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Contents

APPENDIX 4

Environmental Pollution

Table of Contents

Pollution - Environmental pollution is any discharge of material or energy into water, land, or air that causes or may cause acute (short-term) or chronic (long-term) detriment to the Earth's ecological balance or that lowers the quality of life. Pollutants may cause primary damage, with direct identifiable impact on the environment, or secondary damage in the form of minor perturbations in the delicate balance of the biological food web that are detectable only over long time periods.

Until relatively recently in humanity's history, where pollution has existed, it has been primarily a local problem. The industrialization of society, the introduction of motorized vehicles, and the explosion of the human population, however, have caused an exponential growth in the production of goods and services. Coupled with this growth has been a tremendous increase in waste by-products. The indiscriminate discharge of untreated industrial and domestic wastes into waterways, the spewing of thousands of tons of particulates and airborne gases into the atmosphere, the "throwaway" attitude toward solid wastes, and the use of newly developed chemicals without considering potential consequences have resulted in major environmental disasters, including the formation of smog in the Los Angeles area since the late 1940s and the pollution of large areas of the Mediterranean Sea. Technology has begun to solve some pollution problems (see pollution control), and public awareness of the extent of pollution will eventually force governments to undertake more effective environmental planning and adopt more effective anti-pollution measures.

Different Types of Pollution

WATER POLLUTION

Water pollution is the introduction into fresh or ocean waters of chemical, physical, or biological material that degrades the quality of the water and affects the organisms living in it. This process ranges from simple addition of dissolved or suspended solids to discharge of the most insidious and persistent toxic pollutants (such as pesticides, heavy metals, and nondegradable, bioaccumulative, chemical compounds).

Conventional

Conventional or classical pollutants are generally associated with the direct input of (mainly human) waste products. Rapid urbanization and rapid population increase have produced sewage problems because treatment facilities have not kept pace with need. Untreated and partially treated sewage from municipal wastewater systems and septic tanks in unsewered areas contribute significant quantities of nutrients, suspended solids, dissolved solids, oil, metals (arsenic, mercury, chromium, lead, iron, and manganese), and biodegradable organic carbon to the water environment.

Conventional pollutants may cause a myriad of water pollution problems. Excess suspended solids block out energy from the Sun and thus affect the carbon dioxide-oxygen conversion process, which is vital to the maintenance of the biological food chain. Also, high concentrations of suspended solids silt up rivers and navigational channels, necessitating frequent dredging. Excess dissolved solids make the water undesirable for drinking and for crop irrigation.

Although essential to the aquatic habitat, nutrients such as nitrogen and phosphorus may also cause overfertilization and accelerate the natural aging process (eutrophication) of lakes. This acceleration in turn produces an overgrowth of aquatic vegetation, massive algal blooms, and an overall shift in the biologic community--from low productivity with many diverse species to high productivity with large numbers of a few species of a less desirable nature. Bacterial action oxidizes biodegradable organic carbon and consumes dissolved oxygen in the water. In extreme cases where the organic-carbon loading is high, oxygen consumption may lead to an oxygen depression: (less than 2 mg/l compared with 5 to 7 mg/l for a healthy stream) is sufficient to cause a fish kill and seriously to disrupt the growth of associated organisms that require oxygen to survive.

Nonconventional

The nonconventional pollutants include dissolved and particulate forms of metals, both toxic and nontoxic, and degradable and persistent organic carbon compounds discharged into water as a by-product of industry or as an integral part of marketable products. More than 13,000 oil spills of varying magnitude occur in the United States each year. Thousands of environmentally untested chemicals are routinely discharged into waterways; an estimated 400 to 500 new compounds are marketed each year. In addition, coal strip mining releases acid wastes that despoil the surrounding waterways. Nonconventional pollutants vary from biologically inert materials such as clay and iron residues to the most toxic and insidious materials such as halogenated hydrocarbons (DDT, kepone, mirex, and polychlorinated biphenyls--PCB). The latter group may produce damage ranging from acute biological effects (complete sterilization of stretches of waterways) to chronic sublethal effects that may go undetected for years. The chronic low-level pollutants are proving to be the most difficult to correct and abate because of their ubiquitous nature and chemical stability.

THERMAL POLLUTION

Thermal pollution is the discharge of waste heat via energy dissipation into cooling water and subsequently into nearby waterways. The major sources of thermal pollution are fossil-fuel and nuclear electric-power generating facilities and, to a lesser degree, cooling operations associated with industrial manufacturing, such as steel foundries, other primary-metal manufacturers, and chemical and petrochemical producers.

The discharge temperatures from electric-power plants generally range from 5 to 11 C degrees (9 to 20 F degrees) above ambient water temperatures. An estimated 90% of all water consumption, excluding agricultural uses, is for cooling or energy dissipation.

The discharge of heated water into a waterway often causes ecologic imbalance, sometimes resulting in major fish kills near the discharge source. The increased temperature accelerates chemical-biological processes and decreases the ability of the water to hold dissolved oxygen. Thermal changes affect the aquatic system by limiting or changing the type of fish and aquatic biota able to grow or reproduce in the waters. Thus rapid and dramatic changes in biologic communities often occur in the vicinity of heated discharges.

LAND POLLUTION

Land pollution is the degradation of the Earth's land surface through misuse of the soil by poor agricultural practices, mineral exploitation, industrial waste dumping, and indiscriminate disposal of urban wastes.

Soil Misuse

Soil erosion--a result of poor agricultural practices--removes rich humus topsoil developed over many years through vegetative decay and microbial degradation and thus strips the land of valuable nutrients for crop growth. Strip mining for minerals and coal lays waste thousands of acres of land each year, denuding the Earth and subjecting the mined area to widespread erosion problems. The increases in urbanization due to population pressure presents additional soil-erosion problems; sediment loads in nearby streams may increase as much as 500 to 1,000 times over that recorded in nearby undeveloped stretches of stream. Soil erosion not only despoils the Earth for farming and other uses, but also increases the suspended-solids load of the waterway. This increase interferes with the ecological habitat and poses silting problems in navigation channels, inhibiting the commercial use of these waters.

Solid Waste

In the United States in 1988 municipal wastes alone--that is, the solid wastes sent by households, business, and municipalities to local landfills and other waste-disposal facilities--equaled 163 million metric tons (1980 million U.S. tons), or 18 k (40lb) per person, according to figures released by the Environmental Protection Agency. Additional solid wastes accumulate from mining, industrial production, and agriculture. Although municipal wastes are the most obvious, the accumulations of other types of waste are far greater, in many instances are more difficult to dispose of, and present greater environmental hazards.

The most common and convenient method of disposing of municipal solid wastes is in the sanitary landfill. The open dump, once a common eyesore in towns across the United States, attracted populations of rodents and other pests and often emitted hideous odors; it is now illegal. Sanitary landfills provide better aesthetic control and should be odor-free. Often, however, industrial wastes of unknown content are commingled with domestic wastes. Groundwater infiltration and contamination of water supplies with toxic chemicals have recently led to more active control of landfills and industrial waste disposal. Careful management of sanitary landfills, such as providing for leachate and runoff treatment as well as daily coverage with topsoil, has alleviated most of the problems of open dumping. In many areas, however, space for landfills is running out and alternatives must be found.

Recycling of materials is practical to some extent for much municipal and some industrial wastes, and a small but growing proportion of solid wastes is being recycled. When wastes are commingled, however, recovery becomes difficult and expensive. New processes of sorting ferrous and nonferrous metals, paper, glass, and plastics have been developed, and many communities with recycling programs now require refuse separation. Crucial issues in recycling are devising better processing methods, inventing new products for the recycled materials, and finding new markets for them.

Incineration is another method for disposing of solid wastes. Advanced incinerators use solid wastes as fuel, burning quantities of refuse and utilizing the resultant heat to make steam for electricity generation. Wastes must be burned at very high temperatures, and incinerator exhausts must be equipped with sophisticated scrubbers and other devices for removing dioxins and other toxic pollutants. Problems remain, however: incinerator ash contains high ratios of heavy metals, becoming a hazardous waste in itself, and high-efficiency incinerators may discourage the use of recycling and other waste-reduction methods.

Composting is increasingly used to treat some agricultural wastes, as well as such municipal wastes as leaves and brush. Composting systems can produce usable soil conditioners, or humus, within a few months (see compost).

PESTICIDE POLLUTION

Pesticides are organic and inorganic chemicals originally invented and first used effectively to better the human environment by controlling undesirable life forms such as bacteria, pests, and foraging insects. Their effectiveness, however, has caused considerable pollution. The persistent, or hard, pesticides, which are relatively inert and nondegradable by chemical or biologic activity, are also bioaccumulative; that is, they are retained within the body of the consuming organism and are concentrated with each ensuing level of the biologic food chain. For example, DDT provides an excellent example of cumulative pesticide effects. (Although DDT use has been banned in the United States since 1972, it is still a popular pesticide in much of the rest of the world.) DDT may be applied to an area so that the levels in the surrounding environment are less than one part per billion. As bacteria or other microscopic organisms ingest and retain the pesticide, the concentration may increase several hundred- to a thousandfold. Concentration continues as these organisms are ingested by higher forms of life--algae, fish, shellfish, birds, or humans. The resultant concentration in the higher life forms may reach levels of thousands to millions of parts per billion.

Many pesticides are nondiscriminatory; that is, they are not specific for a particular plant or organism. A dramatic example of this effect is DDE (a product of the breakdown of DDT), which effectively inhibits the ability of birds to provide sufficient calcium deposits for their eggs, producing fragile shells and a high percentage of nested eggs that break prematurely. Another reported side effect of pesticides is their effect on the nervous system of animals and fish; they can cause instability, disorientation, and, in some cases, death. These examples are generally a result of relatively high body residuals producing acute (short-term) readily recordable results.

The long-term (chronic) effects of persistent pesticides are virtually unknown, but many scientists believe they are as much an environmental hazard as are the acute effects. Nonpersistent (readily degradable) pesticides or substitutes, insect sterilization techniques, hormone homologues that check or interfere with maturation stages, and introduction of animals that prey on the pests present a potentially brighter picture for pest control with significantly reduced environmental consequences.

RADIATION POLLUTION

Radiation pollution is any form of ionizing or nonionizing radiation that results from human activities. The most well-known radiation results from the detonation of nuclear devices and the controlled release of energy by nuclear-power generating plants (see nuclear energy). Other sources of radiation include spent-fuel reprocessing plants, by-products of mining operations, and experimental research laboratories. Increased exposure to medical X rays and to radiation emissions from microwave ovens and other household appliances, although of considerably less magnitude, all constitute sources of environmental radiation.

Public concern over the release of radiation into the environment greatly increased following the disclosure of possible harmful effects to the public from nuclear weapons testing, the accident (1979) at the Three Mile Island nuclear-power generating plant near Harrisburg, Pa., and the catastrophic 1986 explosion at Chernobyl, a Soviet nuclear power plant. In the late 1980s, revelations of major pollution problems at U.S. nuclear weapons reactors raised apprehensions even higher.

The environmental effects of exposure to high-level ionizing radiation have been extensively documented through postwar studies on individuals who were exposed to nuclear radiation in Japan. Some forms of cancer show up immediately, but latent maladies of radiation poisoning have been recorded from 10 to 30 years after exposure. The effects of exposure to low-level radiation are not yet known. A major concern about this type of exposure is the potential for genetic damage.

