Key Themes in Education for Sustainability

UNDERSTANDING ECOSYSTEMS

Learning for a Sustainable Future

LSF

CANADIAN SUSTAINABILITY CURRICULUM REVIEW INITIATIVE

Theme: Understanding Ecosystems

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Background

Understanding Ecosystems is one of twelve theme documents that have been prepared to contribute to the review of curriculum policy in Canada. The project supports the United Nations Decade of Education for Sustainable Development call to review current policies and procedures to ensure that students are prepared to meet the current and future challenges we all face. A full project description is available on the Learning for a Sustainable Future (LSF) website www.lsf-lst.ca.

Theme documents follow a template designed for this project. An explanation for the layout and content of the project is found on the LSF website under Curriculum Policy Review.

Revisions of this document occur regularly as new research and learning programs come to light. Comments and contributions to this ongoing process and application and testing of the ideas presented here are encouraged.

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CONTEXT AND DESCRIPTION OF ECOSYSTEMS

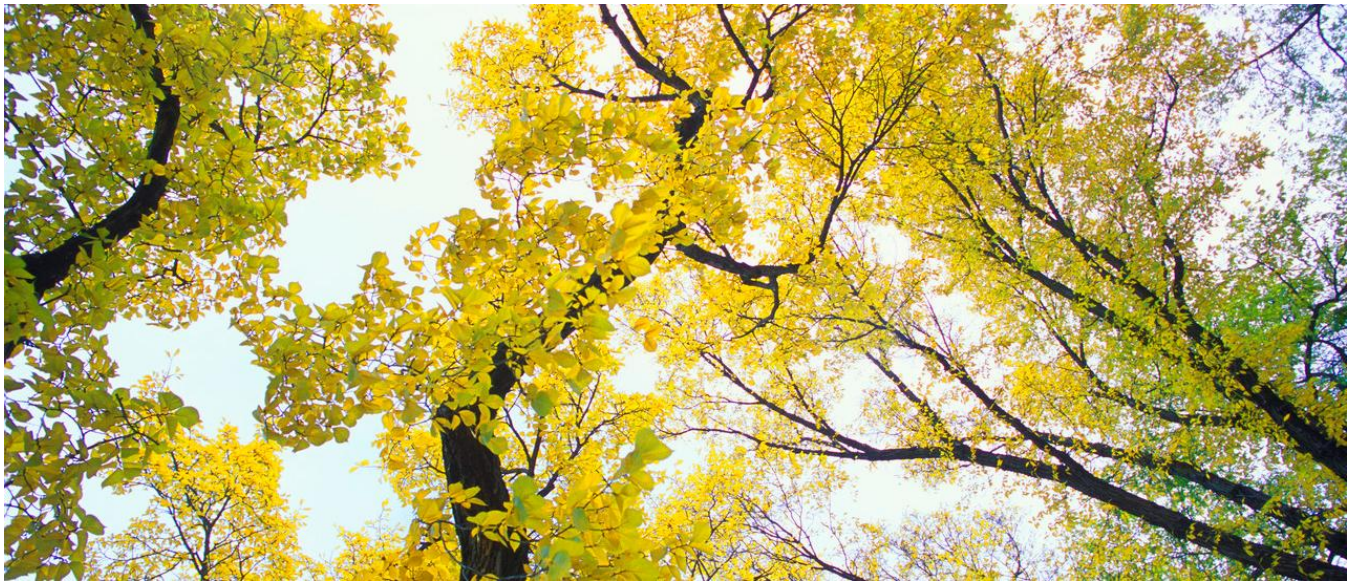
This document is best reviewed and applied along with the related theme Biodiversity.

The study of ecosystems provides insights into how the world works or the rules that govern nature. The traditional approach to ecological education has focused on the discipline of science. With increasing ecological stress evident, linked to aspects of social and economic factors, it is important that curriculum policy evolve to support an interdisciplinary approach to understanding how the world works and the human impact upon it. In this way we have greater opportunity to find and apply solutions to the mounting global ecological challenges.

UNDERSTANDING ECOSYSTEMS – ORGANIZING STRANDS

This document supports an interdisciplinary approach to the study of ecosystems and is organized in the following strands:

1. **Ecosystem Components and Processes**
   - Addresses the ecological science including components of ecosystems and the processes that occur between them.
2. **Human Dependence and Impact on Ecosystems**
   - Identifies how humans are dependent on ecosystems and how in turn they make positive and negative changes to them.
3. **Economic and Ecosystem Interactions**
   - Notes the links between human economic activity and ecosystem components and functioning.
4. **Managing Human Interactions with Ecosystems**
   - Addresses cultural issues, social interaction, and the role of government with ecosystems.



NOTES FOR CURRICULUM DESIGNERS

"At a time when Americans are increasingly facing challenging environmental choices, we learn that our citizenry is by and large both uninformed and misinformed."[1]

Unfortunately, there is no indication that this recent summary of citizen knowledge and perceptions about environmental challenges by citizens in the U.S. does not hold for Canadians as well. There is reason to seriously reconsider our approach to teaching about humans and ecosystems.

An understanding of ecosystems, ecosystem functions, and human dependence and interactions with non-human nature should be a fundamental aspect of each person's knowledge and awareness. The complete dependence of human existence on the natural functions and components of the biosphere currently takes a backseat to human-centered concerns such as the economy and global trade, the advance of technology, and the latest entertainment craze. Meanwhile, as human populations grow and exert their influence on every aspect of ecosystem functioning in every part of the world, the very stability of life itself is increasingly undermined.[2]

Though the ecological challenges facing us are daunting, curriculum policy needs to carefully consider what is appropriate and beneficial for children to be exposed to as their views of the world mature. Introducing children of a young age to ecological problems can lead to 'ecophobia'[3] and should be avoided until middle school and high school. Consequently, in grades 1- 6 we advocate for curriculum policy that leads to an understanding of how the world works based on local contexts and experiences, leaving the depth of the human impact on ecosystems to grades 7- 9, with further exploration of its complexity during grades 10- 12.

Curriculum policy developers need to ensure that teachers do not have to make choices about what to teach about ecosystems. Policy should avoid an overemphasis on imparting information and focus on developing conceptual understanding of ecosystems and sustainability.[4]

The instructional direction for teachers should be clear; learning should be interdisciplinary and connected to the students' daily lives, with many opportunities to develop insightful relationships with the natural environment through experiences that take place outdoors.

Instead of promoting particular views on ecosystem issues, teachers need to facilitate student access to, and investigation of, the range of positions on any issue. Contradictions, such as calls for consumption and conservation in the media, abound in the students' lives and should be addressed, not left for the students to sort out on their own. The social and emotional realms are important aspects of inquiry and should not be avoided simply because they are difficult to tackle or contrary to the practices that teachers have adopted in their personal lives.

As students mature, a number of age-related issues need to be considered for each grade group:

Grades 10 to 12

- Recently published popular literature investigating historical cases of unsuccessful human relationships with the ecosystems within which they were located (e.g. Easter Island, the Anasazi, the Mayans, and the Greenland Norse); provide learning opportunities and a basis on which to compare current practices.[5]

- Comparative case studies (such as the unsuccessful case of forestry fire-prevention practices in North America, and the successful case of oyster production in France) provide insights into the complexity and difficulty of addressing human-ecosystem interactions.

Grades 7 to 9

- During these years, student learning should progress from the study of individual organisms to the study of patterns in the natural world.[6]

- An emphasis should be placed on analysing food webs and following the flow of matter through them. Studying local food webs provides a concrete starting place for these investigations.[7]

- Students should be introduced to the transfer of energy that occurs as one organism eats another. A beginning point for understanding energy transfer is an understanding of the differences between how plants and animals obtain food and from it the energy they need.[8]

- Ecologically related project-based learning can assist students in the development of critical design, observation, and analysis skills. [9]

- Middle-school students are generally aware of science-technology-society issues from the media, but their awareness is fraught with misunderstandings. Teachers should begin developing student understanding with concrete and personal examples that avoid an exclusive focus on problems.[10]

- An analysis of the risks and benefits to human health and the survival of other species that are associated with common products and technologies can begin to challenge students' thinking during these grades.[11]

Grades 4 to 6

- Fieldtrips to a variety of local natural environments (woodlot, stream, wetland, and park) provide opportunities to investigate the similarities and differences between these environments and the living things that are found in each.

- Introduce students to the negative and positive interactions between people and the local ecosystem but take care not to overburden them with environmental problems. Instead, focus on observable issues and engage students in personal, concrete actions that can be pursued to address the issue and influence their communities.[12]

- Encourage students to begin to question where substances come from and where they go when they are finished being used. As this line of questioning evolves, students should begin to realize that substances do not appear from nowhere nor do they simply disappear. Rather, substances change form and move from place to place.[13]

Grades 1 to 3

- Student learning should focus on individual organisms, the simple interactions[14] and dependences within their habitats and the differences that help them survive.

- Teachers should make every attempt to avoid promoting the misconception that plants get food from soil. The big picture of energy flow and matter cycling grows slowly over time for students and, in their early years, the temptation to simplify matters by saying plants get food from the soil should be resisted.[15]

- During these early grades, students tend to be concrete thinkers with a curiosity for the natural world. An overall goal during these years should be to provide students with numerous opportunities to observe, explore and play in the natural environment.[16]

- When introducing environmental issues to these early grades, it is imperative that they be kept simple and local.[17] Do not overburden these young learners with major global problems.

