Learning Progression Framework and Assessments for Community Ecology: How Students Progress Toward Systems Thinking

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Thanks to:

- **Participating teachers & students**
- **Teachers in Residence** - Marcia Angle, Mitch Burke, Terry Grant, Debi Kilmartin, MaryAnn Murphy, Liz Ratashak, Michael Schiebout
- **Research Collaborators –** Carol Blanchette, Michele Johnson, Shawna McMahon, Johnathon Schramm, Scott Simon, Brook Wilke
- **Student Coders** – Beth Kennicutt, Anthony M., Katrina Marzetta, Trent Smith
- **The National Science Foundation**

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Learning Progressions for Environmental Literacy

Our Research Question

- How do students reason about ecological disturbance?
- Reasoning requires:
  - Using microscopic processes to link among scales in the hierarchical ecosystem structure.
  - Ability to identify constraints and predict a system's likely response to disturbance.
- This reasoning ability is important if we expect students to make citizenship decisions that preserve biodiversity and ecosystem function.

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Challenges with assessing student understanding of ecosystems

- Ecosystems are complex and contingent
  - Governed by a large variety of principles.
  - Principles vary in importance depending on context.

- Students lack experiences with the natural world
  - Don’t have many experiences.
  - Experiences are geographically constrained.
  - Many students have spent more time watching movies and nature shows than actually being outdoors.

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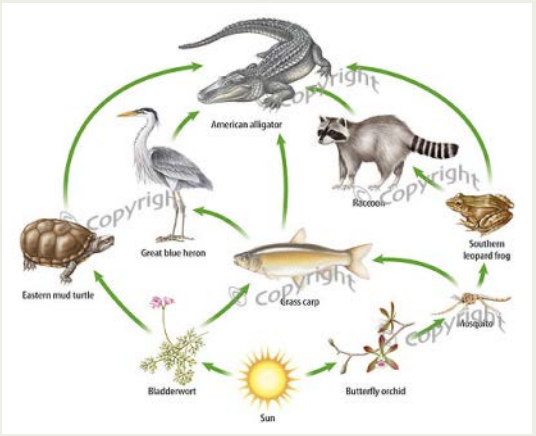
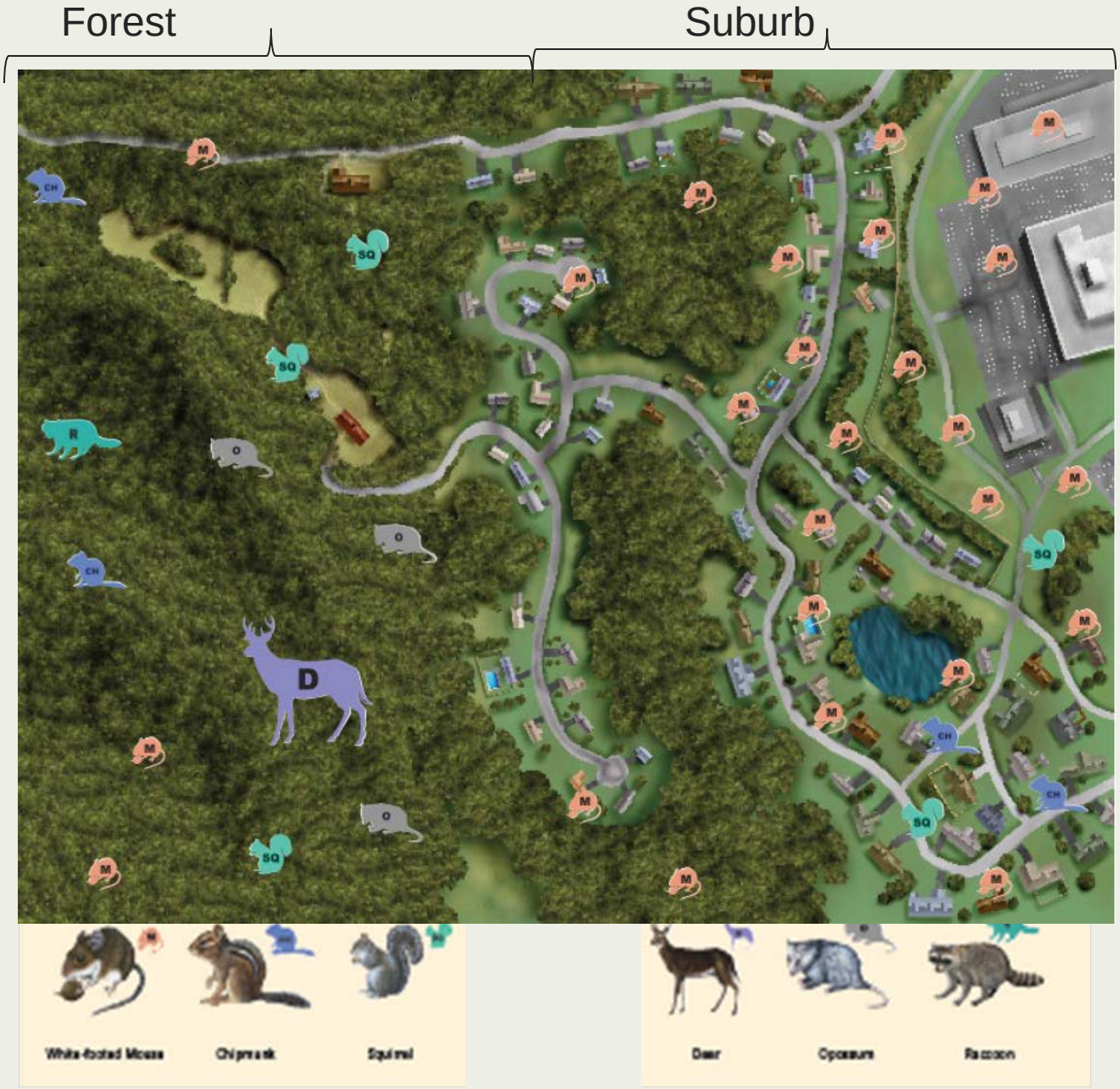
Methods