Radioactive nuclear wastes cannot be treated by conventional chemical methods and must be stored in heavily shielded containers in areas remote from biological habitats. The safest of storage sites currently used are impervious deep caves or abandoned salt mines. Most radioactive wastes, however, have half-lives of hundreds to thousands of years, and to date no storage method has been found that is absolutely infallible.

NOISE POLLUTION

Noise pollution has a relatively recent origin. It is a composite of sounds generated by human activities ranging from blasting stereo systems to the roar of supersonic transport jets. Although the frequency (pitch) of noise may be of major importance, most noise sources are measured in terms of intensity, or strength of the sound field. The standard unit, one decibel (dB), is the amount of sound that is just audible to the average human. The decibel scale is somewhat misleading because it is logarithmic rather than linear; for example, a noise source measuring 70 dB is 10 times as loud as a source measuring 60 dB and 100 times as loud as a source reading 50 dB. Noise may be generally associated with industrial society, where heavy machinery, motor vehicles, and aircraft have become everyday items. Noise pollution is more intense in the work environment than in the general environment, although ambient noise increased an average of one dB per year during the 1980s. The average background noise in a typical home today is between 40 and 50 decibels. Some examples of high-level sources in the environment are heavy trucks (90 dB at 15 m/50 ft), freight trains (75 dB at 15 m/50 ft), and air conditioning (60 dB at 6 m/20 ft).

The most readily measurable physiological effect of noise pollution is damage to hearing, which may be either temporary or permanent and may cause disruption of normal activities or just general annoyance. The effect is variable, depending upon individual susceptibility, duration of exposure, nature of noise (loudness), and time distribution of exposure (such as steady or intermittent). On the average an individual will experience a threshold shift (a shift in an individual's upper limit of sound detectability) when exposed to noise levels of 75 to 80 dB for several hours. This shift will last only several hours once the source of noise pollution is removed. A second physiologically important level is the threshold of pain, at which even short-term exposure will cause physical pain (130 to 140 dB). Any noise sustained at this level will cause a permanent threshold shift or permanent partial hearing loss. At the uppermost level of noise (greater than 150 dB), even a single short-term blast may cause traumatic hearing loss and physical damage inside the ear.

Although little hard information is available on the psychological side effects of increased noise levels, many researchers attribute increased irritability, lower productivity, decreased tolerance levels, increased incidence of ulcers, migraine headaches, fatigue, and allergic responses to continued exposures to high-level noises in the workplace and the general environment.

AIR POLLUTION

Air pollution is the accumulation in the atmosphere of substances that, in sufficient concentrations, endanger human health or produce other measured effects on living matter and other materials. Among the major sources of pollution are power and heat generation, the burning of solid wastes, industrial processes, and, especially, transportation. The six major types of pollutants are carbon monoxide, hydrocarbons, nitrogen oxides, particulates, sulfur dioxide, and photochemical oxidants.

Local and Regional

Smog has seriously affected more persons than any other type of air pollution. It can be loosely defined as a multisource, widespread air pollution that occurs in the air of cities. Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal. The infamous London fogs--about 4,000 deaths were attributed to the severe fog of 1952--were smog of this type. Another type, ice fog, occurs only at high latitudes and extremely low temperatures and is a combination of smoke particles and ice crystals.

As a coal economy has gradually been replaced by a petroleum economy, photochemical smog has become predominant in many cities. Its unpleasant properties result from the irradiation by sunlight of hydrocarbons (primarily unburned gasoline emitted by automobiles and other combustion sources) and other pollutants in the air. Irradiation produces a long series of photochemical reactions (see photochemistry). The products of the reactions include organic particles, ozone, aldehydes, ketones, peroxyacetyl nitrate, and organic acids and other oxidants. Sulfur dioxide, which is always present to some extent, oxidizes and hydrates to form sulfuric acid and becomes part of the particulate matter. Furthermore, automobiles are polluters even in the absence of photochemical reactions. They are responsible for much of the particulate material in the air; they also emit carbon monoxide, one of the most toxic constituents of smog.

All types of smog decrease visibility and, with the possible exception of ice fog, are irritating to the respiratory system. Statistical studies indicate that smog is a contributor to malignancies of many types. Photochemical smog produces eye irritation and lacrimation and causes severe damage to many types of vegetation, including important crops. Acute effects include an increased mortality rate, especially among persons suffering from respiratory and coronary ailments. Air pollution also has a deleterious effect on works of art (see art conservation and restoration).

Air pollution on a regional scale is in part the result of local air pollution--including that produced by individual sources, such as automobiles--that has spread out to encompass areas of many thousands of square kilometers. Meteorological conditions and landforms can greatly influence air-pollution concentrations at any given place, especially locally and regionally. For example, cities located in bowls or valleys over which atmospheric inversions form and act as imperfect lids are especially likely to suffer from incidences of severe smog. Oxides of sulfur and nitrogen, carried long distances by the atmosphere and then precipitated in solution as acid rain, can cause serious damage to vegetation, waterways, and buildings.

Global

Humans also pollute the atmosphere on a global scale, although until the early 1970s little attention was paid to the possible deleterious effects of such pollution. Measurements in Hawaii suggest that the concentration of carbon dioxide in the atmosphere is increasing at a rate of about 0.2% every year. The effect of this increase may be to alter the Earth's climate by increasing the average global temperature. Certain pollutants decrease the concentration of ozone occurring naturally in the stratosphere, which in turn increases the amount of ultraviolet radiation reaching the Earth's surface. Such radiation may damage vegetation and increase the incidence of skin cancer. Examples of stratospheric contaminants include nitrogen oxides emitted by supersonic aircraft and chlorofluorocarbons used as refrigerants and aerosol-can propellants. The chlorofluorocarbons reach the stratosphere by upward mixing from the lower parts of the atmosphere (see ozone layer). It is believed that these chemicals are responsible for the noticeable loss of ozone over the polar regions that has occurred in the 1980s.

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Bioindicators: Types, Development, and Use in Ecological Assessment and Research

An excerpt from the article by JOANNA BURGER

Attributes of Successful Bioindicators

Bioindicators are especially important today where there is increasing interest in efforts to manage and use ecosystems sustainably (Marques 2001; Wells 2003; Gauthier and Wiken 2003; Beratan et al. 2004). Thus, indicators should be selected to maximize their biological, methodological, and societal relevance (Table 2, after Burger and Gochfeld 2004b). First and foremost, an indicator must exhibit changes in response to a stressor, but not be so sensitive that changes occur when there is no cause for concern (no lasting reproductive, survival, or population effects). The response should not be so sensitive that it indicates trivial or biologically unimportant variations, or simply varies randomly. The changes must be attributable to a particular stressor (or series of stressors), and important to the well-being of the organism (Linthurst et al. 1995). Further, the changes being measured should reflect not only impairment to the species itself, but to populations, communities, and ecosystems (EPA 1997).

An indicator that is biologically relevant, but is not methodologically relevant, will simply not be employed (Burger and Gochfeld 2001a, 2004b). A good indicator should be easy for scientists to measure, for managers to use in their resource management, for conservationists to employ in species preservation, and for regulators to employ in compliance mandates. Ease of measurement is a key characteristic, and includes such aspects as clarity in objectives, relationship to a problem, ease of identification of important features, and ease of data gathering and analysis. To be assured that an indicator is easy to use requires extensive field testing with a range of sampling and observational scenarios by multiple technicians.

Table 2

<u>Features of bioindicators for environmental and ecological health assessment</u>

Biological Relevance

•Provides early warning

•Exhibits changes in response to stress

•Changes can be measured

•Intensity of changes relate to intensity of stressors

•Change occurs when effect is real

•Changes are biologically important and occur early enough to prevent catastrophic effects

•Change can be attributed to a cause

•Change indicates effects on both organisms themselves, and on others higher on trophic scale

•Can be used as sentinels for humans

Methodological Relevance
•Easy to use in the field
•Can be used by non-specialists
•Easy to analyze and interpret data
•Measures what it is supposed to measure
•Useful to test management questions
•Can be used for hypothesis testing
•Can be conducted in reasonable time
•Doesn't require expensive or complicated equipment
•Easily repeatable with little training
Societal Relevance
•Of interest to the public
•Of interest to regulators and public policy makers
•Easily understood by the public
•Methods transparent to the public
•Measures related to environment, ecological integrity, and human health
•Cost-effective
•Adds measurably to other indicators
•Complements other indicators

Societal relevance is an important attribute of a useful indicator because without public and governmental support, the indicator will not be used over appropriate spatial and temporal scales that provide meaningful information (Fox 1994). Collecting data on a bioindicator for only one site, or for only one or two years, generally will not provide usable data for scientists to evaluate populations, for managers to select among management methods, or for regulators to identify species requiring protection or restrictions. Governmental agencies must be willing both to fund the implementation of the indicators, and to act on the results. Institutional controls are essential to ensure the continuation of the monitoring schemes, including funding, analysis, and corrective actions. Charismatic species, such as bald eagles (Haliaeetus leucocephalus) or peregrine falcons (Falco peregrinus), are often used as indicators (Fox 1994) because there is sustained public and governmental interest. Population failures of these species in the early 1950s served as bioindicators of chlorinated hydrocarbon pesticide contamination long before the term was used. Further, charismatic or large species, such as colonial water birds, raptors, and loons, have proved to be of great interest to the public (Risebrough 1991; Kushlan 1993; Burger et al. 1994; Evers 2001; Evers et al. 2003; Burger and Gochfeld 2004a).

Types of Bioindicators

In this section, I discuss the different types of bioindicators. The term indicator was initially used for economic (e.g., GNP), and later social, indicators and was used to refer to measures used to assess the health of the economy. In its broadest sense, three kinds of ecological indicators can be distinguished, including media indicators (soil, air, water), ecosystem health assessments, and human health indicators. To this traditional matrix форма, I add human intervention indicators that can be used to evaluate interventions such as remediation, restoration, and sustainability.

The Environmental Monitoring and Assessment Program (EMAP) of the US EPA (Summers et al. 1995) defines three types of indicators:

1) response indicators that quantify condition of the ecosystem,

2) exposure indicators that can be related to direct exposure, and

3) stress indicators that relate to the probable sources of pollution or degradation

This distinction is worth critical thought during selection of bioindicators, as different indicators may be required for each of the three indicator types. The importance of selecting bioindicator endpoints that can be measured cannot be underestimated (Suter 1990; Norton et al. 1992). Human and ecological well-being, however, also includes social/economic features, requiring indicators as well. To be most useful, ecological and human health indicators should be combined or coordinated (Burger and Gochfeld 1996, 2001a, 2004b).

There are several axes for development of bioindicators that include:

1) biological level of organization.

2) type of stressor (physical, biological, chemical, and radiological),

3) single versus multiple stressors, and

4) degree of anthropogenic effects (pristine to human-dominated).

These categories are not mutually exclusive, but bear consideration and suggest the importance of clearly defining the objective of the monitoring plan — why is a particular indicator being developed?

The recent emphasis on indicators of sustainability brings us closer to the original use of indicators for economic and societal stability (Hart 1999). Although some argue that even ecological indicators of sustainability are mainly public policy issues (McCool and Stankey 2004), the importance of developing these indicators for managing specific ecosystems is clearly established (Gauthier and Wiken 2003; Wells 2003; Diaz-Balteiro and Romero 2004). Managers often use indicators specifically to evaluate the effectiveness of particular measures on the sustainability of populations or ecosystems (Barnthouse

et al. 2002), and may integrate a suite of indicators of sustainability for specific habitats (Wulf 2003). There is disagreement about the meaning of sustainability, as well as what is being sustained. For example, whereas most ecologists use sustainability to refer to natural resources, the Department of Energy uses sustainability to refer to continued safety or protection from risks due to chemicals and radionuclide wastes. Although sustainability is a laudable goal, it is also difficult to accomplish (Beratan et al. 2004), and developing indicators for ecological sustainability is a daunting task. Finally, developing bioindicators for sustainability (often a combination of other types of indicators) represents a forward-looking approach to management, since indicators are not only being used to evaluate past human disruptions, but to predict and manage future populations or ecosystems.

