exploitation

– N America 12,000 Myr ago: 56 large mammal species lost very fast

– Madagascar 1,500 Mya: 14 spp lemurs, 6 spp elephant birds

– 19th Century

* Great Auk (huge penguin)
* Passenger Pigeon (were million of them)
* Labrador Duck

• Over-exploitation

– Fisheries

eg) cod fish over-fished; unorganized political and biological management

• Pollution

eg) DDT has impact on biodiversity

– Peregrine falcons

– Bald eagles

– Brown Pelicans

– Cormorants

– Ospreys

– Bioaccumulation

– Food-web magnification

DDT is a lipid soluble chemical, so it accumulates in zooplankton, by the time the osprey eats the infected fish, the amount of DDT has accumulated so much that there is a 8,000,000x magnification of DDT conc.

• Overall Vulnerability

– Reproduction rate

– Specialized reproductive needs

– Body size

– Trophic level

– Specialized feeding habits

– Fixed migratory patterns

Conservation Responses

• Remove exploitation pressure

• Ecotourism

– Kenya 7 yr old lion

– Harvest - $1,000

– Ecotourism - $515,000

• Remove pollution threat

• Protect habitat

• Captive breeding & release

• Nature Preserves

How should we build nature preserves?

Best area is more concentrated size