- Developed 3 scenarios about ecological disturbance
- Administered semi-structured interviews
- Students in rural Michigan, suburban Colorado, and urban Maryland
  - 46 grade 6-12 students
  - 3 undergraduates
  - 4 post-doctoral researchers ecology

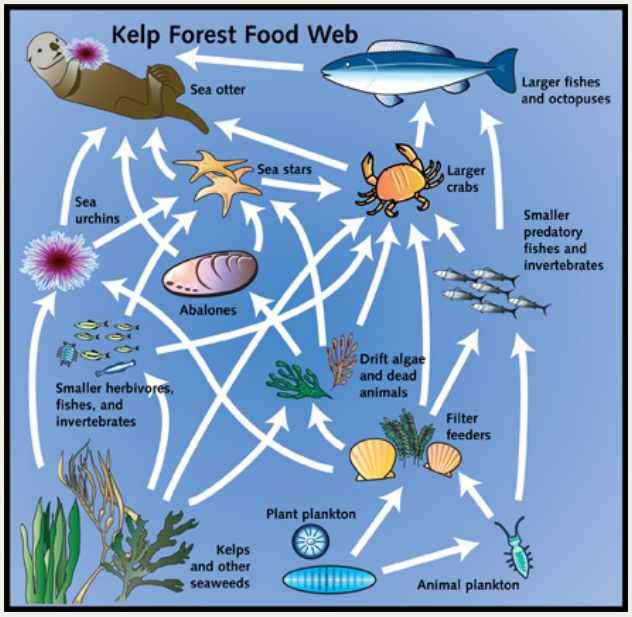


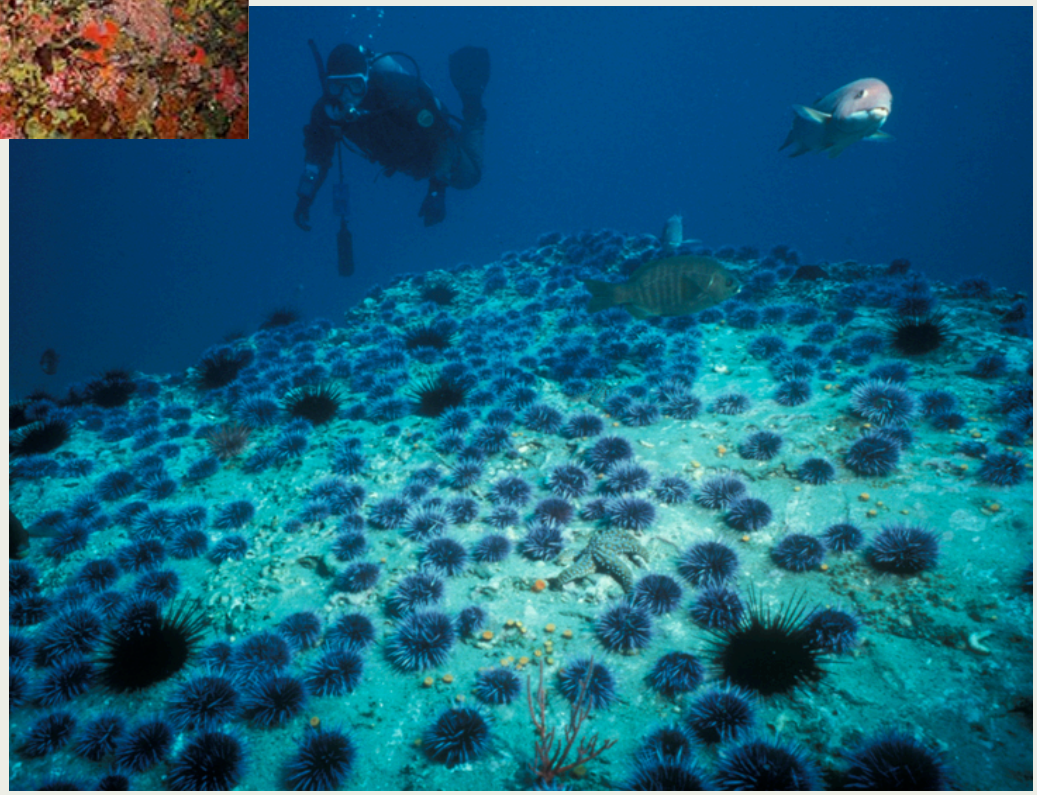
Scenario 1: Python Introduction to the Florida Everglades



Scenario 2: Habitat Fragmentation and Lyme Disease Risk

Scenario 3: Loss of Kelp Forest Habitat





Explaining Ecosystems and Subsystems

Comparison Tasks	Traits of Organisms; Life Cycles	Population Change Over Time and Space	Interactions among Organisms	Interactions among organisms and their environment

Black: Linking processes that students at all levels can tell us about
Green: Upper anchor accounts based on ecological/ systems reasoning
Red: Lower anchor accounts based on anthropomorphic/ teleologic/essentialist reasoning

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Analysis methods

Used grounded theory to look for trends in how students think about:

- How communities are structured
- How individuals, populations, communities, and ecosystems respond to disturbance