Most books devoted to environmental monitoring and ecological risk assessment provide methods for evaluation at different levels of ecological organization, but do not provide a comprehensive plan for any one habitat or land type, although some have provided plans for regions (see Hunsaker et al. 1990; Suter 1990; Cairns 1990). Excellent methods are available (Linthurst et al. 1995), but authors seldom commit to a specific plan, or to a specific set of indicators, although there have been attempts to rank the utility of individual species as bioindicators (Golden and Rattner 2003). In the next section, I discuss examples of bioindicators to illustrate the complexity that surrounds a given bioindicator, and the levels of biological organization that can be examined with them.

Specific Bioindicators

Toxicology, conservation, and biology have largely developed bioindicators for their respective stressors, without considering the implications of other stressors. Environmental protection agencies have dealt primarily with understanding how levels of contaminants in organisms, and their effects, have varied over time and space, often in relation to point source pollution. Fish and wildlife departments and environmental conservation programs have examined changes in wildlife and habitats as a function of predator changes, competition, invasive species, weather, and human disturbance. Biologists have some- times developed bioindicators for reproductive success, survival, and behavior without taking into account the effects or presence of contaminants. Sometimes they have even ignored human effects, preferring instead to study pristine populations removed from human intervention. It is important, however, to remember that biological, physical, and chemical (and radiological) stressors all affect ecological receptors, including humans.

Interpretation of data from monitoring schemes with indicators should incorporate a range of stressors.

A wide range of species or tissues have been used as bioindicators, such as algae and other plants, invertebrates, fish, amphibians, birds, seabird eggs, bird blood, and mammals, to name just a few. The main objective of this paper is not to develop or describe specific indicators (a monumental task that several agencies and organizations have undertaken; Harwell and Kelly 1990; Hunsaker et al. 1990; Norton et al. 1992; Peakall 1992; Holl and Cairns 1995; Burger and Gochfeld 2001b, 2004b). However, two examples will be given to illustrate that any species (or species group) can serve a multitude of bioindicator roles, for itself, for organisms it eats, and for organisms that eat it.

Bass (or any predatory fish) can serve a range of bioindicator functions because of their complex role in their communities (Figure 2, see Burger 1999a). Largemouth bass (Micropterus salmoides) are ideal as indicators because they are widespread, numerous, and are a popular sport fish (Burger et al. 2001a,b,c; Burger and Campbell 2004). Other intermediate-sized predatory fish are also ideal, including bowfin (Amia calva), chain pickerel (Esox niger), yellow perch (Perca flavescens), and bluefish (Pomatomus saltatrix).

largemouth bass

bowfin

chain pickerel

Bioindicators in Ecological Assessment and Research 31

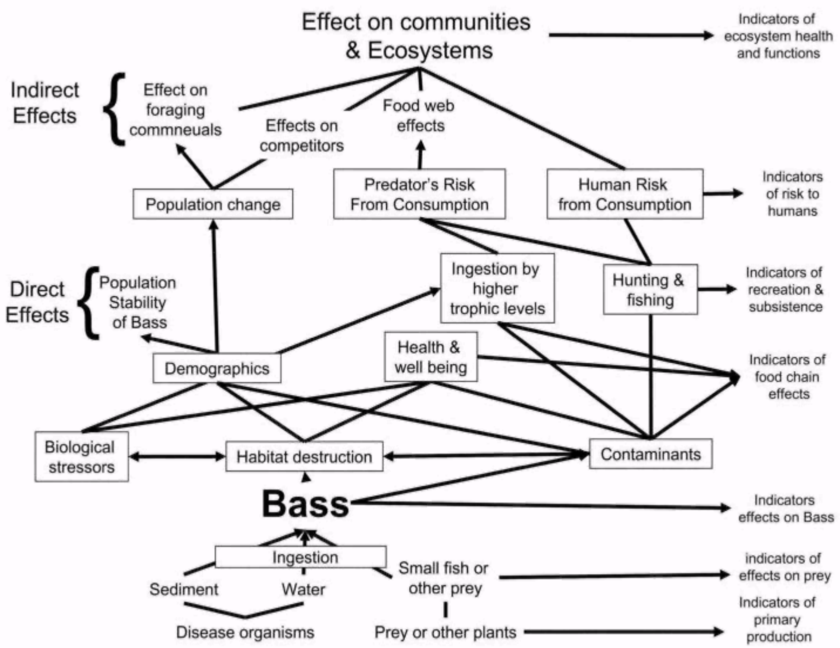

Figure 2. Schematic of bioindicator properties of bass, and other predatory fish. Ingestion exposures of bass are shown on bottom of diagram. Measurement of population, reproduction, growth, human disturbance level, and contaminant levels can all serve as indicators. The three main categories of stressors are biological (e.g., disease, competition, predation), habitat changes, and contaminants.

Measuring contaminants in bass is useful because of the risk that such contaminants pose to higher-level carnivores, such as larger fish, predatory birds, and humans. Understanding reproductive success, growth rates, survival, and population dynamics of bass in a region can lead to information that can serve as a baseline for establishing trends, which in turn are useful indicators of bass populations, community structure, and fish guilds. Because fishing is such a popular pastime, and bass are a preferred fish in many regions (Fleming et al. 1995; Burger et al. 2001a; Campbell et al. 2002), indicators of bass population stability lead directly to establishing creel and size limits for fishing. Bass can also be directly indicative of the health and well-being of the organisms they ingest (plants and animals),of their own populations, of populations with which they interact with (as competitors for space, food, and habitat), and of populations that consume them.

All of these interactions have cascading effects, in that if the population of bass decline (due to a range of stressors), then:

1) species that compete directly with bass for food may increase (due to a lack of competition with bass);

2) some species of prey may increase because their own competitors are being eaten by the bass competitors (which have now increased);

3) species that prey upon bass will decline, causing their own predators to decline; and

4) the disruptions in the normal population numbers could affect nearly all trophic levels because of a change in the relative number of different organisms (to serve as predators, competitors, and prey).

In summary, bass can serve as bioindicators at several ecological levels to evaluate individual and population health, as well as community and ecosystem health.

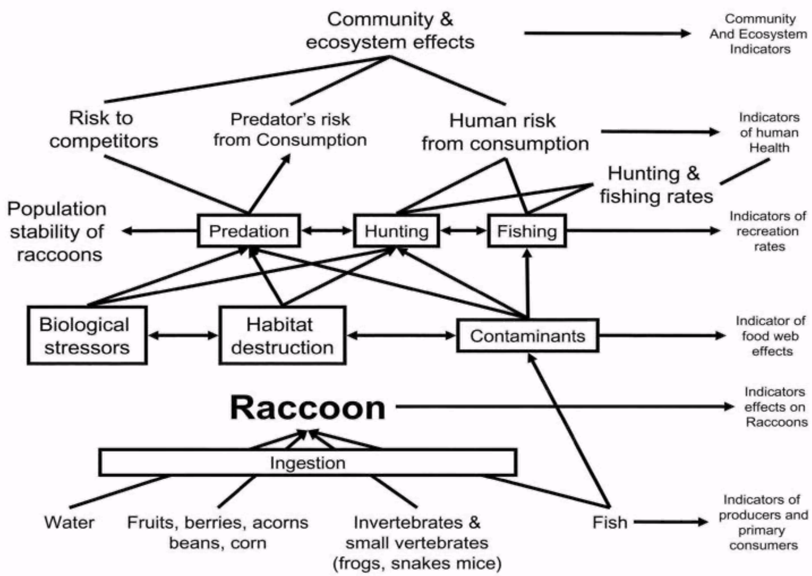

Figure 3. Schematic of bioindicator properties of raccoon, and other mid-level predators. Ingestion exposures of raccoons are shown on bottom of diagram. Measurement of population, reproduction, growth, human disturbance level, and contaminant levels can all serve as indicators.

Raccoons are an example of a mid-level omnivore and predator that has a complex range of plants and animals it eats, and a complex array of animals that consume them (Figure 3, Burger 1999a). Raccoons are useful bioindicators because they are abundant and widespread throughout the United States; occupy a variety of habitats from rural to urban, are omnivores and eat some organisms that are both high and low on the trophic scale, are relatively sedentary, and are hunted and eaten in some parts of the United States (Burgeret al. 1999). Further, they are terrestrial animals that eat prey both on land and from the water. Raccoon hunting is a popular sport in the south, and they are eaten by people or their pets (SCDNR 1996a,b). Because hair can be used, museum collections can provide samples for temporal analyses (Porcella et al. 2004).

Raccoons obtain contaminants from their water and food, which includes fruits, nuts, seeds, vegetable crops, invertebrates, small vertebrates (frogs, snakes), fish, and anything else they can find, including garbage (Burger 1999b). Because males can travel a few kilometers in their daily movements, they are useful for monitoring off-site movement of pollutants from contaminated sites, such as Superfund sites*, or those owned by the Department of Defense or Department of Energy (Gaines et al. 2000; Burger et al. 2000,

2002). They may also serve as prey for larger predators (including humans) and their carcasses are eaten by scavengers (microbes return the rest of the contaminants and nutrients to the ecosystem). Understanding contaminant levels in their tissues can provide information on the health of raccoon populations themselves, on their predators (including humans), on other organisms that occupy the same trophic level, and on other parts of the ecosystem, including the ultimate decomposition of their carcasses. Other stressors, such as habitat changes, can lead to population changes, with associated changes on other organisms within their food web. The complexity shown in Figure 3 illustrates how one species within its food web can link multiple measurement endpoints (shown in rectangles on the figure) that can serve bioindicator roles.

Use of Bioindicators in Management and Research

The development of bioindicators has both a research and a management component, and therefore can be much improved by the inclusion of a wide range of stakeholders in the process (President’s Commission 1997). Nowhere is the distinction between pure research and management less clear than in the development of bioindicators. Managers are dependent upon scientists to develop and test bioindicators, and often to collect the data on the bioindicators. Scientists are dependent upon managers for identification of a particular problem or stressor requiring indicators, and to managers and regulators for the funds and permits to conduct research to develop suitable indicators. Indicators are most useful when both managers and scientists (as well as the public) are involved in their development from the outset.

Understanding how bioindicators are used in both management and research requires surveying what types of indicators are used, for what stressors, and for what species, communities or ecosystems. A review of the articles published in the journal Ecological Indicators reveals the main focus of bioindicator research by scientists and managers.

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* Superfund - U.S. government fund intended to pay for the cleanup of hazardous-waste dump sites and spills.

Superfund site - extremely polluted location that was designated to receive Superfund money to finance the environmental cleanup (U.S. Politics)

More than twenty percent of the papers in this journal (which began in 2001) dealt with aspects of ecosystem functioning, and another fifteen percent dealt with political, regulatory, and cost considerations. Only twelve percent of the papers dealt with pollution and contaminants, and another eight percent dealt directly with human activities (such as mining, agriculture, transportation and the military). It is these two categories (pollution, human activities) that have most often been addressed by formalized risk assessment.