- An awareness of recycling, both in nature and in human societies, may play a helpful role in the development of children's thinking. Familiarity with the recycling of materials fosters the notion that matter continues to exist even though it changes from one form to another.[18]

Grade Grouping: Grades 10 to 12

Exemplary Learning Skills	Developmental Readiness and Major Misconceptions
Sustainability of Ecosystems: A Historical Approach M. Soni a Guelph Ontario teacher starts her Grade 10 class study of ecosystems with the reading of Ronald Wright's book *A Short History of Progress* that examines historical examples of societal collapse due to human induced ecosystem degradation. Films are used to supplement and examine in detail key issues related to ecosystem sustainability. Speakers from the community address the class on related local issues and students attend local events relevant to the topic (a conference, land planning hearing, or a municipally organized public meeting). The unit of study concludes with individual student projects examining current practices that have ecological impact and the ways of addressing these. The projects are presented to the class and a panel of local officials. **Main Instructional Methods Employed:** • co-operative learning/jigsaw • online learning • real world issues • project-based learning • audience beyond the classroom **Forestry Webquest** http://www.edu.pe.ca/rural/class_webs/conservation/forestry_webquest.htm - viewed September 25 2006 Groups of students in the P.E.I. course research the positive impacts of forests and tress and create a slideshow to present to the school officials with the intent of persuading them to protect school green spaces. Students have different roles in the group and present the argument from the side of a student, teacher, environmentalist and citizen. **Main Instructional Methods Employed:** • co-operative learning • online learning • project-based learning • real world issues Relevance of this program would be enhanced if the work of these students was directed to an actual forestry challenge occurring in the province.	**Developmental Readiness** • At this level students can apply their understanding of atoms and molecules to link the conservation of matter and energy flow in ecosystems.[19] **Major Misconceptions** • Many think that some government ministry is ensuring that human activity does not seriously harm ecosystems upon which we depend. /Government ministries have limited mandates and often are unable to prevent ecological degradation. • Many think that claims by the majority of the scientific community that humans are having a significant and dangerous affect on global ecosystems are speculation only. / The global scientific community comes to positions such as those on climate change, based on the best information and accepted procedures that science as a discipline has to offer.[20] • Technological solutions will solve our ecological problems. /Technological solutions will only be one of several necessary responses. Resolution lies more with dealing with moral considerations by those in the affluent world[21] and political transformation.[22] Depending on technology is an expression of faith that negates the record that improvements in technology can cause problems as well as solve them.[23]

Grade Grouping: Grades 10 to 12

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
Ecosystem Components and Processes • Ecosystems consist of both living and non-living components and their interactions. They are so complex that it is not always possible to predict the affect of change in one part on another. System characteristics of ecosystems include: interdependence of parts, feedback, oscillation, inputs, and outputs.[24] • The population of any particular species in an ecosystem is determined by many factors (the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials).[25] • Since the amount of energy available at each stage in a food chain diminishes, the number or total mass of all producers in an ecosystem is greater than all the herbivores. Similarly the number of carnivores is always less than the number of herbivores. • Living things are important components in the carbon cycle. During photosynthesis, plants use atmospheric carbon dioxide to store energy in sugars and release oxygen. In turn, when plants or animals use these sugars during respiration, energy is released, oxygen is used and carbon dioxide is produced. This interaction of plants and animals influences atmospheric carbon dioxide levels. [26] • Atoms and molecules cycle amongst and between the living and non-living components of the biosphere.[27] Chemical elements are recombined in different ways as they pass through food webs. At each link in a food web, some energy is stored in newly made structures but much is lost to the surroundings as heat. Continual input of energy from sunlight keeps the process going.[28] • Ecosystems tend to have cyclical fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.[29] **Human Dependence and Impact on Ecosystems** • Human societies are dependent on the resources available from ecosystems and the capacity of ecosystems to absorb waste products, both of which are limited.[30] • Human populations are exceeding the capacity of ecosystems to support them in many parts of the world. Historically, whenever this has occurred people have either moved to a new region, engaged in conflict, or suffered a drop in population due to starvation, disease, or other factors.[31] • The degree of negative impact on ecosystems resulting from human activity is a function of population, rates of consumption, and the use of technology and is related to the direct harvesting of plants and animals, agriculture, mining, use of energy, release waste including chemical pollutants, and urban sprawl.[32] • Human activity is now such that it has global ecological impact however ecosystem characteristics, such as lag times, cloud our perception of this human-induced influence.[33] • Non-human nature inspires peoples' creative acts, thoughts, and feelings. Many minority worldviews provide alternatives to the prevailing one that humans are meant to dominate nature.[34]	**Securing Information** • Use the business section of the newspaper to determine ecological views held by this sector. **Communication** • Correctly use the following terms verbally and in writing: photosynthesis, respiration, ecosystem, oscillation, biosphere, and interdependence. **Measurement and Data** • Use geographic tools to access and interpret past and present ecosystem patterns and forecast the future. **Analysis** • Determine the economic and ecosystem impacts of a resource project (construction of a new dam, exploitation of a mineral resource, a new global trade agreement). **Evaluation** • Identify the factors that influence the source of electricity that people use. Prepare a position paper for the decisions made in your household.[42] **Plan/Design/Build** • Identify opportunities to reduce the use of resources through repair and reuse of machinery and equipment as an alternative to purchasing new items. Promote these in the community.

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
Economics and Ecosystem Interactions • Ecosystems provide humans with services (flood prevention, pollination of crops, aesthetic enjoyment, cleaning the air and water) that are not taken into consideration in economic terms. Full cost accounting is one means of addressing this imbalance. • Mainstream economic practices usually lead to the depletion of commonly held resources or the disruption of ecosystem services. It is often economically beneficial to maximize private returns by depleting commonly held resources (common grazing land, fresh water, wild stocks, and public forests). Business works to maximize returns by directing costs to others while privatizing profits.[35] • Technology increases the ability of people to access ecosystem resources. Advertising increases the desire by people to use more resources. Together these forces exert tremendous pressure on ecosystems with little feedback. • Alternative economic practices provide some means of maintaining ecosystem health and meeting human wants and needs (fair trade, local consumption, sustainable forestry, and community shared agriculture). **Managing Human Interactions with Ecosystems** • Reductions in ecological impact can be achieved through a wide variety of means including technological efficiency, voluntary reductions in consumption, pricing/taxation, quotas, or use of alternative technology. Some are more effective than others and some are not often considered.[36] • Decisions that have an impact on ecosystems of one generation can expand or limit the possibilities of the next generation. [37] • Governments can reduce the impact of human activity on ecosystems through a variety of measures (direct expenditures, taxation and tax breaks, regulations, volunteer measures, subsidies, rationing, incentives, defining property rights, establishing pollution trading markets, and participation in international treaties and international organizations). At present these are not being applied effectively for most ecological problems. • Scientific observations provide examples of past experiences and evidence of current human impact on ecosystems. These are not always heeded by society. It is common for some groups to attempt to undermine scientific findings if those findings are counter to the group's short-term interests.[38] • Competition for resources has lead to conflict.[39] Oil is the single largest energy source used worldwide leading to concerns about economic, climate and civil security.[40] • There are many examples of governments, non-governmental organizations, corporations, and individuals taking steps to address the current human ecological crisis.[41]	

Grade Grouping: Grades 10 to 12

Societal Perspectives	Classroom Level Instructional Notes
• Ecosystems are complex and are not yet fully understood; we should adopt the precautionary principle because of this lack of understanding. / People have a right to invent and use technology to solve problems and stay competitive regardless as to how they might impact ecosystems. • Human beings are not separate from the natural environment but rather a part of it. / The world was created for people and we can do with it as we please. • Wilderness should be preserved. / Wilderness is there to be exploited to keep the economy running and people employed. • We should come to know and respect the local ecosystem in which we live. / Human created environments and endeavours dominate and are what is most important. • Humans must recognize their responsibility to future generations. / Future generations will have to solve their problems just as we are solving ours. • Population declines due to personal choices will have a negative effect on the economy. Immigration rates should be increased to overcome this. / The ecological capacity of Canada to accommodate a population should be the main criteria for determining the population we should have. • As humans we are entrusted with the stewardship of the natural world and other living things. / The economy selects the fittest and determines what should continue to exist. • Polluters should be required to pay for the damage they create. / Excessive environmental laws have a negative impact on the economy and do not allow us to compete against others.	• Compare the ecological, social and economic status and future of Haiti and the Dominican Republic as a means of gaining insight into the challenges of sustainability. • Use case studies to evaluate the impact of natural processes and human-induced changes on communities (e.g. collapse of the northern cod). • Identify current and past examples of societies that have suffered due to ecological mismanagement (e.g. Easter Island, Mayans, Anasazi, and Greenland Norse).[43] • Use case studies that provide examples of how individuals, businesses, or groups are moving toward sustainable living. • Have students use an Ecological Footprint calculator to determine their footprint. Identify the ecological footprints of those living in other nations. Through research and discussion identify the rationale that people use to justify the differences in ecological footprint that exist.[44] • Identify and promote members of the community or groups who have made positive contributions to ecosystem conservation or restoration and engage in activities to share their contributions[45] • Site examples of how the introduction of foreign species has changed local ecosystems and how this has positively or negatively impacted local biodiversity, agriculture, and other human activity.[46] • Survey and interview members of the community to determine their awareness of ecosystem importance, local stress on ecosystems, impacts of development and species extinction due to human influence. • Write a report using newspapers, magazines and other popular media about the issues being popularized by media concerning ecosystems. Compare these results to what the scientific research indicates. Are they similar or different? • Identify the process of applying for development of an area and the environmental assessments that are carried out before the permit is given. Interview people whose job it is to identify the potential impact on an ecosystem. • Take students to a section of the schoolyard with a variety of living things. Assign them each a square meter to study, note living and non-living things and photograph digitally. Back in the class the research group uses any information resources available to prepare a chart paper diagram of the one square meter showing how carbon compounds enter and leave. Include the processes of photosynthesis, respiration of food and decomposition. Present in groups.