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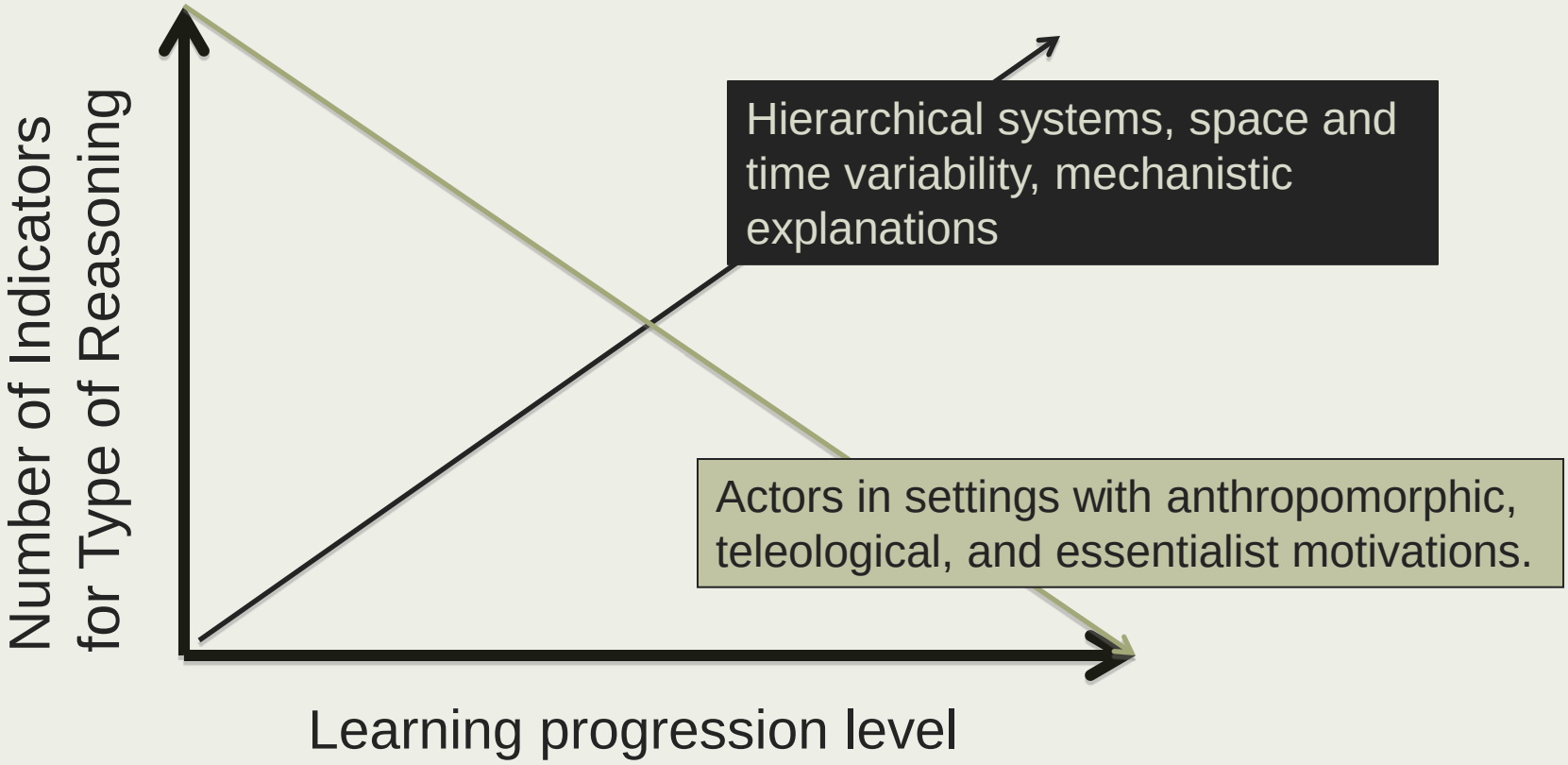
Results



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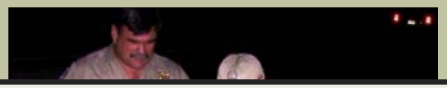
Attributes of Lower Level Responses

Focus on Individual Scale

Human Agency

Drama

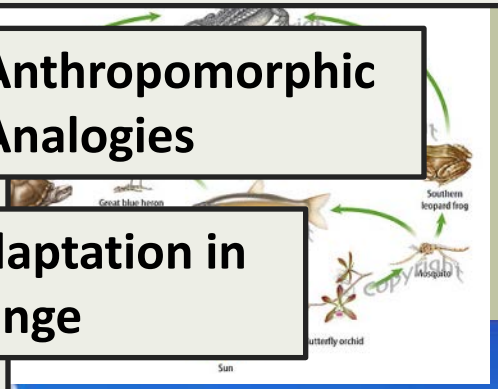
Views environment in terms of general suitability