There are, of course, many other journals that publish papers on indicators.

These data, and my own research and observations suggest that there are four main types of ecological indicators:

1) ecosystem health assessment,
2) human effects,
3) human interventions, and
4) human health and well-being.

Although the latter represents one receptor within ecological systems, it deserves special mention because of our self-interest in our health and well-being, and in the user services provided to us by ecosystems (clean air and water, hunting and fishing, recreation, and aesthetics). Animals can also serve a special bioindicator role as sentinels for human health hazards, where animals are placed in specific environments for that purpose (NRC 1991; van der Schalie 1997; van der Schalie et al. 1999; Rabinowitz et al. 1999; Stahl 1997; Fox 2001).

Ecosystem health assessment indicators are those traditionally developed by ecologists for relatively pristine environments. They help us understand the pure aspects of community and ecosystem functioning, and they form the basis for examining both the human effects of stressors and whether human interventions (remediation, restoration) are successful. Used in the latter context, they can help managers, regulators, and the public make decisions about future remediation and restoration options; for example, what actions have been successful in maintaining healthy populations and communities?

Conclusions

Bioindicators (and biomarkers) were developed along with biomonitoring plans because they are the main tool for such plans. The formalized process of risk assessment, which developed in the early 1980s, stimulated the further development of key indicators by state and federal governmental agencies, as well as other land and ecosystem managers. Some federal government agencies, such as EPA and NOAA, underwent a formalized process of establishing risk assessment guidelines that codified some bioindicators (or at least types of bioindicators, such as top-level predators within ecosystems). To be of greatest use to managers, regulators, and the public, bioindicators should be part of a long-term biomonitoring plan that examines both temporal and spatial trends. This requires bioindicators to be biologically, methodologically, and societally relevant. They should measure responses to stressors before the effects become catastrophic, be easy to use, be cost-effective, and important to the public.

There are four main types of indicators, which are not mutually exclusive, that relate to ecosystem health assessment, human effects, human interventions, and human health and well-being. All of these can be used as indicators of sustainability, which can in turn be used for a range of purposes, including

1) assessing past damage,

2) evaluating the efficacy of restoration of ecosystems and remediation from biological, chemical/ radiological, physical and other insults, and

3) predicting future health and well-being.

Most ecologists deal mainly with ecosystem health assessment, but the separation of ecosystem health indicators from a range of human-dominated indicators limits both their applicability and their interest to the public, regulators, and politicians. Moreover, bioindicators can be selected so that encompass more than one type. For example, to examine the effects of remediation or restoration, it is essential to select ecosystem health assessment indicators as the measurement endpoints. Further, indicators can be selected so that tell us something about both human and ecological health (Burger and Gochfeld 2001a, 2004b), and these will often receive greatest societal support.

Butterflies as Bioindicators for Climate Change Effects

An excerpt from the article by Camille Parmesan

Earth's climate is changing. Weather patterns over the last century have shown trends toward warmer temperatures, increased cloudiness (especially at night), and increased precipitation occurring in fewer, more extreme events. Evidence is mounting that these trends bear a human fingerprint: the products of industrialization are altering atmospheric processes at the molecular level. If this assessment is correct, these trends will continue. In particular, what are now extreme events in terms of temperature and precipitation may become the norm. Extreme weather events affect many aspects of natural populations, communities, and ecosystems, from behavior to reproductive physiology to dynamics.

It is important for both scientific understanding and future policy to assess the effects of current climatic trends. Analyses of current impacts are essential for prediction of future impacts on natural populations under global warming scenarios. Further, studies can cross-validate observations stemming directly from climatic data, providing independent support for the conclusion that systematic climate change is occurring. Further, the magnitude of biotic response indicates the importance of the relatively small level of climate change that has already occurred. While biologists have studied biotic responses to past major climatic shifts on a time scale of several centuries (i.e., after equilibrium), responses on a decadal time scale during a transition period are not well understood. Thus, close analyses of biotic changes over the last century are essential to future predictive models.

A first approach to these questions is best taken with a model system in which the effects of climate are understood at a mechanistic level. Much wild plant and animal life has a shared form of population structure characterized by small, discrete populations with low dispersal. Though there are some true migrants, most butterfly species fit this pattern.

In the face of a local environmental change, such as a systematic change in the climate, wild species have three possible responses:

1. Move to a new place to track the environmental changes—either through whole-range shifts or through changes in the timing or destination of migrations
2. Remain in the same place, but change to match the new environment—through either a plastic or a genetic response
3. Suffer local extinction

Studies of responses to past large-scale climate changes during the Pleistocene glaciations provide a good basis for predicting biotic responses to current climate change. Overwhelmingly, the most common response was for a species to track the climate change such that it maintained, more or less, a species-specific climatic envelope in which it lived. Typically, a species' range shifted several hundred kilometers with each 1°C change in mean annual temperature, moving poleward and upward in elevation during warming trends.

For very mobile or migratory animals, such as many birds, large mammals, or pelagic fishes, range movement occurs via the process of individuals moving or migration destinations changing. Thus, these movements actually track yearly climatic fluctuations, causing range changes on an annual basis. These mobile species are very sensitive indicators of climate change because they show an immediate response, but, as with climatic data itself, one then needs very longtime series in order to distinguish year-to-year variation from the long-term trends. Even then, it may prove difficult to discern a consistent pattern.

Bretherton (1983), for instance, presented some explorations of the arrival dates and subsequent abundances of migrant macro-Lepidoptera in Britain, with some records going back to the 1850s. He noted that while these metrics varied widely over the years, extreme values appeared sporadically without seeming linked to decadal trends. Further, species were not particularly synchronized in their behavior. There is some climatic signal in fluctuations of migrant abundances among years; for example, high abundances of many migrants in 1858 and 1859 followed a decade of favorable weather. However, following a distinct warming period that began in the 1920s, there was only a slight trend toward more subsequent peak years, and migrant numbers were not consistently high every year during this 20-year warm phase. This mismatch between decadal climatic trends and yearly migrant fluctuations is nearly impossible to interpret without considerable debited analysis: it could be due either to high sensitivity of the butterflies to subtle climatic variations or to relative insensitivity to those variations coupled with non-climatic factors. Arrival dates appeared even more chaotic, leading Bretherton to lament that "forecasting the arrivals of immigrant species is likely to prove a disappointing pastime."

In contrast, for the bulk of wild species that are sedentary, range changes stem not from changes in the pattern of individual movement's, but from the much slower process of population extinctions and colonizations. Because species' responses have an inherent lag lime stemming from limited dispersal abilities, ranges may take from decades to centuries to shift noticeably, but are more likely to follow long-term climatic trends than are yearly fluctuations. Detection of such changes occurring in natural populations in recent times is increasing.

Other responses that have been documented are phenological shifts, such that germination, breeding, and so forth are beginning earlier in response to advancement of spring weather conditions. With these sorts of broad patterns emerging, the challenge is to understand not only the general impacts of climate change, but their mechanistic basis as well.

Butterflies as bioindicators

Appropriate Attributes

Ideal target species, communities, or systems in which to look for biotic responses to climate change are those that meet the fallowing criteria:

1- They are known from basic research to be climatically sensitive with respect to the hypothesized change. It is best if the actual mechanism is known, though correlational studies are also indicative.

2- They are robust to some level of anthropogenic influence (i.e., relatively insensitive to possible confounding factors stemming from direct effects of human activities).

3- A short (decadal) or no lag time is expected between climate change and respond.

4- There are good historical records for the system, either from being a model system for basic research or from a history of amateur collecting**.**

5- Current data are available (from monitoring schemes, long-term research) or easy to gather.

6- Data are available over a large area—preferably over the whole species' range.

Though different taxonomic groups might satisfy some of these requirements, butterflies and birds ate perhaps the only taxa that meet all of these criteria (even then, not all species within each group fit the list). For example, tree rings provide long time series of growth rates, but it is difficult to determine whether changes in growth were due to changes in temperature or precipitation or to other forms of stress, such as insect attack or disease

Early Studies

Since the early part of the twentieth century, butterfly aficionados and researchers have remarked on their sensitivity to spring and summer temperatures. Ford, in his masterpiece on British butterflies [1945], noted the northward range shifts of several species in England, including *Limenitis Camilla*. Ford attributed these shifts to a warming trend in Britain:

White Admiral Limenitis Camilla

In 1907 or 1908 Canon Godwin liberated large numbers of the white admiral in Wateringbury Woods, from which the species was then apparently absent, but none survived. Long afterwards, that locality became included within the range of the butterfly, which had extended naturally, and in 1934, Canon Godwin saw at least 200 specimens in the area where he had unsuccessfully attempted to establish the species in the past.

Kaisila independently documented northward shifts in the ranges of many Lepidoptera (primarily moths) in Finland over the same period:

A strong tendency to become commoner and to extend the range has appeared during recent decades in the southern element of the Lepidopterous fauna of southern Finland …Most of the species concerned, expanding species, show two periods of extension of their area of occurrence: one in the 1910s, and another which started about 1930 and still continues, to some extent at least. These phases of extension and abundance correspond accurately to the periods of warm summers during the recent... change of climate…..Although a considerable proportion of these expanding species favour a cultivated environment, an increase in the intensity of cultivation has but little effect on the extension of the range; the changes in this have taken place very gradually and over a very long period.

Ability to interpret patterns of change

The beauty of butterflies as bioindicators lies in the breadth and depth of our basic ecological, evolutionary, and behavioral knowledge. Their macro-and microhabitat requirements are often understood in such detail that the cause of a distributional change can be inferred from known processes operating at the population level. This understanding has become extremely important as the anthropogenic onslaughts of the twentieth century have subjected wild species to a suite of factors that can alter their distributions; competition with invaders, acid rain, nitrogen rain, habitat destruction and general habitat fragmentation, and land management changes. Starting with an observed distributional change and then teasing apart these nonclimatic human impacts from those stemming from climate change requires detailed knowledge of each species' idiosyncratic ecological specificities and sensitivities.

For an example of this process, I again turn to the large literature on British butterflies. Many species ranges that extend over most of Europe have their northern edges situated in Britain. Various analyses of distribution limits and climatic variables show that most British butterflies' northern range limits correspond to species-specific climatic isotherms. These studies, along with others on correlations between population dynamics and climate, have led to a consensus view that climate largely determines the distributions of British butterflies and that, barring future habitat destruction, most species should respond to climatic warming trends by expanding northward.

pearl-bordered fritillary (Boloria euphrosyne) small pearl-bordered fritillary (B. selene)

But a close look at three of these species paints a more complex picture. The white admiral *(L. Camilla)* has a northerly limit corresponding to the 15.9° C mean July isotherm. Two fritillaries, the pearl-bordered and small pearl-bordered *(Boloria euphrosyne* and *B. selene)* follow the 8.9°C mean July isotherm. All three species share open woodland habitat, and their host plants extend beyond their ranges, so expansion should be possible. Further, their population structures are similar, being described as "rare and localized". From the turn of the twentieth century to the present day, mean annual temperature in Britain has risen by 0.8 C. As predicted, *L. Camilla* has responded by expanding its distribution: its northern limit now lies about 200 km north of where it was in the early 1900s. Both *Boloria* species, however, have contracted considerably from the eastern half of England.

With only this information, we would conclude that simple correlations between temperature isotherms and range limits provide a false causation. So, while *L. camilla* appears to be limited by summer isotherms and to be responding to an increase in temperature with an expansion of its distribution, *Boloria* species appear to be reacting in an opposite fashion. It would seem, then, that we must consider nonclimatic factors to understand *Boloria's* distributional changes.