Grade Grouping: Grades 7 to 9

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
The Biosphere Challenge: Developing Ecological Literacy[47] *"Create whatever you think has to happen so that multiple generations of spiders can live inside a sealed 20-liter container."* Students are presented with this challenge as the first activity in their ecology unit and continue to revisit it as their understanding of ecosystems develops. On the first day of this project, students gather at a local natural area to create their biospheres. Once the sealed biospheres have been created, they are placed in the classroom and students are invited to observe and compare their biospheres as the ecology unit progresses. During the course of the unit, students are given several opportunities to unseal their containers and apply what they have learned about ecosystem functioning to their biosphere. **Main Instructional Tools Employed:** • activity-based learning • inquiry **Schoolyard Ecosystems** http://www.kfs.ucalgary.ca/schoolyard.php#1 Ecosystems develop and are maintained by natural processes and are affected by human action. To foster an understanding of ecosystems, this unit develops student awareness of ecosystem components and interactions, as well as natural cycles and processes of change. Building on this knowledge, students investigate human impacts and engage in studies that involve environmental monitoring and research. By reflecting on their findings, students become aware of the intended consequences of human activity, and recognize the need for responsible decision-making and action. **Main Instructional Tools Employed:** • integrated learning • inquiry • activity based learning **3. What About Shady Acres?** http://www.cpawscalgary.org/education/pics/shady-acres05.pdf#search=%22%22what%20about%20shady%20acres%22%22	**Developmental Readiness** • Students understand ecosystems and the interactions between organisms and environments well enough by this stage to introduce ideas about matter and energy flow. Students explain concepts such as community and competition between organisms in terms of their own experiences rather than scientific explanations. Teachers can use these to build toward more scientific understandings.[48] • These students begin to develop a more conceptual understanding of environmental problems and are able to study issues of a larger and more abstract nature.[49] **Major Misconceptions** • Many think that most environmental problems are the fault of industry or municipalities and that action should be directed at these sectors. /At one time larger companies and institutions were the leading cause of environmental problems but today's leading problems are the collective result of individual actions and choices.[50] • Many think that matter is not conserved. / Many students see food webs and cycles as involving the creation and destruction of matter, rather than the breakdown and reassembly of invisible units.[51] • Many think that 'food' refers to the nutrients that plants and animals must take in so that they may grow and survive./ The term "food" poses a problem for many students because they do not distinguish between the scientific and common use of the term.[52] • Many think that natural substances are not pollutants./ Many naturally occurring materials can be harmful depending on concentration (mercury, radon, lead etc) while some naturally occurring biological agents (pollen and mould) can have negative health effects.[53] • Many think that humans are very different from other living things and are not subject to the same laws of ecology. / Humans share all similar biological processes with other living things and are more alike than different. Our use of technology has allowed us to utilize the natural

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
In the first activity, students work through the process of municipal government to decide on the future of Shady Acres: they decide whether to preserve the Shady Acres natural area, an untouched forest that provides shade, peace, and homes for animals; or to create the Shady Acres subdivision, providing much-needed economic development and affordable housing for humans. Subsequent activities teach students about the nature and the implications of compromise; encourage students to reflect on their feelings about nature by bringing them outdoors; and empower students to take action by introducing them to the power of letter-writing campaigns. **Main Instructional Tools Employed:** • case Studies • cooperative learning • real World Issues	world for our own benefit over that of other species however when it comes to basic needs we are still ultimately dependent on limited natural sources.[54] • Many think that oceans are limitless resources. / Accumulation of pollutants in coastal marine communities and worldwide declines in almost all commercial fish populations do not support this view.[55] • Many think that ecosystems and economic systems are not directly linked. /All economic activity takes place within the context of the environment. Major disruptions in economic activity have occurred in the past due to a disregard of ecological limits. Unfortunately, these experiences have not modified modern economic practices.[56] • Many think that ecosystems do not change over time unless negatively impacted by human interactions. /Though ecosystems can remain stable for long periods of time, change is an ongoing process in most ecosystems in response to variations in climatic and other conditions.[57]

Grade Grouping: Grades 7 to 9

Fundamental Concepts

By the end of this level of schooling, students should know:

Ecosystem Components and Processes

- An ecosystem consists of all the living and non-living components of a natural community and their interactions. Many ecosystems are very complex and are not fully understood.[58]
- Producers use a process called photosynthesis to produce food from light energy, water, and carbon dioxide. The food produced is used by the plant for growth and for energy to carry out plant processes.
- Consumers are animals that eat plants or other animals to obtain materials for growth and maintenance of body systems, and energy for movement and heat. Decomposers (primarily bacteria and fungi) are consumers that use waste materials and dead organisms for food .[59]
- The matter that makes up living things is used over and over again as it moves back and forth amongst organisms and the surroundings. The total amount of matter remains constant, even though its form and location change.[60]
- The energy that living things use changes form as it moves from plants to animals to decomposers. The total amount of energy decrease with use by each life form due to losses in the form of heat. The continuous input of energy into ecosystems as a result of plants capturing sunlight during photosynthesis allows life processes to continue.[61]
- The number of living things (including people) that can exist in an area (carrying capacity) is limited by the nutrients, space, water, and energy available to them.[62]
- The number of living things in an area increases and decreases cyclically, depending on reproduction rates and death rates (which are related to the availability of resources). Due to resource depletion, a very large increase in population invariably leads to a population decline.[63]
- All ecosystems undergo changes. Due to ecosystem complexity, the effect of changes on ecosystems cannot always be anticipated . Living things currently found in an area are often different from those that were found there in the past.[64]

Human Dependence and Impact on Ecosystems

- The impact of human activity on ecosystems is a function of population level, rates of consumption, and technological capability. Each person has an ecological footprint or effect determined by their consumption rate.[65]
- As the overall human population increases, it reduces the number of other living things that exist.[66]
- Human activity is causing negative changes in every ecosystem on the planet (either directly or indirectly), which is reducing the overall ability of ecosystems to support life.[67]
- People benefit from various ecosystem functions that cannot readily be replaced if lost (e.g. wetlands and groundwater recharge, forests, transpiration and rainfall).
- The current dominant worldview supports people exploiting non-human nature with little regard for its well-being. Perspectives held by others are less human-centred and support the view that humans are a part of nature and not above it.[68]

Related Skills

Securing Information

- Use a variety of information sources to examine the range of views on an environmental issue. Evaluate the credibility and reliability of various sources.

Communication

- Correctly use the following terms verbally and in writing: carrying capacity, population, succession, ecological footprint, energy, matter, photosynthesis, sustainable.

Measurement and Data

- Apply probability estimates to risks and compare them to estimated personal and social benefits.[76]

Analysis

- Analyze the positions of various groups and stakeholders for bias in regards to a chosen environmental issue.

Evaluation

- Evaluate media messages for their underlying assumptions about human/ecosystem interactions.

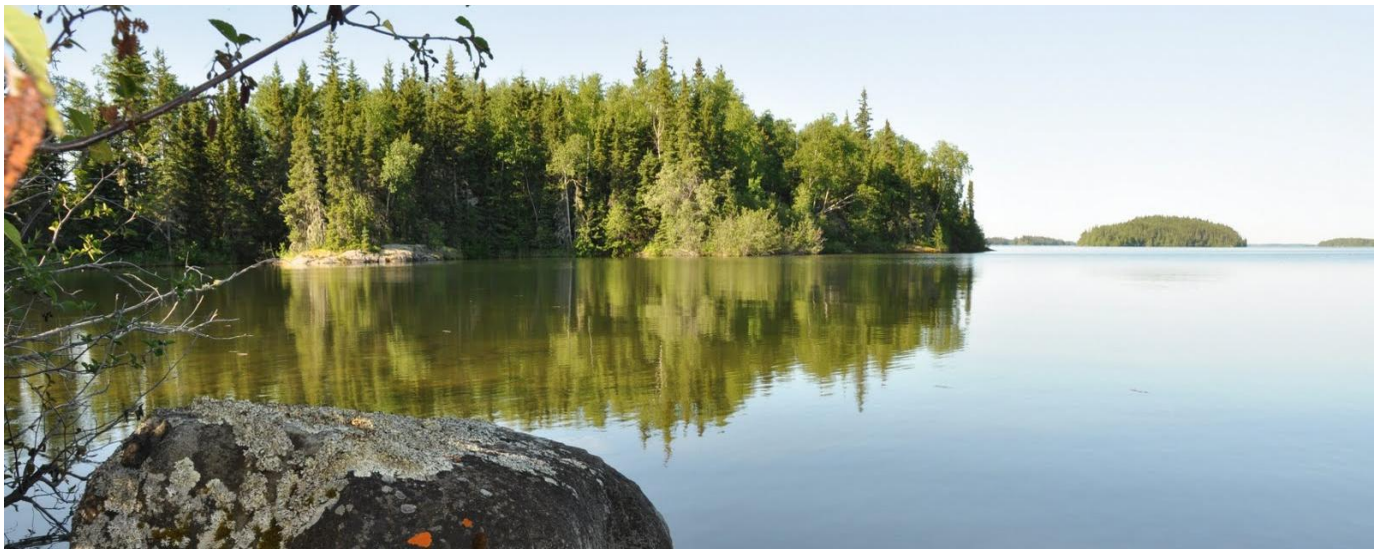
Plan/Design/Build

- Research the issue of automobile use by students and their families getting to and from school. Design a campaign to increase the use of alternative means of transportation.

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
Economics, Technology and Ecosystem Interactions • Primary industries (forestry, agriculture, fishing, and mining) use and advance technology in order to secure the natural resources they need from ecosystems. As technology has improved, so has the capability of people to exploit resources from all parts of the world, thus increasing the overall human impact.[69] • Increases in economic activity almost always result in greater negative impact on ecosystems. Standard business practices and government policies that support them do not include the costs to ecosystems in the purchase cost of goods and services. As a result, common resources such as air and water are degraded, and wild stocks are depleted.[70] • Every technology has the potential to solve and cause problems. Following the Precautionary Principle has been proposed as a means of ensuring that the potential harm caused by new technology is not greater than the benefits.[71] • International trade extends the ecological impact of economic activity.[72] **Managing Human Interactions with Ecosystems** • As human populations continue to rise, global competition for limited ecological resources increases. The fundamental crisis of increasing human demand and decreasing capacity of ecological systems to meet it is not being addressed adequately.[73] • Governments at all levels (municipal to international) have a variety of mechanisms to manage use of natural resources and human impact on ecosystems (taxation, regulation, and subsidization, creation of parks and reserves, voluntary compliance programs). Some are more effective than others and some are never used to address an ecological problem. • The corporate sector has the capacity to apply business practices and innovation to meet human needs sustainably. The government intervention usually needed to initiate this change in perspective is often severely resisted through various forms of political participation.[74] • Non-governmental organizations play an important role in identifying ecological problems, developing solutions, communicating these to the public and leading the call for governments to act.[75]	

Grade Grouping: Grades 7 to 9

Societal Perspectives	Classroom Level Instructional Notes
• Government has to play a greater role in directing how people use natural resources, so as to control fair access, reduce ecological impact, and prevent resource depletion. / The economy is the best tool to control the use of natural resources. • We should follow the Precautionary Principle when deciding if a technology (product or process) should be used. / Developers of new products and processes have the right to use them if they can be sold in the marketplace and should not be deterred from doing so. • Individuals can and should make changes in how they live in order to solve environmental problems. / The solution to environmental problems rests at the community level otherwise it will not occur fairly or effectively. • The world's population is currently excessive and needs to be reduced in order to avoid ecological collapse. / The world can still accommodate more humans and this is good for the economy. Technology will solve the problems as they occur. • The natural world is alive with many different living things that have an inherent right to exist. We should work to ensure this occurs. / Living things are only as important as their usefulness to humans. • The natural world is here for people to use as they see fit. / People are only one part of the world and should share it with other living things.	• Explore the change in regional ecological communities over the past 200 years and identify the human activities involved in the changes that have taken place. Determine what the best course would be for the future. • Identify and analyze a local ecological restoration project. Take steps to participate in its work.[77] • Conduct case studies of resource use in the past and present.[78] • Follow the production of some item back to its source and determine the social and ecological impact at each stage. Identify alternatives.[79] • Select a waste item that is included in a local recycling program. Investigate how the practice of recycling impacts a specific ecosystem. Share the finding with others. • Have students use an Ecological Footprint calculator and plan how they can reduce their impact without affecting their quality of life.[80] • Trace matter as it moves in and out and through the ecosystem. Display the results in mural form. The food webs that students investigate should first be local ones they can study directly.[81] • Create a closed ecosystem in the classroom as a means of simplifying and studying ecosystem components and interactions.[82] • Use case studies of historical examples of human use of natural resources (buffalo, passenger pigeon, North American temperate forest).