Direct Interactions Only

Free Will/Want

Anthropomorphic Analogies



Do you think we might see the

Overly simplistic view of response to change

Learning and adaptation in response to change

ome pythons r

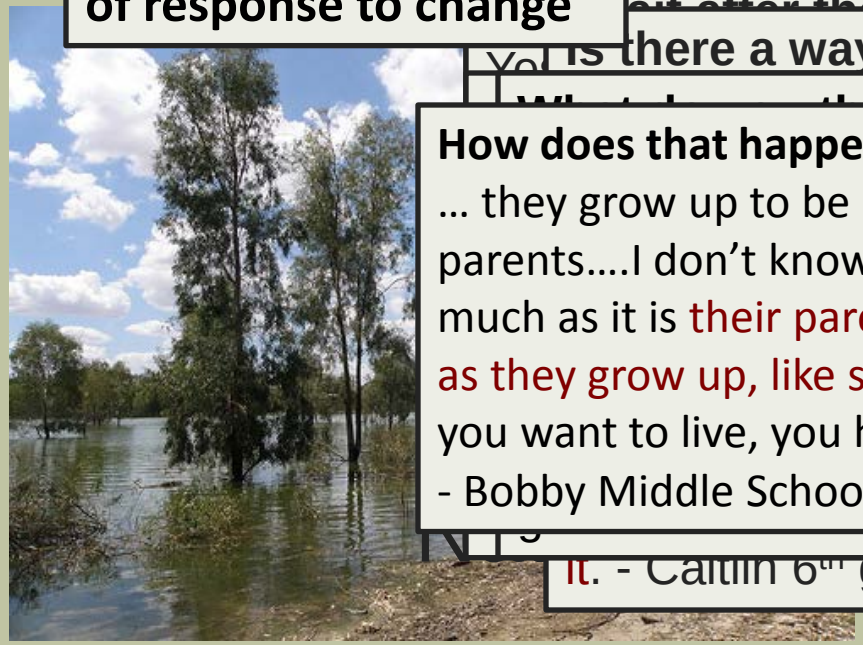
it after they'

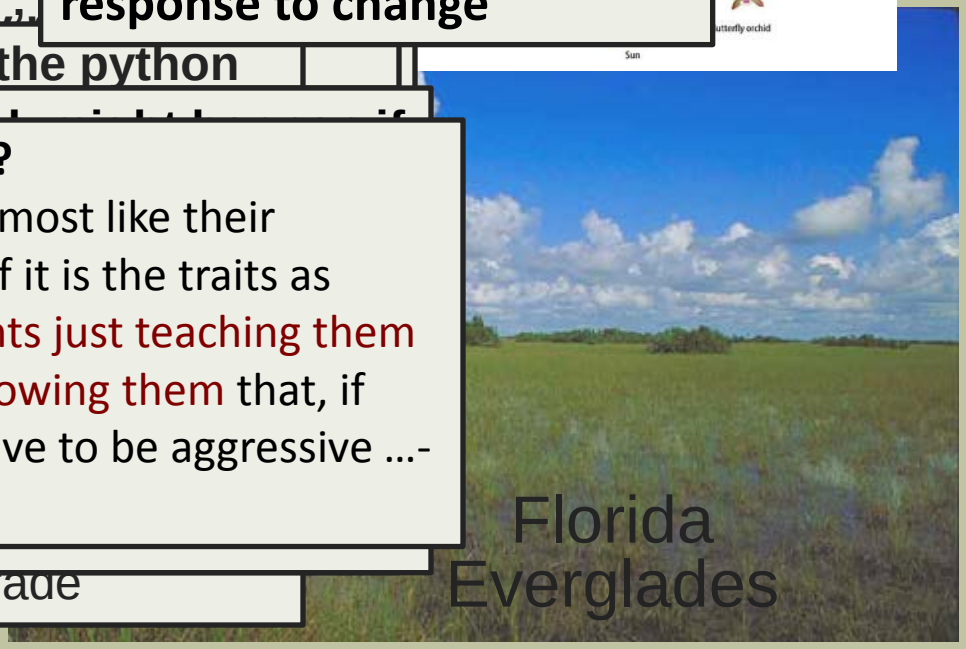
Is there a way the python

How does that happen?

… they grow up to be almost like their parents….I don't know if it is the traits as much as it is their parents just teaching them as they grow up, like showing them that, if you want to live, you have to be aggressive …-- Bobby Middle School

it. - Caitlin 6th grade





Florida Everglades

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Attributes of Upper Level Responses

Microscopic to Ecosystem Scale

Rich abiotic description with spatial and temporal variation

Actions are result of genes X environment, randomness, emergent properties

Relative strengths of interactions, changes in interactions of life cycle

Indirect and Aggregate effects

Functional redundancy

Constraints on ability to

How would you say, using this diagram, that the

So there's these two sibling sets, one in Burma and one in Florida. Would you expect the traits of the baby pythons born in Burma to be different than the traits of the baby pythons born in Florida? No. I imagine they would be the same …. whatever genetics or series of traits that they get from both parents, as well as environmental controls mostly dealing with what resources they're able to gather. Sam - College