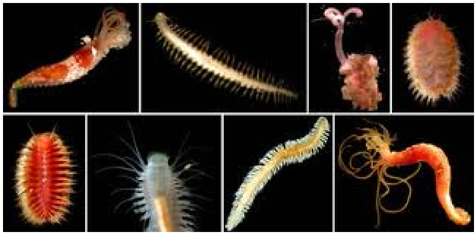
Focusing on micro- rather than macrohabitat requirements indicates that *B. Selene* and *B. Euphrosyne* are, in fact, extremely temperature-sensitive, laying their eggs only where the air temperature at the host plant surface is 17°-19°C. In the southern parts of their ranges (southern France), these temperature requirements are met even when the host plants (violets) are shaded by overgrowing shrubs, but in Britain the violets must be in open clearings to be suitably warm. The contraction of *Boloria* species can be explained by changes in coppicing practices in the United Kingdom, which have allowed understory shrubs and saplings to shade ground-level herbs: the hosts are present but are no longer in a suitable microclimate. Thus, from the perspective of *Boloria*, the climate of much of Britain has become cooler. In contrast, the honeysuckle host of *L. Camilla* is a vine, and females oviposit at a height where the temperature has been much less affected by land management changes. Therefore, in all probability, both of these distributional changes are related to climate: to macroclimatic shifts in the case of *L. Camilla* and to microclimatic shifts in the case of *Boloria*. If Britain were to warm by as much as 3°C, then *Bolori*a might be able to recolonize those more shaded woodlands and once again be distributed throughout England.

Crustaceans as Bioindicators

Manfred Rinderhagen, Jürgen Ritterhoff and Gerd-Peter Zauke

Introduction

bivalve



polychaetes

echinoderms

Crustaceans are frequently used as bioindicators and biomonitors in various aquatic systems. One reason is that they are a very successful group of animals, distributed in a number of different habitats including marine, terrestrial and freshwater environments. They are thus interesting candidates for comparative investigations.

Some of the special features of crustaceans, particularly of reproduction strategies, may be highly important for the interpretation of data from bioindicator studies using these organisms, and for the development of ecotoxicological endpoints. The focus of this presentation is on the utilisation of crustaceans, mainly freshwater species, as bioindicators or biomonitors. The two terms are not always clearly distinguished. We use the term (i) bioindicator to define a collective of organisms from the field (in a statistical sense) which give information about the environmental state, with effect variables being their mere presence or absence, their life history status or population dynamics (e.g. regarding age structure, abundance or genetic structure; and the term (ii) biomonitor to define an organism which can be used to establish geographical and temporal variations in the bioavailability of contaminants by measuring the accumulated concentrations of chemicals in the whole body or in specific tissues. Thus, results of standard toxicity tests are not within the scope of this section. In marine systems, crustaceans are not frequently used as bioindicators as yet. Here the emphasis is on other groups, including bivalves, polychaetes and echinoderms, mainly because much of the effort is spent on the benthos.

Review of results obtained at different methodological levels

In this section we shall give an overview of results of investigations (since about 1990) at different methodological levels that have used crustaceans as bioindicators or biomonitors, referring to their most important biological features. This review will focus mainly on freshwater organisms, particularly on amphipods, isopods and Cladocerans, which are often used in freshwater studies as bioindicators and biomonitors. In contrast, crustaceans have seldom been used for that purpose in marine studies, which will thus be only briefly addressed. Bioindicators should be benthic species, distributed over the whole region of interest, and should live in the littoral zone to enable easy sampling. Further, they should be of ecological importance. Thus, it’s recommended the barnacle *Balanus improvisus* as the only crustacean to be used as a sea bioindicator.

Balanus improvisus

Cladocera

Accordingly, mainly benthic littoral bivalves or polychaetes are used as biomonitors and, to lesser extent, as bioindicators in marine systems. Regarding pelagic marine systems, crustaceans are also used as biomonitors, but not yet as bioindicators.

Ecological preferences and distribution

The micro-distribution of various gammarid species depends on particular ecological preferences, such as habitat structure (including water flow, substrate and food) as well as differences in physiological tolerance to oxygen content, temperature and water quality. The presence or absence of predators also plays an important role. Greenberg showed that *Gammarus pulex*, for example, is able to evaluate differences in habitat quality and to respond to it. When artificial streams were modified by adding a coarse substrate, for example, the abundance of amphipods at these sites was increased.

Gammaridae is a family of amphipods.

Gammarus roeseli

Gammarus fossarum

Gammarus pulex

Crane investigated the population characteristics of *Gammarus pulex* in five English streams during 1992. The results showed a great variability of *G. pulex* under different lotic conditions. Significant differences between populations of different streams involve population density, standing crop biomass, individual size and sex ratio. It was suggested that some of these differences were caused by pollutants or by the physical structure of the stream bed.

Invasion of neozoic species may be caused by different tolerance to environmental pollution.

Toxic effects can result in the elimination of local taxa, and neozoic species which are probably more resistant to pollution may fill the empty ecological niches. Streit suggests that this may be a reason for the invasion of *Gammarus tigrinus* in the River Rhine after elimination of *Gammarus fossarum*.

Meijering studied the occurrence of *Gammarus fossarum, Gammarus pulex* and *Gammarus roeseli* in Hessian running waters (Germany) from 1968 to 1988. After considering the ecological preferences of the particular species with respect to temperature, water flow rate, food and geological conditions, the lack of oxygen mainly caused by organic pollution and low pH were recognized as the most important factors which determine the distribution of these Gammarus species. For example, *G. pulex* is more robust against pollution, low oxygen and low pH. Thus, sometimes it may be the dominant or the only Gammarus species in an area affected by these environmental constraints. For the isopod *Asellus aquaticus* it was reported that it not only responds directly to pollution by developing an increased tolerance; it also exhibits an indirect adaptation of life history strategies, as demonstrated by less investment in reproduction, producing fewer, but larger offspring at the polluted site of a stream.

isopod Asellus aquaticus *amphipod Hyalella azteca*

Laboratory studies indicated that these phenomena probably have a genetic basis. Laboratory experiments proved that the North American amphipod *Hyalella azteca* is acid-sensitive like the Gammarus species mentioned above, being also influenced by water temperature. At lower temperatures, the amphipods are able to tolerate an acid stress for a longer period of time than at higher temperatures. These results suggest that tolerance to acidification probably varies seasonally and that the summer months are the most sensitive ones. Most of the natural habitats of *H. azteca* (which prefers ponds to lakes) show seasonal variations of water temperature. Thus, when using *H. azteca* in laboratory bioassays, it is more realistic to use a variety of temperatures simulating the range in the field and acclimatise *H. azteca* to them correspondingly, before pH adjustments are made. The temperature-dependent sensitivity to acidification has then to be taken into account for the prediction of ecological effects.

Reproductive aspects such as egg survival and brood development (each time-related to optimal temperatures), reproductive potential and fecundity of populations of *Gammarus fossarum* and

Gammarus roeseli in Austria were intensively investigated. No significant intra-specific differences were found between populations of either species, but there were differences between the two species, which appear to have different temperature requirements. The optimum temperature for *G. fossarum* is a little bit lower than that for *G. roeseli*; moreover, *G. fossarum* has a wider optimal temperature range for egg survival and reproductive success (50% survival or more, with 3.6-19.2 °C for egg survival and 4.5-19.1 °C for reproductive success) compared to *G. roeseli* (egg survival: 11.9-15.1 °C; reproductive success: 7.0-21.0 °C). These attributes may well influence the distribution patterns of both species. The reproductive period of *G. fossarum* extends from December to September, and that of *G. roeseli* from March to September. Conditions will be optimal for *G. fossarum* in streams that stay cool in summer, whereas for *G. roeseli* optimal conditions will occur in summer-warm streams, from which *G. fossarum* is ordinarily absent. Only *G. fossarum* is able also to breed in winter-cold streams, with development times of more than 3 months (at <10 °C) and thus long to breed s.

Gammarus minus

Gammarus zaddachi

A specialised investigation of the presence and habitat preferences of the amphipod *Gammarus minus* is provided by Glazier. The presence or absence of this amphipod was evaluated in several cold springs in central Pennsylvania, showing differences in pH and ionic content. The amphipods were missing in springs with pH<6.0 and conductivity <25 µS·cm-1, and there was a gradual linear decrease in population density with decreasing alkalinity and water hardness (Ca2+ and Mg2+). Brood size and brood mass were independent of spring pH and ionic content, but correlated with maternal body size. Furthermore, the percentage of females breeding was independent of pH and ionic content in the various springs. Most of the observed differences between the populations in the different springs could not be clearly explained. It was suggested that the population density is possibly more a function of food availability than of direct physiological effects on the amphipods of alkalinity and hardness.

As outlined by Meurs, it is not sufficient to examine the abundance of organisms in a given ecological system to obtain a complete picture of potential ecological processes. To achieve this goal, detailed investigations into the population dynamics are required, as demonstrated for the amphipod *Gammarus zaddachi* in the Weser estuary and a major freshwater tributary (River Hunte). At freshwater sites in the River Hunte, the length distribution of gammarids shows distinct seasonal fluctuations, with small juveniles appearing in late spring (April-May) and larger adults appearing in winter (December-February). Most interestingly, although precopulatory pairs were frequently observed in winter, no mature females carrying juveniles in the brood pouch occurred at all, and the abundance of the population at these sites approached zero between February and March.

The authors inferred that the gammarid populations at these freshwater sites were not maintained by autochthonous reproduction, but by invasion of juveniles from other parts of the river system. *G. zaddachi* is known to reproduce in brackish waters and this was also observed at a site in the Weserestuary. Females carrying juveniles in the marsupium were abundant in December and in March-April. An analysis of water movements during ebb and flood revealed that it might well be possible for juveniles (released in the brackish water region of the estuary) to move upwards and reach the freshwater sites of the River Hunte as predicted by the corresponding seasonal analysis. The authors stress the necessity of such detailed investigations in complex river systems before the ecological situation can be fully assessed — for example, in the context of environmental impact assessments.

Bioaccumulation in experiments and field studies

Crustaceans, particularly amphipods and isopods, are often used in bioaccumulation experiments and in field studies.

Results for the amphipod *Gammarus fasciatus* are described by Amyot. The authors inferred that *G. fasciatus* is a suitable biomonitor for Cd, Ni and Pb, but not for Cu and Zn, which seem to be regulated. Significant variations in concentrations of Ni, Cd and Pb in field samples were reported for different seasons. It should be mentioned, however, that metals were only measured two times a year, so that the data base might be too small to infer 'seasonal' variations. No significant differences were found for Mn, Cu, Zn and Cd. It was hypothesised that these variations could be related to moulting or food contamination.

Bioaccumulation of As, Cd, Cu, Pb and Zn was investigated in two groups of the amphipod

Hyalella azteca. One control group was exposed for 28 days under laboratory conditions to sediments collected from a depositional area of a river. Another group of organisms was collected from riffles adjacent to the depositional area and their metal accumulation under field conditions was measured. Although the patterns of accumulated metals were similar in the two groups, metal concentrations were 50-75% lower in organisms from the control group, exposed in laboratory experiments. It was concluded that long-term monitoring of contaminated rivers should not only rely on short-term sediment bioassays, but should also include the evaluation of long-term bioaccumulation in the field.

polychaete Armandia brevis *Gammarus fasciatus*

Bioaccumulation by the non-deposit-feeding amphipod *Rheopoxynius abronius* of polycyclic aromatic hydrocarbons (PAHs) from contaminated sediments was examined by Meador.