Grade Grouping: Grades 4 to 6

Exemplary Learning Skills	Developmental Readiness and Major Misconceptions
Investigating Local Natural Areas Within a twenty minute walk of the school is a small remnant woodlot managed by the municipality. This site is used as the focus of the study of natural communities. Trips are made to the woodlot several times throughout the year, including excursions simply to enjoy the natural setting for a lunch picnic and some reading. During the first trip, a local field naturalist accompanies the class to the site to gain insight into its ecological richness and learn the names of some of the common plants and animals. A later trip usually focuses on some practical work that helps restore the site (as simple as trash pick up or removal of same alien species). In the classroom, learning activities relate back to the fieldtrips and include students making field guides for common living things found at the site. Students conclude their study by sharing what they have learned with others through communication activities such as postcard writing to woodlot neighbours or three-panel displays put up in the local library. Many students return to the site out of school time with members of their families to continue to enjoy what they have discovered. **Main Instructional Tools employed:** • fieldtrip • activity-based learning • service learning • audience beyond the classroom • disciplinary process • integrated learning **Visiting a Meadow Habitat: An introduction to Field Study** http://www.wildlifehc.org/managementtools/backyard-pollinators.cfm This field journal may be used to introduce students to the concepts of butterflies, other pollinators and their meadow habitat. This journal, to be used on a visit to a meadow habitat in your area, is designed to be incorporated into existing curricula on insects, ecosystems, animal studies or habitats. It should not function as a stand-alone "field trip" experience, but rather, be part of a logical sequence of planned hands-on activities, content sessions and experiences that immerse the student in a topic area. A Student field guide for this activity and teachers guide book is available for downloading. **Main Instructional Tools Employed:** • activity based learning • integrated learning • field trip	**Developmental Readiness** • The concept of biological energy transfer is too complicated for this grade group. Start students on chains of what eats what in various environments but avoid labeling the steps in the chain as energy transfer.[83] • Understanding that plants produce their own food using light energy is sufficient for this grade group. The photosynthetic process involved in plants making their own food is very difficult for elementary students and should be saved for middle school.[84] • Students find it difficult to connect living systems at this age. For example the connection between a cows, grass, human beings and decomposing bacteria is seen as they call grow.[85] • Student focus on the visual parts of systems and find it difficult to understand microscopic ideas.[86] **Misconceptions** • Many think that 'food' is material that living things take in or eat to grow and survive. / To qualify as food in the scientific use of the term, ingested material must provide the living thing with both energy and building materials. The term "food" poses a problem for many students because they do not distinguish between the scientific and common use of the term.[87] • Many think that plants get their food from soil. /This misconception often arises during the early years of education and it is particularly resistant to change.[88] Students may form this misconception due to the common usage of the term 'plant food' when referring to fertilizers.[89] During these grades, students should begin to understand that plants produce their own food using energy from sunlight. Simple class hands-on activities such growing plants with and without soil and sunlight should help to demonstrate how plants get their food.

Grade Grouping: Grades 4 to 6

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
Ecosystem Components and Processes • Each living thing can only survive where it can get its basic needs (water, air, food, space, and light for plants). [90] • A group of living things that is found in a particular area forms a community. Each natural community consists of the particular living things (plants and animals) and non-living things (water, warmth, light, air, nutrients, and climate) found there.[91] • Plants are the only living things that can produce their own food using the energy from sunlight. This food is the only source of energy for the plant.[92] • Animals depend on plants and other animals for their food. This food is the source of energy for the animal.[93] • Materials are continually being exchanged between the living and non-living parts of the environment. Living things grow, die, decompose and are used again by other living things. Soil life is important in this recycling of materials.[94] • All living things and non-living things have an effect on each other. The interactions of plants, animals, and the non-living things around them can be either helpful or harmful to themselves and others.[95] **Human Dependence and Impact on Ecosystems** • People get everything they need from the world around them. The use of various tools and techniques makes this easier than in the past.[96] • Every time people take something for their use from the world around them it has an effect on other living things. • The natural world provides people with many non-material benefits including beauty and inspiration, places for solitude, quiet and relaxation, and places for outdoor recreation. Being in natural surroundings provides many people with feelings of well-being. • People have diverse perspectives, beliefs and ways of interacting with non-human nature.[97] **Economics and Ecosystem Interactions** • The supply of all the resources (energy sources, soil, food, water, forest products and minerals) used by people in agriculture, forestry, fishing, and mining come from the world around us and is limited.[98] • The technology that we use to get, process, and transport resources often has drawbacks as well as benefits. A technology that helps some people or organisms may hurt others-either deliberately (as weapons can) or inadvertently (as pesticides can).[99] • In order to increase employment and economic activity, businesses use many practices to encourage people to buy more resources than they need. Almost all economic activity has some negative impact on other living things. • All waste materials people create are returned to the world around us. This often has a negative effect on the quality of the environment. Those who create	**Securing Information** • Use field guides to identify plants and animals found in local natural areas. • Survey family members to identify individual needs and wants. **Communication** • Correctly use the following terms verbally and in writing: habitat, community, decomposition, recycling, compost/humus, food chain, resource. • Create a field guide for a local natural area or naturalized area of the schoolyard. Use it to lead younger students on a tour. **Measurement and Data** • Conduct a field investigation to compare the number of different kinds of plants found in different local communities (e.g. lawn versus old growth field). Graphically present the results. **Analysis** • List the benefits and drawbacks of various technologies (e.g. automobiles, lawn mowers, bicycles, water saving shower heads). **Evaluation** • Determine the impact of lunch options on other living things and identify alternative choices. **Plan/Design/Build** • Develop a plan for reducing resource use and waste within the classroom and the school. Put this plan into action. • Create a pamphlet to communicate with parents the alternatives to the contents of student lunches that have serious environmental impacts.

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
air, water and solid waste pollution often do so with having to pay for their actions or clean up. **Managing Human Interactions With Ecosystems** • Using a variety of approaches, many people work to help wild plants, animals, and natural areas survive. [100] • There are not enough resources to satisfy all of the desires of all people and so there has to be some way of deciding who gets what.[101] • Individuals, businesses, organizations, and governments have a variety of means of ensuring that human activity does not cause significant harm to the environment harm. These are not always used.	• Investigate the habitat requirements of a small local invertebrate (e.g. sow bug, earthworm, or cricket). Design a living space for the creature following research ensuring that all of its needs are met. Keep the creature in its enclosure for several days, study, and release.

Grade Grouping: Grades 4 to 6

Societal Perspectives	Classroom Level Instructional Notes
• Each natural community is unique in some way and is worth learning about and preserving. / If you have seen one natural area you have seen them all. There is no need to be concerned about local natural areas since they are just about the same. • People should not use too many resources, since by doing so they have a bad effect on other living things. / People should be able to buy what they want if they have the money. • Humans depend on natural environments for many things, so they should look after the environment. / People can invent things to replace what is lost in the environment. • We should reduce the amount of waste we produce by buying things with less packaging and by reusing things. Then we should recycle. / Reducing, reusing and recycling are too much effort. • People are separate from the natural world. / People are a part of the natural world.	• Identify basic human needs (water, food, air, warmth) and trace each need back to its source (example water in the school fountain, source of warmth, food, various materials). • Visit a local natural area (woodland, field, or stream). Identify the major components of that natural community and the human influences upon it. Share the findings with others in the community through writing, art, or digital photography displays. • Investigate the habitat requirements of selected local native species and compare. Determine the impact of human activity on each. • Research the ecological history of your local area to determine the changes that have occurred over time and the different approaches to land use that have occurred since pre-contact times. Present through student art works. • Link classroom learning to local ecological restoration projects through student participation. • Use historical fiction and historical accounts to investigate human resource use and impact, and different views of nature (e.g. Last of the Curlews by Fred Bodsworth). • Use a survey to identify all the methods that people engage in to help the environment and have less of an impact on other living things.

Grade Grouping: Grades 1 to 3

Exemplary Learning Skills	Developmental Readiness and Major Misconceptions
Investigating Local Ecosystems and Look at those Lea ves http://www.sciencenetlinks.com/lessons.cfm?BenchmarkID=5&DocID=80 The purpose of this series of activities is to investigate the habitats of local plants and animals and to explore some of the ways animals depend on plants and each other. The students are encouraged to keep an online field journal with an adult to help keep track of their findings and ideas. The idea is to observe very closely various ecosystems the children are familiar with and begin to communicate about what they find. Students can then complete the Look at those Leaves lessons that begin students sorting and comparing leaves in their area. **Main Instructional Tools Employed:** • online learning • activity-based learning • integrated learning **Soil and Plants Grow Together – An Integrated One-Day Field Trip Program** http://www.willowparkecology.com/about.html Through a number of outdoor, activity-based learning centres (featuring Plants Have Different Parts, Animals Need Plants, People Need Plants, Plant Life Cycles, Soil Life, What is Soil?), students learn about the connections between plants, animals, soil and themselves. Groups of children rotate through the outdoor learning centres. Each small group creates a poster to illustrate the key ideas from the last centre they visit and presents it to the rest of the class to reinforce and clarify concepts. Later, students participate in sustainable gardening activities that demonstrate practical application of what was learned earlier in the day. Students communicate what they have learned by creating postcards (pictures and written messages) that convey an important message about their experiences and learning. These postcards are mailed to members of the local community and government (the Mayor, council members, MPP, clubs). **Main Instructional Tools Employed:** • fieldtrip • activity-based learning • service learning • integrated learning • audience beyond the classroom	**Developmental Readiness** • In the early elementary school years, students are able to grasp an understanding of the food link between two organisms.[102] During these years, students should begin to gain an awareness of the basic parts of the food chain (plants need sunlight to grow, some animals eat plants, and other animals eat both plants and animals). The concept that plants make their own food is difficult for students of this age group to comprehend and should be saved for middle school.[103] • Students in these grades are just beginning their study of basic systems. The concept of an ecosystem is beyond them and should not be introduced until the grade 7 to 9 age range.[104] • These students think of environmental problems as isolated issues. This is consistent with their limited cause and effect scope therefore it is questionable whether it is worth pushing beyond this level of understanding at this time.[105] **Major Misconceptions** • Many think that plants get their food from soil. / • Students tend to think that plants get their food from the soil and that they need soil to live.[106] Classroom demonstrations of plants living and growing without soil should help to dispel this notion.[107] • Many think that current environmental problems generally do no involve plants. / • Children in these grade levels tend to view environmental problems as having negative effects on people and animals, however plants are not usually considered.[108] • Many think that animals are dependent on people for food and shelter. / • Students in these grade levels often think of organisms as independent of each other but dependent on people to supply them with food and shelter.[109]