Structure of the System

Level	Focal Scale	Description of environment	Description of Interactions	"Why?"
Low	Individual	general suitability, "likes", essentialist, fuzzy distinction of biotic and abiotic factors	direct interactions only, anthropomorphic analogies	free will of organisms, human control
Middle	Population & Community	specific abiotic factors, tolerance ranges of organisms or suitabilities	indirect interactions with links to population regulation	survival and reproduction, life cycle
High	Microscopic to Ecosystem	rich abiotic descriptions including spatial and temporal variation	relative strengths of interactions, changes in interactions over life stages, space or time	Genes X environment + stochasticity

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Change

Level	POV, scale	Causes of change	Responses to change
Low	individual and immediate surroundings	free will of organisms, actions of humans, disruption to the "natural order"	overly simplistic: everything will go exinct, learning
Middle	single populations	"events" with various causes, other organisms	Adaptation with incomplete understanding of natural selection, functional redundancy
High	community and ecosystem, aggregate effects of individuals	events, stochastic factors, variability over time and space, collective actions of multiple organisms	natural selection, dependent on genetic resources and relative pace of change

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Discussion

- The majority of the students we interviewed were at the low level or in transition to the middle level.
- We need citizens to be able use systems based reasoning about disturbance, but it is hard.
  - Link microscopic processes to macroscopic events.
  - Understand variability over life cycle, time, and space.
  - Accept randomness as a structuring element.
  - Reason about emergent processes (e.g. collective effects of individuals).
  - Use principles to constrain reasoning
  - Navigate different contexts (i.e. What are the important essentialist characteristics?, Which analogies are appropriate and which analogies are not in a given context?)

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Characteristics of the lower anchor

- Communities are hierarchically organized (think Great Chain of Being) and include interspecific and intraspecific relationships (think anthropomorphic) among individuals within the environment (think setting of a play) in which they live.
- Although there is larger community, the focus tends to be on a single organism with anthropomorphic characteristics whose actions tend to be based on free will.
- There is a natural order or balance of nature that governs relationships and each kind of organism has essential characteristics and its place in the natural order.
- Disturbances are disruptions to the natural order and the struggle is to return to the status quo.

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Attributes of Middle Level Responses

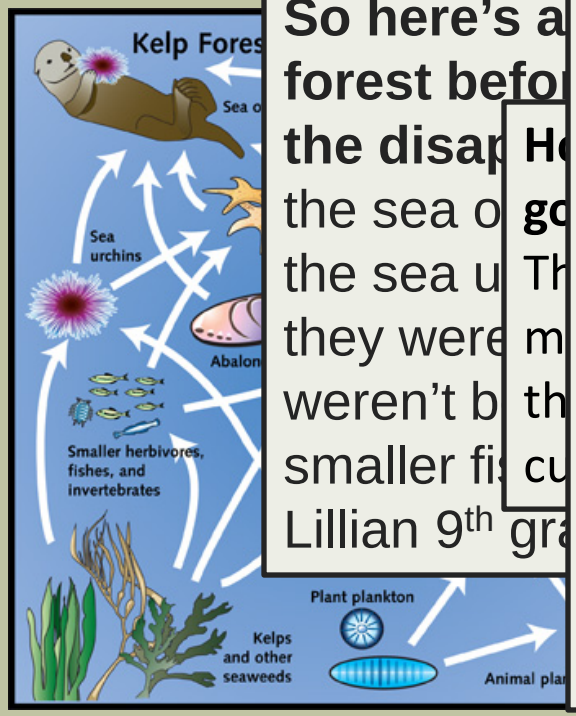
Focus on Populations and Communities

Indirect connections among organism

Links actions to survival, reproduction, changes in population size, life cycle changes, randomness