Sediments were collected at the Hudson-Raritan estuary and the organisms were exposed to them for 10 d. Analyses of the tissue concentrations of 24 PAHs and comparison of the data for *R. abronius* with that for the non-selective, deposit-feeding polychaete *Armandia brevis* did not yield significant differences for the low molecular weight PAHs (LPAHs). In contrast, bioaccumulation of high molecular weight PAHs (HPAHs) differed markedly between the two species. After analysing correlations between concentrations in tissues and environmental substrates as well as partition coefficients, the authors concluded that the bioavailability of HPAHs was significantly lower for *R. abronius*, probably due to their partitioning to dissolved organic carbon, while it was still high for the deposit-feeding polychaete.

The preceding examples show that bioaccumulation is a very complex process, influenced by several environmental factors. For example, the uptake route plays an important role, and it may be that no simple correlations can be established between the concentrations of pollutants in the substrate and in the organism, or that more than one uptake route is involved.

Effects on feeding activity and growth

Feeding activity and growth are two sensitive sublethal indicators at the level of the individual organism which can themselves affect higher levels of biological organisation (the population, community or ecosystem).

In a series of field studies, it was found that the feeding rate of *Gammarus pulex* is a sensitive indicator of water quality. In these studies, individuals of different populations of *G. pulex* were deployed in cages at different stream sites above and below metalliferous discharges. By comparing feeding rates with the measured bioaccumulation, Maltby found that the two were negatively correlated for, and manganese as well as iron was taken up by the animals. However, this effect could not be explained by adsorption of these substances alone. Laboratory experiments were carried out to validate the results from the field study. It was shown that exposure to iron concentrations similar to those measured in the field experiment did indeed reduce the feeding rate of *G. pulex*, while manganese had no additional effect. Differences in sensitivity between populations of different sites were reported and the authors concluded that animals originating from a polluted site might have developed a greater metal tolerance. Thus, results obtained for different Gammarus collectives must be regarded with some caution. Moreover, Crane found differences between the feeding rates measured in two different laboratories. These differences did not seem to be systematic, but the reasons remained unclear, pointing to the necessity of appropriate intercalibration procedures. It should be noted, however, that a reduction of feeding rate under metal exposure is not restricted to crustaceans, as shown, for example, for Fe and larvae of the ephemerid *Leptophlebia marginata*.

Moore examined the relationship between food rations and growth rates of *Hyalella azteca*. Growth rates decreased significantly with reduced food rations, whereas survival was not influenced after 10 days. However, reproduction was also reduced with low food rations. Effects like those reported in this study might be confused with toxic effects in corresponding experiments and should be carefully considered.

Scope for Growth

Scope for growth is a measure of the energy budget, that is the difference between energy absorbed (from food intake) and energy metabolised. It gives an indication of the metabolic condition of an organism. Scope for growth is frequently used as an indicator of pollution stress in marine systems (e.g. regarding mussels), but rarely in freshwater systems. If implemented properly, it provides a highly relevant ecological indicator. Maltby, for example, investigated the sensitivity of scope for growth in the benthic freshwater crustacean *Gammarus pulex*. The organisms were exposed to zinc, 3,4-dichloraniline, oxygen and ammonia under laboratory conditions. It was shown that scope for growth provides a sensitive assay, with a response to the different stressors. Scope for growth was reduced by any of the four substances applied. A field deployment of a scope for growth assay using *G. pulex* is described by Maltby. The animals were caged up- and downstream from a pollution source. Compared to the upstream reference site, scope for growth was reduced at all sites downstream from the pollution source.

Gammarus pulex

Behavioural changes

Behavioural changes have been shown to be a very sensitive, rapid sublethal response to a wide range of pollutants. They basically represent an integrated response of an individual organism, although some behavioural changes such as precopulatory disruption may lead to changes at the community or population level.

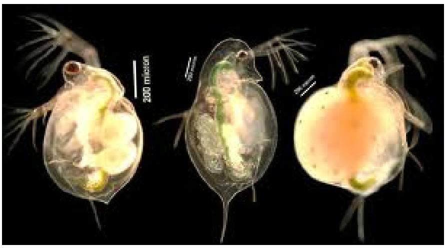
Poulton described a behavioural bioassay to evaluate environmental stress using the freshwater amphipod *Gammarus pulex*. Here the disruption of precopulatory pairing is taken as a signal of the presence of pollutants or parasites. The induced separation time, that is the time from introduction of a pair to the test solution to the release of the female by the male, was measured using cadmium as pollutant. The mean induced separation time decreased with increasing cadmium concentrations. Mean separation times ranged from 944 s in the control to 471 s at the highest cadmium concentration. The bioassay has also been successfully used in the field. Disruption of precopulatory pairing has also been described as a result of exposure to various concentrations of γ-hexachlorocyclohexane (lindane).

Within 4 to 72 h after exposure, recovery of precopulatory pairing occurred. Malbouisson further investigated the use of feeding rate and repairing of precopulatory period to assess lindane toxicity. Feeding rate was significantly reduced either by long exposure to low concentrations of lindane or by short exposure to high concentrations. Repairing of precopulatory period was only affected by combining higher concentrations and longer exposures.

Drift

Drift is a special active behavioural response of lotic animals to environmental stress. Liess used Gammarus pulex as an indicator of pesticide stress related to surface water runoff in small rural rivers. G. pulex showed an increased drifting behaviour as a result of pesticide pollution (e.g. due to lindane, permethrine or fenvalerate), following enhanced farmland runoff. The animals give very sensitive responses to low amounts of fenvalerate. Furthermore, G. pulex is capable of recolonising the site within some days or weeks. Other species (e.g. the trichopterean larvae Limnephilus lunatus) did not show any drift behaviour and, in staying at contaminated sites, may become less abundant due to toxicants.

Effects on survival, reproduction / mixed effects



Cladocerans

Hyalella azteca

Many tests using organisms focus on acute toxicity and provide LD50 values. Various sublethal effects are often evaluated together with effects on survival. Amphipods, isopods and Cladocerans are the crustaceans mainly used in toxicity tests (bioassays). *Gammarus pulex* is one of the amphipods most frequently used in Europe, particularly in aqueous-phase toxicity tests, whereas *Hyalella azteca* is the most frequently used amphipod in the USA, particularly for sediment toxicity tests. Both the aqueous-phase and the sediment can be an important source of contaminants for organisms in natural systems.

Conclusions

As has been shown in numerous investigations on different methodological levels, crustaceans offer excellent opportunities to derive sensitive and ecologically relevant indicators of environmental stress. This is mainly due to their specific biological attributes, including their life history strategies.

Because the females often carry eggs or juveniles in specialised structures on the body (e.g. in the marsupium), the reproductive behaviour, for example, can be assayed in laboratory and semi-field experiments as well as in biological field surveys. If it can be proved in such field surveys that the population can reproduce under the given environmental constraints, this finding can be regarded as a true ecological indicator. On the other hand, if life history traits like fecundity deteriorate in laboratory or semi-field experiments, this finding provides a meaningful endpoint which allows some prediction of the potential future development of the populations under study. Not only reproduction, but also other behavioural responses of crustaceans, such as changes in feeding, drifting, locomotion or precopulatory behaviour have proved to provide sensitive endpoints with respect to bioindication. In all these aspects, crustaceans have great advantages compared to other groups, for example, bivalves or gastropods. It is striking, however, that almost no explicit indicator system has been developed for the marine environment as yet. One reason might be that strong pollution gradients on a local or even regional scale have been documented mainly for freshwater systems, e.g. in relation to degradable domestic waste waters or to acidification and metal emissions in lakes. Another reason might be that limnology is the leading discipline in the development of theoretical concepts.

In the last few years we have seen increasing numbers of papers dealing with exposures to mixtures of contaminants or to contaminated sediments collected in the field. Such approaches are particularly relevant to this chapter, more so than the application of classical standard toxicological protocols. Nevertheless it is surprising to note that most studies deal either with ecotoxicological effects or with bioaccumulation, but not with both aspects in combination. A combined approach would be particularly appropriate when animals are exposed to mixtures of contaminants or under field conditions, because we can expect that especially those substances that are taken up can produce adverse effects. However, in this context it would also be necessary to evaluate potential detoxification mechanisms — for example, the binding of metal ions to metallothioneins or granules and the metabolism of organic xenobiotics, probably resulting in less toxic products. Thus, in the future more integrated studies are required, taking into account all these different aspects. Furthermore, we need the development of predictive models, relating bioaccumulation (e.g. on basis of compartment models) to effects, as well as subsequent verification and field validation of these models. To assess the significance of bioindicators, stringent methods for a calibration are required, to test whether a finding from a contaminated area is statistically significantly different from a finding derived for a reference site.

To achieve this goal, we need closer co-operation among different scientific groups, now working in isolation in their particular classical fields, and a funding policy which favours innovative integrated approaches instead of stabilising the classical concepts.

Lichen Indicators of Ecosystem Health in Nova Scotia's Protected Areas

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SUMMARY

Nova Scotia

Air pollution and climate change are threats to maintaining ecological health of protected areas. Protected Area managers require a meaningful way to measure impacts of these threats. Lichens provide a relevant, sensitive and measurable indicator for long-term monitoring. Hundreds of studies have linked lichen communities to air quality, and several long-term lichen monitoring programs in Europe and the US are using lichens to assess climate change. Other studies have shown strong correlations of lichen abundance to ecosystem biodiversity and productivity. Analyses of existing lichen survey data suggest sensitivity of Nova Scotia lichens to air quality. The Protected Areas Branch (PAB) of the Nova Scotia Department of Environment and Labour will establish a province wide network of lichen monitoring plots within protected areas involving partners from industry, government and academia. Objectives of the project are to provide long-term monitoring in forests of: 1. air quality impacts on ecosystems; 2. climate change impacts on ecosystems; 3. elements of forest ecosystem productivity; and 4. elements of biodiversity in forest ecosystems

1. INTRODUCTION

1.1 Issue

A primary objective of most protected areas is to protect natural processes and biological diversity. Despite legal protection, threats to protected areas continue. Human activities external and internal to protected areas can affect the biota and processes occurring within the protected areas. Air quality and climate change are two significant issues affecting ecological integrity of protected areas with which managers must deal.

1.2 Air Quality and Climate Change

Despite initiatives to reduce airborne pollutants, air quality problems continue to be an issue and are anticipated to be for the next 20 to 50 years. Environment Canada reports that growth in air pollution sources has the potential to outpace any gains made in recent years. Effects of acid rain continue to impact ecosystems. Recent modelling studies show that up to one quarter of lakes in eastern Canada still will be chemically damaged even after 2010 emission targets are reached. High levels of heavy metals are being found in ecosystems in Nova Scotia as a result of pollution.

Lakes in Ontario (eastern Canada)

Nova Scotia provides an ideal region to monitor impacts of pollutants on ecosystems. The Maritime provinces of Canada are uniquely situated within storm tracks and prevailing winds which transport industrial emissions from central and eastern North America. Thus, Nova Scotia receives the brunt of pollutants from industrialized areas of North America. Nova Scotia can provide an early warning system for the rest of North America on ecosystem effects of pollutants.

Climate change impacts on species and ecosystems are increasingly evident. Two recent syntheses and re-analyses of hundreds of studies on biota have shown significant changes in breeding, flowering, nesting and abundance of plants and animals consistent with expected effects of climate change. Modelling studies are predicting significant effects to biological diversity and species abundance with some of the largest effects occurring in temperate forest regions.