Grade Grouping: Grades 1 to 3

Fundamental Concepts By the end of this level of schooling, students should know:	Related Skills
Ecosystem Components and Processes • All living things are similar in that they need food, air, water, shelter and space to survive. Plants need light to grow.[110] • Living things get what they need to live from the world around them and return what they have used back to it.[111] • There are many living things in the world. Different living things are found in different places. Plants and animals have differences that help them to get what they need to live in different places.[112] • Animals, including people, get all their food by eating plants or other animals. • Plants can affect animals and other plants in many ways.[113] • Animals can affect plants and other animals in many ways.[114] **Human Dependence and Impact on Ecosystems** • People get everything they need or want from the world around them.[115] • When people go about getting what they need or want to live, they harm other living things (plants and animals, including other people) in many ways, often without even knowing it. • Some plants, animals, and places are very special to different people. **Economics and Ecosystem Interactions** • We can help other living things and save money by not wasting what we need to live or want (food, air, water, medicines, materials for clothing, building materials, and materials for various objects). There are different ways to do this.[116] **Managing Human Interactions With Ecosystems** • When a group of people wants to build or do something, they can try to figure out ahead of time how it might affect other living things, including people.[117] • By learning about the impacts our actions, we can learn to do less harm. There are many things that we can do to help other living things.[118]	**Securing Information** • Observe living and non-living things in the schoolyard or local natural area to determine their characteristics. • Use picture books to identify how selected local living things obtain what they need to live.[119] **Communication** • Correctly use the following terms verbally and in writing: living, non-living, need, want, water, food, air, shelter, space, animal, and plant. • Create a post card featuring a plant or animal living in the schoolyard or a local natural area. **Measurement and Data** • Keep daily records of the growth of plants when grown under different conditions. **Analysis** • Create a chart and list specific plants and animals with their similarities and differences. **Evaluate** • Use magazine photographs to create a collection of those things that we need and those that we want to live. Discuss the results. **Design/Build/Use** • Create a plan for a litter less lunch and explain why this is important. Take the plan home and implement it. • Select an animal and create a map that shows how it gets everything it needs to live. Form the animal out of plasticine for your display.

Grade Grouping: Grades 1 to 3

Societal Perspectives	Classroom Level Instructional Notes
• Living things are dirty and dangerous and should be avoided or eliminated. / Living things are trying to get what they need to survive just like everyone else. They are very interesting and usually harmless if respected. • Other living things are there for humans to do with as they please. / We should treat other people and other living things with respect. • Needs are things that people must have in order to survive. Wants are things that people desire but do not need. We should try to reduce our wants so that other living things are not harmed. / We should be able to do as we please because we are the most important. 	• Build on students' natural inclinations to ask questions and investigate their world by bringing different items/CREATURES into class, taking short field trips, reading picture books, or viewing presentations. • Distinguish between the characteristics of living and non-living things and challenge students to classify various living things and objects as one or the other. • Use picture books to explore the ways that different living things get what they need to survive and to introduce the concept of living things taking and returning materials from their surroundings. • Set up a bottle composter or vermi-composter in the classroom so that students can observe the decay of plant material (e.g. fruit and vegetable lunch waste and paper) to form humus (compost). Use the compost or compost tea that results on plants in the classroom or schoolyard to demonstrate the recycling of materials.[120] • Sprout seeds in class (as simple as seeds on a wet paper towel in a plastic bag) to give students the opportunity to observe life unfolding and the conditions that affect it. Growing plants from seeds in the classroom can reveal the stages in the entire life cycle and the impact of conditions on each stage (e.g. light levels, water availability). • Use the schoolyard or local natural areas to provide students with ongoing experiences in local natural ecosystems through both structured and unstructured learning activities. • Observing common invertebrates in class (sow bugs, earthworms, and garden snails) is a strong motivating force for learning and it provides a context for discussion about the appropriate treatment of living things. • Use the contents and packaging of student lunches as a starting point for tracing back items to their origin in the natural world and discussing the impacts of their use.

ECOSYSTEMS LEARNING PROGRESSION

ECOSYSTEM COMPONENTS AND PROCESSES

1 to 3	4 to 6	7 to 9	10 to 12
• All living things are similar in that they need food, air, water, shelter and space to survive. Plants need light to grow.[121] • Living things get what they need to live from the world around them and return what they have used back to it.[122] • There are many living things in the world. Different living things are found in different places. Plants and animals have differences that help them to get what they need to live in different places.[123] • Animals, including people, get all their food by eating plants or other animals. • Plants can affect animals and other plants in many ways.[124] • Animals can affect plants and other animals in many ways.[125]	• Each living thing can only survive where it can get its basic needs (water, air, food, space, and light for plants). [126] • A group of living things that is found in a particular area forms a community. Each natural community consists of the particular living things (plants and animals) and non-living things (water, warmth, light, air, nutrients, and climate) found there.[127] • Plants are the only living things that can produce their own food using the energy from sunlight. This food is the only source of energy for the plant.[128] • Animals depend on plants and other animals for their food. This food is the source of energy for the animal.[129] • Materials are continually being exchanged between the living and non-living parts of the environment. Living things grow, die, decompose and are used again by other living things. Soil life is important in this recycling of materials.[130] • All living things and non-living things have an effect on each other. The interactions of plants, animals, and the non-living things around them can be either helpful or harmful to themselves and others.[131]	• An ecosystem consists of all the living and non-living components of a natural community and their interactions. Many ecosystems are very complex and are not fully understood.[132] • Producers use a process called photosynthesis to produce food from light energy, water, and carbon dioxide. The food produced is used by the plant for growth and for energy to carry out plant processes. • Consumers are animals that eat plants or other animals to obtain materials for growth and maintenance of body systems, and energy for movement and heat. Decomposers (primarily bacteria and fungi) are consumers that use waste materials and dead organisms for food.[133] • The matter that makes up living things is used over and over again as it moves back and forth amongst organisms and the surroundings. The total amount of matter remains constant, even though its form and location change.[134] • The energy that living things use changes form as it moves from plants to animals to decomposers. The total amount of energy decrease with use by each life form due to losses in the form of heat. The continuous input of energy into ecosystems as a result of plants capturing sunlight during photosynthesis allows life processes to continue.[135] • The number of living things (including people) that can exist in an area (carrying capacity) is limited by the nutrients, space, water, and energy available to them.[136] • The number of living things in an area increases and decreases cyclically, depending on reproduction rates and death rates (which are related to the availability of resources). Due to resource depletion, a very large increase in population invariably leads to a population decline.[137] • All ecosystems undergo changes. Due to ecosystem complexity, the effect of changes on ecosystems cannot always be anticipated. Living things currently found in an area are often different from those that were found there in the past.[138]	• Ecosystems consist of both living and non-living components and their interactions. They are so complex that it is not always possible to predict the affect of change in one part on another. System characteristics of ecosystems include: interdependence of parts, feedback, oscillation, inputs, and outputs. [139] • The population of any particular species in an ecosystem is determined by many factors (the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials). [140] • Since the amount of energy available at each stage in a food chain diminishes, the number or total mass of all producers in an ecosystem is greater than all the herbivores. Similarly the number of carnivores is always less than the number of herbivores. • Living things are important components in the carbon cycle. During photosynthesis, plants use atmospheric carbon dioxide to store energy in sugars and release oxygen. In turn, when plants or animals use these sugars during respiration, energy is released, oxygen is used and carbon dioxide is produced. This interaction of plants and animals influences atmospheric carbon dioxide levels. [141] • Atoms and molecules cycle amongst and between the living and non-living components of the biosphere.[142] Chemical elements are recombined in different ways as they pass through food webs. At each link in a food web, some energy is stored in newly made structures but much is lost to the surroundings as heat. Continual input of energy from sunlight keeps the process going.[143] • Ecosystems tend to have cyclical fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.[144]

HUMAN DEPENDENCE AND IMPACT ON ECOSYSTEMS

1 to 3	4 to 6	7 to 9	10 to 12
• People get everything they need or want from the world around them.[145] • When people go about getting what they need or want to live, they harm other living things (plants and animals, including other people) in many ways, often without even knowing it. • Some plants, animals, and places are very special to different people.	• People get everything they need from the world around them. The use of various tools and techniques makes this easier than in the past.[146] • Every time people take something for their use from the world around them it has an effect on other living things. • The natural world provides people with many non-material benefits including beauty and inspiration, places for solitude, quiet and relaxation, and places for outdoor recreation. Being in natural surroundings provides many people with feelings of well-being. • People have diverse perspectives, beliefs and ways of interacting with non-human nature.[147]	• The impact of human activity on ecosystems is a function of population level, rates of consumption, and technological capability. Each person has an ecological footprint or effect determined by their consumption rate.[148] • As the overall human population increases, it reduces the number of other living things that exist.[149] • Human activity is causing negative changes in every ecosystem on the planet (either directly or indirectly), which is reducing the overall ability of ecosystems to support life.[150] • People benefit from various ecosystem functions that cannot readily be replaced if lost (e.g. wetlands and groundwater recharge, forests, transpiration and rainfall). • The current dominant worldview supports people exploiting non-human nature with little regard for its well-being. Perspectives held by others are less human-centred and support the view that humans are a part of nature and not above it.[151]	• Human societies are dependent on the resources available from ecosystems and the capacity of ecosystems to absorb waste products, both of which are limited.[152] • Human populations are exceeding the capacity of ecosystems to support them in many parts of the world. Historically, whenever this has occurred people have either moved to a new region, engaged in conflict, or suffered a drop in population due to starvation, disease, or other factors.[153] • The degree of negative impact on ecosystems resulting from human activity is a function of population, rates of consumption, and the use of technology and is related to the direct harvesting of plants and animals, agriculture, mining, use of energy, release waste including chemical pollutants, and urban sprawl.[154] • Human activity is now such that it has global ecological impact however ecosystem characteristics, such as lag times, cloud our perception of this human-induced influence.[155] • Non-human nature inspires peoples' creative acts, thoughts, and feelings. Many minority worldviews provide alternatives to the prevailing one that humans are meant to dominate nature.[156]