Organisms can affect environment locally

Mechanism for change, but incorrect NS or unconstrained



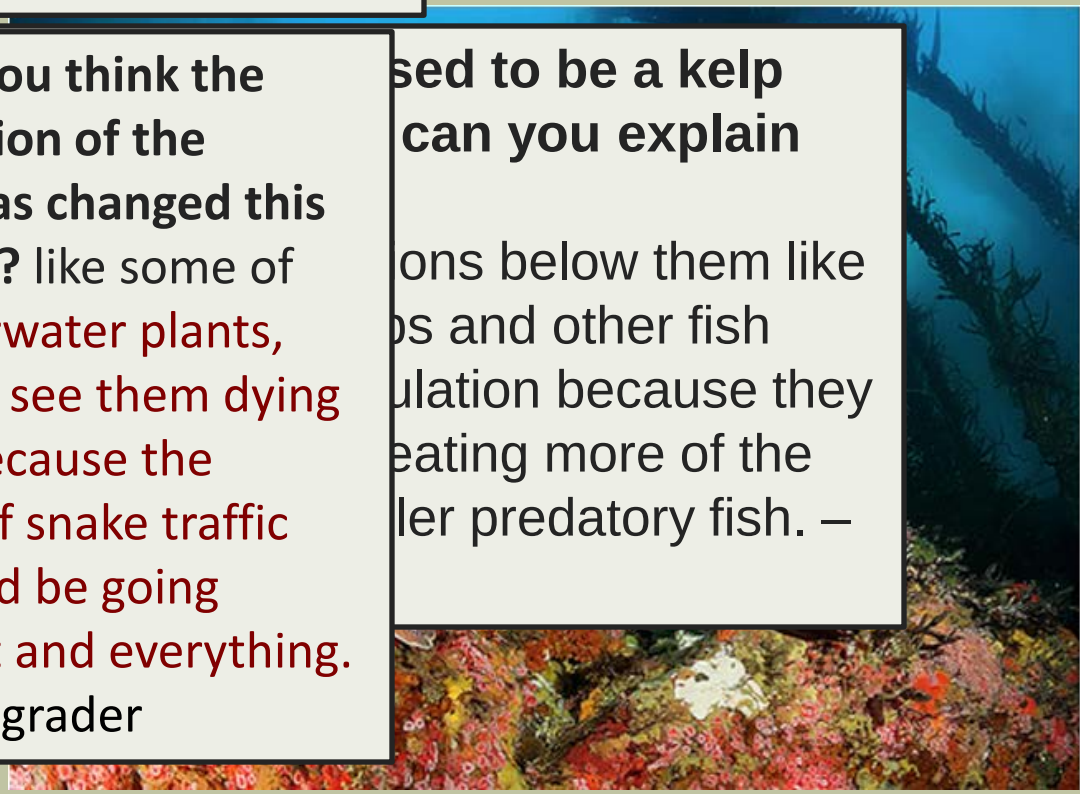
So here's a forest befo the disap the sea o the sea u they were weren't b smaller fi Lillian 9th gra

H g T m th cu

How do you think the introduction of the python has changed this food web? like some of the underwater plants, you could see them dying off just because the amount of snake traffic that would be going through it and everything. Jack 12th grader

sed to be a kelp can you explain

ons below them like s and other fish ulation because they eating more of the ler predatory fish. –



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Characteristics of the Upper Anchor

- Structure of the System
  - Species have central tendencies but are phenotypically and genotypically variable. (contrast to essentialist thinking)
  - Actions of individuals are related to survival and reproduction and are dictated by genetic resources, emergent properties of the system, and stochasticity. (contrast to teleological thinking and anthropomorphic thinking)
  - The environment is hierarchically organized. Matter, energy, and information are important at each scale and can be traced across scale. (contrast to actor within a setting)

- Nature of Change
  - System changes over time and space and has emergent properties. (contrast to “natural order” thinking)
  - Outcome of disturbance is dependent on strength of interactions, genetic resources and plasticity, and relative pace of change among populations (contrast to “returning to balance”)

Learning Progressions for Environmental Literacy

Conclusions

- The majority of the students we interviewed were at the low level or in transition to the middle level.
- We need citizens to be able use systems based reasoning about disturbance, but it is hard.
  - Link microscopic processes to macroscopic events.
  - Understand variability over life cycle, time, and space.
  - Accept randomness as a structuring element.
  - Reason about emergent processes (e.g. collective effects of individuals).
  - Use principles to constrain reasoning (i.e. What are the important essentialist characteristics?, Which analogies are appropriate and which analogies are not in a given context?)
- NGSS focuses on
- Analogies and essentialist ideas are helpful in predicting and explaining, but the upper anchor students
  - can pick out which are appropriate and which are not appropriate for a particular context.
  - Can constrain their use