The relationship of lichens as early warning indicators of air pollution, particularly acidifying or fertilizing sulfur and nitrogen-based pollutants, has been documented in hundreds of scientific papers. Air quality monitoring studies have been done worldwide and permanent monitoring programs using lichens exist in the US, Netherlands and Switzerland. Lichens' sensitivity to air quality stems from their reliance on airborne nutrients and water, as well as lack of protective structures such as cuticles found in vascular plants. Trees and other vascular plants are affected by pollution but are much slower to show impacts than lichens.

More recently, lichens are being used in assessing climate in Europe and the US.

Distributions of certain species are a response to regional moisture and temperature gradients.

Mapping distribution of climate sensitive species provides an indication of climatic conditions and monitoring over time reveals climate change effects. The first challenge to manage these problems is to know when these impacts occur in ecosystems, what parts of ecosystems are most affected, and how significant the threats are.

Answers to these questions can also help direct research. Because ecosystems are so complex, short-term studies are often unable to detect long-term trends such as climate change. It is most practical to answer these questions with a long-term monitoring program using ecological indicators. Indicators provide a practical way to monitor complex ecological conditions and to serve as early warning mechanisms. Thus indicators must be relevant, telling us something useful about a system, and they must be sensitive so that they indicate perturbation before significant impact occurs to the rest of the ecosystem. Further, indicators must be efficiently measurable.

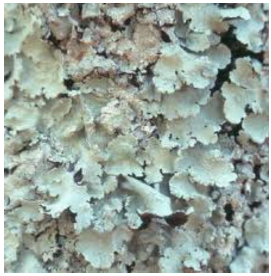
Lichens meet the criteria as useful indicators for assessing impacts of both air pollution and climate change.

1.3 Biodiversity and Ecosystem Productivity

Lichens

shrubby lichens

hairy lichens

crusty lichens *leafy lichens*

The role of lichens in ecosystem processes and biodiversity also makes them a useful group to monitor. Lichens represent a significant proportion of biodiversity in many ecosystems. A study in boreal forests of Scandinavia showed increasing diversity of spiders with increasing lichen diversity. It has been suggested by researchers that forest bird diversity may be associated with lichen diversity. Lichens also provide food for animals and habitat for invertebrates. Many lichens are habitat specific and thus a diversity of lichens at a site indicates habitat heterogeneity. Given the close relationship of lichens with other organisms, and their contribution to biodiversity, lichens provide an ideal group to monitor for changes in diversity in ecosystems.

Lichens play an important role in nutrient cycling. Lichens intercept air and rain-borne nutrients, absorbing nutrients for their use and contributing to cycling in ecosystems. Some studies have shown these aerosol and water-borne nutrients would be largely leached away without interception by lichens or other epiphytes. Some lichen species fix nitrogen through a symbiotic relationship with cyanobacteria. Studies from a variety of areas reveal that cyanolichens can contribute significant quantities of nitrogen to forest ecosystems.

Lichens are sensitive to air quality and climate change, are relevant indicators of components of ecosystem productivity and biodiversity, and are measurable. In this respect, lichens are unique in their ability to be used as indicators for such a broad range of issues. A lichen monitoring program has the potential to attract interest from a number of scientific disciplines and multiple stakeholders. A network of long-term lichen monitoring plots in protected areas is proposed for Nova Scotia. The USDA Forest Service has developed a rapid lichen assessment process that we propose to adapt. The method determines presence and abundance of macrolichens on all standing woody plants within a plot. A number of plots across the province are required to capture and account for regional variability. Plots will be re-surveyed every five years. Partners will be solicited from industry, government and academia.

2. A PRELIMINARY LOOK AT LICHEN SURVEY DATA AND AIR POLLUTION IN NOVA SCOTIA

Erioderma pedicellatum

Epiphytic lichens

Boreal felt lichen (*Erioderma pedicellatum*), a globally rare species, has had more than a 90% decline in the last two decades in Nova Scotia. This decline is largely attributable to acid rain, although habitat loss and climate change may also be a factor. Nova Scotia has one of the few remaining populations of this species. It is believed to be extirpated from New Brunswick and on the brink of extinction in Europe. Newfoundland has the last population of significant size. The Committee on the Status of Endangered Wildlife in Canada designated the Atlantic population (Nova Scotia and New Brunswick) as Endangered and the boreal population (Newfoundland) as a species of Special Concern in 2002.

Evidence of sensitivity to air quality can be seen in other lichen species in Nova Scotia.

Epiphytic lichens can be used as an indicator of environmental stress. I compared species richness of epiphytic lichens between two areas of Nova Scotia. Data from Cape Breton Island were from Selva. Data from southwestern Nova Scotia were from 1998 Tuckerman Workshop.

Since 1990, northern Cape Breton Island has consistently received less than 12 kg/ha/yr of wet non-marine sulphate deposition. Southwestern Nova Scotia, however, has consistently received more than 12 kg/ha/yr during that time period. Species of epiphytic lichens were counted for five sites on Cape Breton Island and five sites in southwestern Nova Scotia. Mean species richness for Cape Breton Island is higher than southwestern Nova Scotia. The difference is statistically significant.

Cape Breton Island *Southwestern Nova Scotia*

Lichen species presence can be affected by numerous factors including forest growth stage, tree species composition and local climate. The Cape Breton and southwestern sites are comparable in growth stages with both areas having sites of mature to old growth forest.

However, the southwestern sites include coniferous as well as deciduous forest while the Cape Breton sites include only deciduous forest. Some of the differences may also be attributable to regional climatic differences.

Halifax City *Kejimkujik National Park*

Although there are no repeated surveys within regions, there is a single survey for Halifax City as well as for Kejimkujik National Park in Annapolis County. Halifax metropolitan area has a population density of 65.4 people per square km while Annapolis County has a population density of only 6.8 people per square km. Along with the high population density in Halifax are associated local sources of pollution including vehicular traffic, a power generation station and an oil refinery. The number of epiphytic lichen species from the Halifax survey was 38, while for Kejimkujik it was 97.

2.1 Conclusions for Nova Scotia

Limited evidence from past studies suggests potential impacts of air pollution on lichens in Nova Scotia. However, comparisons using past studies are not statistically valid. Questions of validity can be addressed with a well designed monitoring project.

3. PROPOSED METHODS

A province-wide network of long-term lichen monitoring plots will be established in Nova Scotia's protected areas. The objectives of the program are to provide long-term monitoring in forests of:

1. air quality impacts on ecosystems;
2. climate change impacts on ecosystems;
3. elements of forest ecosystem productivity; and
4. elements of biodiversity in forest ecosystems

3.1 Plot Size

A 0.4 ha circular plot with a 36-meter radius will be used. This plot size is comparable to USDA Forest Service national lichen monitoring program plot size of 0.378 ha. Cameron reported that sampling a minimum of 16 trees is required to include most lichen species in a coniferous forest in Nova Scotia. Stewart reports an average density of 509 trees per ha for old growth coniferous forest and 414 trees per ha for old growth deciduous forest in Nova Scotia. In order to sample the minimum 16 trees, 0.031 and 0.039 ha plots are needed in coniferous and deciduous old growth forests, respectively. The larger plot suggested for this study exceeds the required minimum, allows for a more rapid assessment method (see collection method below), reduces 'noise' from micro-habitat variation and increases the probability of capturing rarer species.

A difficulty associated with a large single plot, rather than several intensively measured subplots, is that accuracy of abundance measures may be lower for the single large plot. However, a larger plot increases the number of species captured. Further, smaller plots result in lower counts, which then require more plots to obtain desired statistical power.

3.2 Number of Plots

Local variability will be reduced by stratified sampling in tolerant hardwood stands within protected areas. Lichens are very sensitive to microclimate changes. Activities such as adjacent tree harvesting, local vehicular traffic, adjacent use of fertilizers or pesticides can affect presence and/or abundance of lichens. Protected areas are less likely to be affected by these human activities. The protected area can be an area with formal protection or under a stewardship agreement. Old growth forests provide a relatively stable environment with a high abundance of lichens. Deciduous forests tend to have a higher diversity of lichens. Thus, analytical problems associated with low abundance values are reduced.

Hypogymnia physodes *Hypogymnia tubulosa*

Data from the Netherlands were used to perform statistical power analysis because Europe is the only area with long-term lichen abundance data. Five species of lichen from the Netherlands data and also known to commonly occur in Nova Scotia (Hypogymnia physodes, H. tubulosa, Parmelia sulcata, P. caperata, P. saxatilis) were used in the analyses. Statistical power is the ability of a statistical test to detect a change when it is actually occurring. For long-term monitoring, detecting a real change is of greater interest than falsely detecting a change when none has occurred. The power analysis was used to determine the minimum number of plots needed to detect a 10% change in abundance over 5 years.

Parmelia sulcata *Parmelia caperata* *Parmelia saxatilis*

Number of plots needed ranged from 15 for Parmelia sulcata to 60 for Parmelia caperata.

We plan to initially establish 30 plots. Once multi-year data is collected for Nova Scotia, power analysis can be calculated to determine if the sample size is large enough to detect a given amount of change.

3.3 Sampling Method

At each plot, field staff will search for all species of macrolichens. All tree and shrub boles between 0.5 m and 2.0 m from the ground will be searched. Fallen branches and lichens will be examined and recorded, as these provide a good sample of canopy lichen species and their relative abundances. Field staff will estimate the abundance of each species using the following scale: 1 = rare (<3 individuals in the plot), 2 = uncommon (4-10 individuals in the plot), 3 = common (>10 individuals in a plot but less than half the boles and branches have the species present), 4 = abundant (more than half of the boles and branches have the species present). Any species which cannot be identified in the field will be assigned a number code and abundance value. A sample of the unknown species will be collected for later identification. Resampling using the same methods will be done every five years.

3.4 Analyses

3.4.1 Air Quality

Lichen species sensitivity to air quality needs to be calibrated for the region. This will be done by gradient analyses as described by McCune et al. or through development of lichen diversity classes as described by Asta et al. The result will be an air quality lichen index for each plot which can be used to map air quality regions for the province and allow monitoring over time.

3.4.2 Climate Change

Climate change analyses will follow methods similar to van Herk et al. Historical latitudinal distribution of species will be derived from published lichen checklists and studies and divided into five categories: 1.tropical; 2. warm-temperate to (sub) tropical; 3. cool temperate species; 4. boreal/arctic; 5.unknown distribution (these species will be excluded from analyses).

Abundances of species in each category will be monitored over time to detect climate change effects.

3.4.3 Biological Diversity

Species presence and abundance can be used to determine species richness and various diversity measures and compared over time.

3.4.4 Ecosystem Productivity

Changes in lichen abundance can indicate corresponding changes in ecosystem productivity.

Nitrogen fixing cyanolichens are of particular concern when assessing ecosystem productivity.

3.4.5 Interpretation

Data from the monitoring program can be used to identify long-term trends regionally and locally. Other scientific studies and monitoring programs can be tied into the project to help explain trends. For example, Nova Scotia Department of Environment and Labour has air quality monitoring stations across the province which measure levels of particulates, sulphur dioxides, nitrous oxides and ozone. Data for these measured pollutants can be correlated with changes in lichen presence and abundance over time to provide a better understanding of how certain pollutants may affect ecosystems. Because lichens are closely tied to overall biodiversity of ecosystems, a change in diversity of lichens over time may signify impending impacts to other groups of organisms.