ECONOMICS AND ECOSYSTEM INTERACTIONS

1 to 3	4 to 6	7 to 9	10 to 12
• We can help other living things and save money by not wasting what we need to live or want (food, air, water, medicines, materials for clothing, building materials, and materials for various objects). There are different ways to do this.[157]	• The supply of all the resources (energy sources, soil, food, water, forest products and minerals) used by people in agriculture, forestry, fishing, and mining come from the world around us and is limited.[158] • The technology that we use to get, process, and transport resources often has drawbacks as well as benefits. A technology that helps some people or organisms may hurt others-either deliberately (as weapons can) or inadvertently (as pesticides can).[159] • In order to increase employment and economic activity, businesses use many practices to encourage people to buy more resources than they need. Almost all economic activity has some negative impact on other living things. • All waste materials people create are returned to the world around us. This often has a negative effect on the quality of the environment. Those who create air, water and solid waste pollution often do so with having to pay for their actions or clean up.	• Primary industries (forestry, agriculture, fishing, and mining) use and advance technology in order to secure the natural resources they need from ecosystems. As technology has improved, so has the capability of people to exploit resources from all parts of the world, thus increasing the overall human impact.[160] • Increases in economic activity almost always result in greater negative impact on ecosystems. Standard business practices and government policies that support them do not include the costs to ecosystems in the purchase cost of goods and services. As a result, common resources such as air and water are degraded, and wild stocks are depleted.[161] • Every technology has the potential to solve and cause problems. Following the Precautionary Principle has been proposed as a means of ensuring that the potential harm caused by new technology is not greater than the benefits.[162] International trade extends the ecological impact of economic activity.[163]	• Ecosystems provide humans with services (flood prevention, pollination of crops, aesthetic enjoyment, cleaning the air and water) that are not taken into consideration in economic terms. Full cost accounting is one means of addressing this imbalance. • Mainstream economic practices usually lead to the depletion of commonly held resources or the disruption of ecosystem services. It is often economically beneficial to maximize private returns by depleting commonly held resources (common grazing land, fresh water, wild stocks, and public forests). Business works to maximize returns by directing costs to others while privatizing profits.[164] • Technology increases the ability of people to access ecosystem resources. Advertising increases the desire by people to use more resources. Together these forces exert tremendous pressure on ecosystems with little feedback. • Alternative economic practices provide some means of maintaining ecosystem health and meeting human wants and needs (fair trade, local consumption, sustainable forestry, and community shared agriculture).

MANAGING HUMAN INTERACTIONS WITH ECOSYSTEMS

1 to 3	4 to 6	7 to 9	10 to 12
• When a group of people wants to build or do something, they can try to figure out ahead of time how it might affect other living things, including people.[165] • By learning about the impacts our actions, we can learn to do less harm. There are many things that we can do to help other living things.[166]	• Using a variety of approaches, many people work to help wild plants, animals, and natural areas survive. [167] • There are not enough resources to satisfy all of the desires of all people and so there has to be some way of deciding who gets what.[168] • Individuals, businesses, organizations, and governments have a variety of means of ensuring that human activity does not cause significant harm to the environment harm. These are not always used.	• As human populations continue to rise, global competition for limited ecological resources increases. The fundamental crisis of increasing human demand and decreasing capacity of ecological systems to meet it is not being addressed adequately.[169] • Governments at all levels (municipal to international) have a variety of mechanisms to manage use of natural resources and human impact on ecosystems (taxation, regulation, and subsidization, creation of parks and reserves, voluntary compliance programs). Some are more effective than others and some are never used to address an ecological problem. • The corporate sector has the capacity to apply business practices and innovation to meet human needs sustainably. The government intervention usually needed to initiate this change in perspective is often severely resisted through various forms of political participation.[170] • Non-governmental organizations play an important role in identifying ecological problems, developing solutions, communicating these to the public and leading the call for governments to act.[171]	• Reductions in ecological impact can be achieved through a wide variety of means including technological efficiency, voluntary reductions in consumption, pricing/taxation, quotas, or use of alternative technology. Some are more effective than others and some are not often considered.[172] • Decisions that have an impact on ecosystems of one generation can expand or limit the possibilities of the next generation. [173] • Governments can reduce the impact of human activity on ecosystems through a variety of measures (direct expenditures, taxation and tax breaks, regulations, volunteer measures, subsidies, rationing, incentives, defining property rights, establishing pollution trading markets, and participation in international treaties and international organizations). At present these are not being applied effectively for most ecological problems. • Scientific observations provide examples of past experiences and evidence of current human impact on ecosystems. These are not always heeded by society. It is common for some groups to attempt to undermine scientific findings if those findings are counter to the group's short-term interests.[174] • Competition for resources has lead to conflict.[175] Oil is the single largest energy source used worldwide leading to concerns about economic, climate and civil security.[176] • There are many examples of governments, non-governmental organizations, corporations, and individuals taking steps to address the current human ecological crisis.[177]

EDUCATIONAL RESOURCES

Ecosystems: Environmental Literacy Council

- 10 to 12 – students and teachers can use this website for its wealth of detailed information about ecosystems. http://www.enviroliteracy.org/category.php/3.html

Ecological Footprint Quiz

- 7 to 9 & 10 to 12 – find out what your ecological footprint is and how you can make is smaller http://ecofoot.org/

Edquest Science Resource

- 7 to 9 – A great resource for research and information for teachers and students at this grade level and above.

  http://www.edquest.ca/frontpage/Itemid,1/

Naturewatches

- 7 to 9 and 10 to 12 - Plant Watch, Frog Watch, and Worm Watch.- The following volunteer monitoring programs help students to learn about ecology and help identify ecological changes:

  http://www.naturewatch.ca

Tools of Change

- 4 to 6, 7 to 9, 10 to 12 - provides many positive examples of communities addressing environmental challenges.

  http://www.toolsofchange.com/English/firstsplit.asp

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ENDNOTES

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1 Coyle, 2005: ii.

2 Almost two-thirds of the natural machinery that supports life on Earth is being degraded by human pressure. See Radford,T. (2005) Two-thirds of world's resources 'used up'. The Guardian, March 30, 2005. http://education.guardian.co.uk/higher/research/story/0,,1447996,00.html ï viewed September 30 2006.

3 Sobel, 1996.

4 National Research Council, 1996, 181.

5 Recent works on this theme include Ronald Wright's A Short History of Progress (2004) and Jared Diamond's Collapse (2005).

[6] Students should be moving beyond the study of how individual species survive in their environment to the study of how populations and communities of species interact with each other and with their environment, National Research Council, 1996, 155.

[7] The term *ecosystem* and its full meaning should not be introduced until students have many of the pieces ready to put in place, including knowledge of the relationships between organisms and the environment and knowledge of the earth sciences, AAAS, 1993, 117 & 120.

[8] AAAS, 1993, 120 & Mohan et al, 2006, 4-6.

[9] ñIn the middle-school years, students' work with scientific investigations can be complemented by activities in which the purpose is to meet a human need, solve a human problem, or develop a product rather than to explore ideas about the natural world. The tasks chosen should involve the use of science concepts already familiar to students or should motivate them to learn new concepts needed to use or understand the technology. Students should also, through the experience of trying to meet a need in the best possible way, begin to appreciate that technological design and problem solving involve many other factors besides the scientific issues. Suitable design tasks for students at these grades should be well-defined, so that the purposes of the tasks are not confusingò, National Research Council, 1996, 161. A suitable experience for this topic could include selecting plants for an area of the school, National Research Council, 1996, 165.

[10] National Research Council, 1996, 167- 168.

[11] ñChallenges emerge from the knowledge that the products, processes, technologies and inventions of a society can result in pollution and environmental degradation and can involve some level of risk to human health or to the survival of other speciesé Helping students develop an understanding of risks and benefits in the areas of health, natural hazards--and science and technology in general--presents a challenge to middle-school teachersò, National Research Council, 1996, 167.

[12] Although the emphasis in grades K-4 should be on initial understandings, students can engage in some personal actions in local challenges related to science and technology, National Research Council, 1996, 138.

[13] AAAS, 1993, 119.

[14] Lower elementary students can understand the food link between two organisms, AAAS, 1993, 342.

[15] AAAS, 1993, 118. Misconceptions about plant nutrition exist with some students of all ages. The misconception that plants get their food from the environment rather than manufacturing it internally is particularly resistant to change. Even after traditional instruction, students have difficulty accepting that plants make food from water and air, and that this is their only source of food. Understanding this concept is key to understanding the difference between plants as producers and animals as consumers AAAS, 1993, 342.

[16] In the early years a ñchild's world is closely associated with the home, school, and immediate environment, [and] the study of organisms should include observations and interactions within the natural world of the child. The experiences and activities in grades K-4 provide a concrete foundation for the progressive development in the later grades of major biological concepts, such as evolution, heredity, the cell, the biosphere, interdependence, the behaviour of organisms, and matter and energy in living systemsò(National Research Council, 1996, 128).

[17] Local solid waste and water issues easily fit these basic guidelines, NAAEE, 2004.

[18] AAAS,1993, 119.

[19] AAAS, 1993, 121.

[20] An abruptly changing climatic system de to fossil use has been identified through research but awareness of this is not appreciated amongst policymakers or the general public, National Academy of Science in Romm, Hype about Hydrogen, 5.

[21] Smil, Energy at the Crossroads, 368. See also Romm, Hype about Hydrogen, 187.

[22] Roberts, 2004, 305.

[23] Diamond, 2005, 504

[24] ñThe concept of an ecosystem should bring coherence to the complex array of relationships among organisms and environments that students have encountered. Students' growing understanding of systems in general can suggest and reinforce characteristics of

ecosystems-interdependence of parts, feedback, oscillation, inputs, and outputs. Stability and change in ecosystems can be considered in terms of variables such as population size, number and kinds of species, and productivityò, AAAS, 1993, 117.

[25] ñLiving organisms have the capacity to produce populations of infinite size, but environments and resources are finiteò (National Research Council, 1996, 186). ñThe amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materialsò, AAAS, 1993, 121.

[26] AAAS, 1993, 74.

[27] National Research Council, 1996, 186.

[28] AAAS, 1993, 121.

[29] AAAS, 1993, 117.

[30] Ecosystem processes provide benefits including atmosphere quality, soil generation, control of the hydrologic cycle, assimilation of wastes, and recycling of nutrients, National Research Council, 1996, 198.

[31] As a result of overusing the capacity of ecosystems, wild populations go into rapid decline. It is possible to exceed ecological limits for a time, but this 'deficit spending' leads to the destruction of ecological assets on which our economy depends. These consequences include depleted groundwater, collapsing fisheries, CO_2 accumulation in the atmosphere, and deforestationò, Global Footprint Network, 2004. Historically, there are many examples of societal collapse due to ecosystem degradation. The case of Easter Island is one of many intriguing studies of human consumption and resource depletion. See Ronald Wright, *A Short History of Progress* (2004), and Jared Diamond, *Collapse* (2005).

[32] AAAS, 1993, 117 & 121. National Research Council, 1996, 198 & 199.

[33] The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations (National Research Council, 1996, 199) and lend support to the adoption of the Precautionary Principle.

[34] Other views exist regarding human relationships with nature and natural resources. Among many, these include: Deep Ecology, Eco-Feminism and various religious perspectives.

[35] The ñtragedy of the commonsò phenomenon is a common feature of dominant economic practices. Examples exist where costs are redirected to those sectors of the economy reaping the benefits. For example deposit and return systems for beverage containers are an effective way of transferring recycling/disposal costs to producers and consumers from government and taxpayers.

[36] Environmental problems are inevitable in any society. How a society deals with their environmental problems is a significant factor in the success or failure of that society. When studying past societal collapses and successes, societyôs responses to environmental problems always prove significant, Diamond, 2005, 11.

[37] For example, Smil sees change in energy use as a very long term endeavour that requires critical ingredients of an eventual successé beginning the quest immediately, progressing from small steps to gander solutions, persevering not just for years but for generations and always keeping in mind that our blunders may accelerate the demise of modern, high-energy civilizations, while our successes may extend societal life-span for centuries perhaps for millennia, Smil, 2003, 357.

[38] The pesticide industry vigorously opposed scientific findings that linked decline in populations of birds of prey to the use of various agricultural chemical in the 1960s and 70s.

[39] The Rwandan Genocide has been explained in terms of depletion for diminishing resources. Diamond, 2005.

[40] The consequences of current energy policies includes terrorist actions, support for undemocratic governments, illegal activity, reduction in national sovereignty, warfare, and unequal access to limited energy resources. Governments have intervened regularly to disrupt the working of the economy to influence oil prices, Roberts, End of Oil 104. Changes in energy supply will take place in the next 15 years and will either be peaceful and orderly or chaotic and violent depending on devidions made by policy makers in the intervening years. The Wordwatch Instituteôs State of the World 2005 (available for download at: http://www.worldwatch.org/node/1044) for a discussion of the role of oil dependency on global civic, economic, and climate security.

[41] These include international agreements tat have reduced human impact on the ozone layer, population control initiatives such as Chinaôs one child policy, ecological restoration initiatives, and individual initiatives to reduce consumption.

[42] Recent marketing programs allow households to purchase wind-generated electricity at a higher cost than that generated by traditional sources and therefore reduce contributions to climate change.

[43] See Diamond 2005 and Wright 2004

[44] Take the Ecological Footprint Quiz at http://ecofoot.org/.

[45] Findings suggest that enhancing the social reputation of people who have invested in positive change is a successful approach. Milinski et al 2006.

[46] AAAS, 1993, 56.

[47] Karlan, 2004.

[48] National Research Council, 1996, 156

[49] By this age, students begin to realize the cumulative ecological effects of pollution and are able to study issues such as acid rain and global ozone depletion, National Research Council, 1996, 167.

[50] Great focus on the individualõs environmental impact or footprint is now appropriate. Many of todayõs leading pollution problems are increasingly the result of individual actions, personal consumer decisions and actions of small business. Small personal sacrifices implemented across the board will have a major impact in resolving challenges, Coyle, 2005.

[51] ñThey see various organisms and materials as consisting of different types of matter that are not convertible into one another. Before they have an understanding of atoms, the notion of reusable building blocks common to plants and animals is quite mysterious. So following matter through ecosystems needs to be linked to their study of atomsò, AAAS, 1993, 120.

[52] ñIn popular language, food is whatever nutrients plants and animals must take in if they are to grow and survive (solutions of minerals that plants need traces of frequently bear the label "plant food"); in scientific usage, food refers only to those substances, such as carbohydrates, proteins, and fats, from which organisms derive the energy they need to grow and operate and the material of which they are made. It's important to emphasize that the sugars that plants make out of water and carbon dioxide are their only source of food. Water and minerals dissolved in it are not sources of energy for plants or for animalsò, AAAS, 1993, 120.

[53] National Research Council, 1996, 167.

[54] National Research Council, 1996, 167.

[55] National Research Council, 1996, 167.

[56] The case of the collapse of the northern cod stocks and its impact on Newfoundland society serves as a Canadian example of the connection between ecology and the economy.

[57] ñPhysical and biological systems tend to change until they become stable and then remain that way unless their surroundings change.ò AAAS, 1993, 274.

[58] ñTwo types of organisms may interact with one another in several ways: they may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the otherò, AAAS, 1993, 117.
ñAll living things, including the human species, are part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment, AAAS, 1993, 104.

[59] ñFood provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately or stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organismsò AAAS, 1993,120.

[60] AAAS, 1993, 120.

[61] AAAS, 1993, 120. National Research Council, 1996, 158.

[62] Each natural community has a carrying capacity, or a limit to how many individuals of a species it can sustain. ñGiven adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystemò, National Research Council, 1996, 158.

[63] Under some scenarios the population may decline significantly or crash. When an area becomes overpopulated, the environment will become degraded due to the increased use of resources. National Research Council, 1996, 168. With considerably reduced numbers, the population then starts to recover. Usually this does not happen because there are other factors that limit the growth of any one species in an area

[64] Change constantly takes place in any ecosystem, sometimes very slowly (succession) and sometimes quickly in response to catastrophic events National Research Council, 1996, 140.

[65] The Ecological Footprint is a measure of how much productive land a person needs to obtain all the resources he or she consumes and absorbs all the waste he or she produces. See Wackernel & Rees, 1996. or visit the Global Footprint Network at http://www.footprintnetwork.org/.

[66] Humans are increasingly monopolizing ecosystems at the expense of other living things. Humans numbering in the millions have now replaced the bison of the North American plains, which once number in the millions in the same location.

[67] Human populations directly impact ecosystems where they are located. In other circumstances the impact of human activity is transferred to remote parts of the world by natural processes such as wind and water movement. Human activity that results in soil depletion, loss of forests, fouling of fresh water, and accumulation of contaminants, acid rain, smog, and climate change all contribute to reducing the capacity of an ecosystem to support life. AAAS, 1993, 73. National Research Council, 1996, 168.

[68] Including a variety of religions, indigenous peoples, deep ecology, and animal rights proponents.

[69] As a consequence, the impacts of resource exploitation are often much greater than in the past. Fish stocks in all parts of the oceans are now in decline. Remote forests are being logged and exploitation of natural resources is now occurring from under the ocean.

[70] In exploiting natural resources (fish and animal populations, grazing land, forests, minerals) economic practices often lead to the collapse of the target population or depletion of the resource with little regard for others that depend on the resource (be they other people, later generations, other living things). This pattern is the most common one followed by people in the past and currently around the world. See also Hardin, G. (1985)Filters Against Folly, How to Survive despite Economists, Ecologists, and the Merely Eloquent. Viking, 255.

[71] The Precautionary Principle is a ôbetter safe than sorryô approach to decision-making. This principle states that, in the face of scientific uncertainty, society should assume that the risks of an action are real until it has proven to be safe. See http://en.wikipedia.org/wiki/Precautionary_principle for a discussion on this idea.

[72] Through trade there is a decreasing dependence on local resources due to the use of transportation. As a result, negative ecological and social impact are often not directly visible to those who benefit from the practices involved. For example, tropical wood harvested in the south is shipped to northern economies. The consumers who purchase products made from this wood ultimately are part of the massive deforestation and displacements of indigenous populations in the south often without ever knowing it.

[73] ñThe global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and populationò, AAAS, 1993, 177.

[74] Robert Neild (1995) in *The English, The French and the Oyster,* explains how government action by the French in the 18th century lead to the continuing existence of the French oyster industry, whereas the British oyster population crashed (along with the industry) due to a lack of government intervention. Unfortunately, most examples of human use of commonly held natural resources have resulted in the depletion of the resource and the end of related economic activity causing significant social and economic disruption.

[75] Gemmill & Bamidale-Izu, 2002, 2.

[76] National Research Council, 1996, 169.

[77] See the Society for Ecological Restoration website http://www.serontario.org/

[78] In terms of unsuccessful resource use, there are many historical examples to choose from, including the bison, passenger pigeon, Eskimo curlew, great auk, Great Lakes sturgeon, North American temperate forests, Atlantic cod and the whaling industry. Although there

are fewer examples of successful resource use, those that do exist include the French oyster industry and current initiatives to label sustainable forestry and fisheries products.

[79] For example, compare normal coffee production to fair trade coffee production.

[80] Take the Ecological Footprint Quiz at http://ecofoot.org/.

[81] AAAS, 1993, 120.

[82] Visits Bottle Biology at www.bottlebiology.org for information on creating a bottle ecosystem.

[83] The cycling of matter and flow of energy can be found at many levels of biological organization, from molecules to ecosystems. The study of food webs can start in the elementary grades with the transfer of matter, be added to in the middle grades with the flow of energy through organisms, and then be integrated in high school as students' understanding of energy storage in molecular configurations develops AAAS, 1993, 118 & 119 and Mohan et al, 2006, 19.

[84] AAAS, 1993, 119.

[85] Mohan et al, 2006, 14.

[86] Mohan et al, 2006, 32.

[87] Animals get both energy and materials from the food that they eat. Plants, however, produce their own food using water, air and light. (AAAS, 1993, 120).

[88] It is important to note that water, air, and nutrients from the soil are not considered food. The common use of the term ôfoodô is misleading. For example, fertilizer labelled as plant food is an incorrect use of the term. AAAS, 1993,342.

[89] Mintzes et al., 1991.

[90] Each living thing obtains what it needs from other living things or from the non-living part of its surroundings. National Research Council, 1996, 129.

[91] There are many different kinds of natural communities (forest, grassland, wetland, stream, river, ocean, and desert) that form due to the special conditions found in a particular place. Communities are named after one of their dominant species (e.g. the pine community) or the major physical characteristics of the area (e.g. freshwater pond community).

[92] Some source of "energy" is needed for all organisms to stay alive and grow, AAAS, 1993, 119.

[93] ñInsects and various other organisms depend on dead plant and animal material for foodò AAAS, 1993, 116. ñAlmost all kinds of animals' food can be traced back to plantsò AAAS, 1993, 119.

[94] AAAS, 1993, 119.

[95] National Research Council, 1996, 129. ñLiving things interact with one another in various ways besides providing food. Many plants depend on animals for carrying their pollen to other plants or for dispersing their seedsò AAAS, 1993, 116. Animals use plants for nest and den sites or to create a habitat that is suitable for them.

[96] All materials that people depend on initially come from ecosystems sources. People have always had problems and invented tools and techniques (ways of doing something) to solve them. Trying to determine the effects of solutions helps people avoid some new problems National Research Council, 1996, 138.

[97] Personal and religious beliefs, societal values and governmental laws influence how people understand and interact with the natural world. For examples of some childrenôs conceptions see also, Palmberg & Kuru, 2001.

[98] If used, resources can be extended through recycling and decreased use, National Research Council, 1996, 140.

[99] AAAS, 1993, 55. For example, ñthe damage to crops caused by rodents, weeds, and insects can be reduced by using poisons, but their use may harm other plants or animals as well, and pests tend to develop resistance to poisonsò AAAS, 1993, 185. ñWhen harm

occurs or seems likely, choices have to be made or new solutions foundò AAAS, 1993, 54 & 55. Those who benefit are usually different from those who suffer from the use of a technology.

[100] They do this in many ways, including restoring natural communities, setting aside natural areas in parks and preserves, farming organically, saving energy, not using particular products, buying products with less packaging, recycling, and choosing to buy less.

[101] AAAS, 1993, 169.

[102] AAAS, 1993, 342.

[103] AAAS, 1993, 119.

[104] AAAS, 1993, 117 & 262.

[105] For example, pollution can be solved by cleaning up the environment and producing less waste, scarcity can be solved by using less, and crowding can be solved by having fewer students in class or school. National Research Council, 1996, 139.

[106] Misconceptions about plant nutrition exist with some students of all ages. The misconception that plants get their food from the environment rather than manufacturing it internally is particularly resistant to change. Even after traditional instruction, students have difficulty accepting that plants make food from water and air, and that this is their only source of food. Understanding this concept is key to understanding the difference between plants as producers and animals as consumers. Problems with the term ôfoodôarise due to the inconsistency in the everyday meaning and the biological meaning of the word. Often, students see food as substances (water, air, minerals, etc.) that organisms take directly in from their environment, AAAS, 1993, 342.

[107] Soil does provide plants with very tangible benefits such as a place to anchor their roots and medium to hold water. However, the issue of food and nutrients should be left for later.

[108] Children at this age usually do not consider harm to plants as an environmental problem with the exception of trees. National Research Council, 1996, 139.

[109] AAAS, 1993, 342.

[110] National Research Council, 1996, 129. AAAS, 1993, 111 & 119.

[111] Many of the materials that are used by plants and animals are recycled and used over and over again, sometimes in different forms, AAAS, 1993, 119.

[112] Organisms can survive only in places where they can get what they need to live. The world has many different places that allow many different kinds of plants and animals to live.

[113] In addition to providing food, plants provide nesting materials and create places for animals to live and raise their young. Plants affect each other by competing for light, water, and space.

[114] Animals help plants by pollinating flowers, spreading seeds, and digging up the soil. Animals provide other animals with a food source, nest or den sites (sites that are abandoned by one animal may be used again by another), and a means of movement (via hitching a ride on other animals).

[115] People get food, air, water, medicines, materials for clothing, building materials, and materials for various objects from different sources in nature. It usually costs money to get these things.

[116] A few of the actions that support this concept include reducing how much we buy and use, reusing, recycling, and not wasting by turning off water taps and light switches when not in use.

[117] AAAS, 1993, 54.

[118] The link between daily actions and ecological impact are not always clear for these students. Some examples that thy can readily grasp with instruction include: walking and biking lead to fewer wildlife road fatalities, using less water leaves more for other living things, creating schoolyard natural areas increases home for some living things, and reducing the amount of garbage produced reduces the need for the creation of dump sites.

[119] Teachers should prepare a list of local living things for students to learn about through reading so as to provide them with the full range of life forms. It is beneficial to ensure that those living things that are listed for investigation are ones that the students will have opportunities to view directly in and out of school. These learners are inclined to have a limited view of the animal kingdom, tending to classify only common vertebrates as animals (particularly mammals and birds) but failing to include invertebrates, Mintzes et al, 1991. Learners in these grades are also inclined to hold a limited view of the plant kingdom, often failing to recognize that trees, vegetables, and grasses are all plants, Osborne & Freyberg, 1985. Encouraging students to select a variety of animals (both vertebrates and invertebrates) and plants to study should help to broaden student understanding of the animal kingdom.

[120] Find an example of how to make bottle composter at www.bottlebiology.org.

[121] National Research Council, 1996, 129. AAAS, 1993, 111 & 119.

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[156] Other views exist regarding human relationships with nature and natural resources. Among many, these include: Deep Ecology, Eco-Feminism and various religious perspectives.

[157] A few of the actions that support this concept include reducing how much we buy and use, reusing, recycling, and not wasting by turning off water taps and light switches when not in use.

[158] If used, resources can be extended through recycling and decreased use, National Research Council, 1996, 140.

[159] AAAS, 1993, 55. For example, ñthe damage to crops caused by rodents, weeds, and insects can be reduced by using poisons, but their use may harm other plants or animals as well, and pests tend to develop resistance to poisonsò, AAAS, 1993, 185. ñWhen harm occurs or seems likely, choices have to be made or new solutions foundò, AAAS, 1993, 54 & 55. Those who benefit are usually different from those who suffer from the use of a technology.

[160] As a consequence, the impacts of resource exploitation are often much greater than in the past. Fish stocks in all parts of the oceans are now in decline. Remote forests are being logged and exploitation of natural resources is now occurring from under the ocean.

[161] In exploiting natural resources (fish and animal populations, grazing land, forests, minerals) economic practices often lead to the collapse of the target population or depletion of the resource with little regard for others that depend on the resource (be they other people, later generations, other living things). This pattern is the most common one followed by people in the past and currently around the world. See also Hardin, G. (1985)Filters Against Folly, How to Survive despite Economists, Ecologists, and the Merely Eloquent. Viking, 255.

[162] The Precautionary Principle is a ôbetter safe than sorryô approach to decision-making. This principle states that, in the face of scientific uncertainty, society should assume that the risks of an action are real until it has proven to be safe. See http://en.wikipedia.org/wiki/Precautionary_principle for a discussion on this idea.

[163] Through trade there is a decreasing dependence on local resources due to the use of transportation. As a result, negative ecological and social impact are often not directly visible to those who benefit from the practices involved. For example, tropical wood harvested in the south is shipped to northern economies. The consumers who purchase products made from this wood ultimately are part of the massive deforestation and displacements of indigenous populations in the south often without ever knowing it.

[164] The ñtragedy of the commonsò phenomenon is a common feature of dominant economic practices. Examples exist where costs are redirected to those sectors of the economy reaping the benefits. For example deposit and return systems for beverage containers are an effective way of transferring recycling/disposal costs to producers and consumers from government and taxpayers.

[165] AAAS, 1993, 54.

[166] The link between daily actions and ecological impact are not always clear for these students. Some examples that thy can readily grasp with instruction include: walking and biking lead to fewer wildlife road fatalities, using less water leaves more for other living things, creating schoolyard natural areas increases home for some living things, and reducing the amount of garbage produced reduces the need for the creation of dump sites.

[167] They do this in many ways, including restoring natural communities, setting aside natural areas in parks and preserves, farming organically, saving energy, not using particular products, buying products with less packaging, recycling, and choosing to buy less.

[168] AAAS, 1993, 169.

[169] ñThe global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and populationò, AAAS, 1993, 177.

[170] Robert Neild (1995) in *The English, The French and the Oyster,* explains how government action by the French in the 18th century lead to the continuing existence of the French oyster industry, whereas the British oyster population crashed (along with the industry) due to a lack of government intervention. Unfortunately, most examples of human use of commonly held natural resources have resulted in the depletion of the resource and the end of related economic activity causing significant social and economic disruption.

[171] Gemmill & Bamidale-Izu, 2002, 2.

[172] Environmental problems are inevitable in any society. How a society deals with their environmental problems is a significant factor in the success or failure of that society. When studying past societal collapses and successes, societyôs responses to environmental problems always prove significant, Diamond, 2005, 11.

[173] For example, Smil sees change in energy use as a very long term endeavour that requires critical ingredients of an eventual success é beginning the quest immediately, progressing from small steps to grander solutions, persevering not just for years but for generations and always keeping in mind that our blunders may accelerate the demise of modern, high-energy civilizations, while our successes may extend societal life-span for creatures, perhaps even for millennia, Smil, 2003, 357.

[174] The pesticide industry vigorously opposed scientific findings that linked decline in populations of birds of prey to the use of various agricultural chemical in the 1960s and 70s.

[175] The Rwandan Genocide has been explained in terms of depletion for diminishing resources. Diamond (2005).

[176] The consequences of current energy policies includes terrorist actions, support for undemocratic governments, illegal activity, reduction in national sovereignty, warfare and unequal access to limited energy resources. Governments have intervened regularly to disrupt the working of the economy to influence oil prices, Roberts, End of Oil, 104. Changes in energy supply will take place in the next 15 years and will either be peaceful or chaotic and violent depending on decisions made by policy makers in the intervening years. See The Worldswatch Institueôs State of the World 2005 (available for download at: http://www.worldwatch.org/node/1044) for a discussion of the role of oil dependency on global civic, economic and climate security.

[177] These include international agreements tat have reduced human impact on the ozone layer, population control initiatives such as Chinaôs one child policy, ecological restoration initiatives, and individual initiatives to reduce consumption.