4. CONCLUSION

Lichens are particularly useful for monitoring programs because they can be used as indicators for multiple objectives. Multi-element monitoring provides opportunities to bring together scientists of many disciplines. A system of biomonitoring plots with lichens provides protected areas managers and other resource managers with measurable effects that can aid in informed decision making. Protected areas provide the ideal location for monitoring as local variation is minimized.

Potential Threats and Sensitivities
Disease

chytridiomycete fungus Batrachochytrium dendrobatidis

Disease is an important consideration in the population dynamics of northern leopard frogs since it has the ability to result in mass mortality events. Daszak mentions chytridiomycosis, ranavirus infection and saprolegniasis as the more prevalent diseases of northern leopard frogs.

skin hyperkeratosis of a frog infected by chytridiomycete fungus

limb malformations caused by chytridiomycete fungus

Chytridiomycosis was first discovered in Panama and Australia in 1998. Since then, it has spread to five continents including North America where it has been found responsible for mass mortalities. It is thought to have been spread anthropogenically through "pathogen pollution", when humans unknowingly transfer the fungus into new populations that had no previous exposure to the fungus. Chytridiomycosis is caused by the chytridiomycete fungus Batrachochytrium dendrobatidis which causes a skin infection in keratinized skin of adult and metamorphosed young-of-the-year and to a much lesser extent, tadpoles. Symptoms of chytridiomycosis include vascularization of the limbs, sloughing of the skin, lethargy, changes in behaviour, unusual posture and hyperkeratosis. Scientists hypothesize that the hyperkeratosis (thickening of the outermost layer of the skin) and sloughing of the skin may disrupt cutaneous respiration and osmoregulation. Cohen also states that this condition could leave infected frogs susceptible to absorb toxic products produced by the fungus.

a frog infected by ranavirus

Ranavirus infection is another serious disease which affects amphibians, fish and reptiles. Daszak describes ranavirus as a DNA virus with different strains which can be species-specific or can affect entire orders or classes of animals. A large number of new strains of ranavirus have been discovered and reported in recent years. A strain of ranavirus (FV3) is reported to have been responsible for northern leopard frog die-offs in Canada in the years 1999 and 2000. Die-offs in southwest Ontario in the years 2001 and 2002 studied by Greer were also confirmed to be the result of ranavirus.

a frog infected by Saprolegnia

Saprolegniasis (common water mould disease) is another fungus-caused disease which has been known to lead to mortality of northern leopard frog spawn and tadpoles. Spawn laid close to the surface are most vulnerable since UV-B radiation is believed to compromise the defence of spawn.

a frog infected by Lucke tumour virus

Lucke tumour virus, a type of herpes virus, has also been implicated as the cause of mortality in embryos and overwintering northern leopard frogs. Helminth parasites, although not a disease, are another affliction of northern leopard frogs.

a frog infected by trematode parasites

Ribeiroia trematodes, the well-noted parasite in northern leopard frogs, are known to cause limb deformities in earlier life stages. Cohen reported that these trematodes were correlated to limb anomalies and decreased tadpole survivorship.

Habitat Loss, Fragmentation and Degradation

The loss, fragmentation and degradation of northern leopard frog habitat in North America are believed to be partly responsible for historical population declines. Since northern leopard frogs require three different habitat types to complete their life cycle, they are very susceptible to habitat loss. In the event that one of these habitats is lost from the landscape and no local alternative is present, a local extirpation could occur. Agricultural practices in southern Canada have impacted 59% of wetland basins and 78% of wetland margins. Not only are the three habitat types of the northern leopard frog important but also are the dispersal corridors which they use to move between them. The most common forms of habitat fragmentation in the range of the northern leopard frog are roads, cultivation and industrial development. Road mortalities can be extensive during dispersal.

Suitable habitat does not necessarily need to be lost or fragmented to render it unsuitable for northern leopard frogs. Habitat degradation is most commonly the result of agriculture and development. Livestock grazing has been shown to degrade northern leopard frog habitats by crushing emergent vegetation, eroding and rutting shorelines and reducing water quality parameters. Spawn masses can also be impacted by being crushed or dislodged. Environmental contamination can also be a form of habitat degradation by reducing prey populations, changing water quality and altering the wetland vegetation community.

Northern Leopard Frogs as an Indicator Species

The preceding paragraphs of this report demonstrate that northern leopard frogs are a very sensitive species, known to be affected by low concentrations of contamination. Environmental stress is first noticed at the population level especially in sensitive species like the northern leopard frog that is why amphibians can be important indicators of ecosystem health. Welsh states that the challenge with using amphibians as indicators is discerning between natural population fluctuations and unnatural population declines from anthropogenic sources. Northern leopard frogs are in decline and, due to the specificity of their habitat requirements, are only present in certain wetlands. Wray cautions that, although the presence of amphibians does indicate an overall healthy wetland, their absence is not necessarily indicative of an environmental concern or an unhealthy wetland.

FROGS AND TOADS AS BIOLOGICAL INDICATORS IN ENVIRONMENTAL ASSESSMENT

http://ecology.science.unideb.hu/files/14-Simon-et-al-2011b.pdf

Introdaction

During the past decades the ecology and ecotoxicology of amphibians started to get attention [Sparling et al. 2000] because of global amphibian population declines [Houlahan et al. 2000].Based on the lists of the International Union for the Conservation of Nature (IUCN) there are 787 rare or endangered amphibian species [Frost et al. 2006] and about 1,900 species known to be threatened [Stuart et al. 2008]. Frogs and toads are about 90% of all amphibians [McDiarmid and Micthell 2000] Therefore, they are an important link between human and ecosystem health [Hayes et al. 2002] and they are main components of aquatic and terrestrial ecosystems [Unrine et al. 2007]. Most adult frogs and toads feed on invertebrates, so they are important, energy-efficient trophic link between insects and other vertebrates [Sparling et al. 2000]. They are sensitive to environmental changes both in terrestrial and aquatic habitats because they have highly semi-permeable skins and different life cycle stages [Alford and Richards 1999]. Nevertheless, the information on the effects of environmental contamination on frogs and toads is little known [McDiarmid and Micthell 2000]. The declines of amphibian populations are caused by a number of factors, including habitat loss and fragmentation[Icochea et al. 2002, Beebee and Griffiths 2005], ultraviolet radiation and chemical pollution [Blaustein et al. 2003], climate change [Pounds 2001] and epidemic disease like chytric fungus [Pounds et al.2006].

Some of these factors may also cause deformities and abnormalities in their development [Blaustein and Johnson 2003] lowering further the viability of populations. Effects of contamination may result in shorter body length, lower body mass, malformations of limbs or other organs [Sparling et al. 2000]. Thus, the risk of mortality and exposure to predation is increased by slowed down development, late metamorphosis, and small metamorph size [Rowe et al. 2001, Pahkala et al. 2002, 2003]. As a result, the use of anurans as bioindicators of accumulation of contaminants in pollution studies is increasing [Welsh and Ollivier 1998, Johansson et al. 2001, Loumbourdis et al. 2007]. The aim of this chapter is to review the element concentrations of frog and toad bones in different habitats and to demonstrate a new method for the assessment of environmental load using frogs and toads as bioindicators.

Frogs and Toads as Bioindicator Organisms

Habitats of many frog and toad populations are small, temporary ponds and the surrounding forested area, which are usually suffered by many stressors such as

UV-radiation [Cummins 2003, Hatch and Blaustein 2003], the use of pesticides [Gendron et al. 2006, Fellers et al. 2004] and industrial chemicals [Bishop and Gendron 1998, Sower et al. 2000], urbanization [Barrett et al. 2010], climate change [Corn 2005]. Since frogs and toads are sensitive to the alterations of their environment, they could be used as bioindicator organisms to follow changes in their habitats and in ecotoxicological studies [Henry 2000]. As their populations usually contain high numbers of individuals and they are good representatives of freshwater environments, they are good model organisms for pollution studies [Burger and Snodgrass 1998]. What is more, adult anurans play an important, usually intermediate role in food-webs because they are preys and predators as well but their position changes with their development, i.e. tadpoles also feed on algae [Murphy et al. 2000] making them even more sensitive to different stressors. Thus, frogs and toads may be used as biological indicators to assess the effects of environmental factors that may cause the declines of amphibian population.

In several earlier studies these animals were used to assess the effects of UV radiation [see e.g. Cummins 2003, Hatch and Blaustein 2003]. Its direct effects were demonstrated to cause embryonic mortality [Pahkala et al. 2002], abnormal larval development [Belden and Blaustein 2002], limb and muscular deformities [Weyrauch and Grubb 2006]. Similarly, different pesticides were also tested and deformities were detected [Pickrell 2002] but these studies were based on laboratory toxicity test [Cowman and Mazanti 2000]. Although most pesticides do not accumulate their toxicity is relative high [Kamrin 1997] which may cause paralysis [Fellers et al. 2004], decreased size of metamorphosis [Relyea and Diecks, 2008] and negative effects of liver and kidney [Khan et al. 2003].

Rana catesbeiana *Rana dalmatina* *Bufo bufo*

The use of frogs and toads, as biological indicators of metal pollution is becoming more common [Burger and Snodgrass 1998]. The effects of metal accumulations were studied both under laboratory [Perez-Coll and Herkovits 1996, Herkovits and Helguero 1998, James and Little 2003] and field conditions [Puky and Oertel 1997, Demichellis et al. 2001, Flyaks and Borkin 2004, Fenoglio et al. 2006] but the number of field studies is low. In an earlier study the whole body of *Rana catesbeiana* tadpoles were analysed for different heavy metals (cadmium, chrome, manganese, arsenic, mercury) and the highest concentration of metals were found in the digestive tracts of tadpoles [Burger and Snodgrass 1998]. In another study, the elemental concentration of *Rana dalmatina*, *Bufo bufo* and *Rana* *ridibunda* tadpoles were compared and significant differences were found between the studied species.



Rana ridibunda *Bufo raddei* *Rana esculenta*

The heavy metal concentration of *R. dalmatinain* the whole body was significantly lower than in the other species which is caused by sediment contamination in the *R. dalmatina* habitat [Grillitsch and Chovanec 1995]. In the case of tadpoles Zhang et al [2007] reported that the ATPase activity increased with increasing of Cd and Pb concentrations in *Bufo raddei* tadpoles. This means that the ATPase activity may be a warning signal of pollutant-induced damages in the ionic and osmoregulatory system [Zhang et al. 2007]. In other studies differences were demonstrated between the different development stages [Baudo 1976, Puky and Oertel 1997]. Higher heavy metal concentration in tadpoles than adults may be caused by changes in feeding during development, tadpoles are detritivorus unlike adults, which are carnivorous and the detritivorous diet may be richer in metals [Baudo 1976]. Pavel and Kucera [1986] studied the accumulation of manganese, iron, copper and zinc in the whole body of *Rana esculenta* adults from three different localities. Their study demonstrated that in the case of manganese, iron and copper significantly different concentrations were found at the selected localities. However, studies including all development stages are needed because of the changing of susceptibility of frogs to heavy metals may depend on different stages of development [Perez-Coll and Herkovits 1996]. Puky and Oertel (1997) demonstrated e.g. that eggs contain a relatively low concentration of different heavy metals in comparison with a range of adult tissues such as muscle and parts of the body (e.g. kidney, liver).

Elemental Composition of bones

A lot of elements play an important role in the building of the skeleton. In general, 70% minerals, 20% collagen, 8% water and about 2% non-collagenous components are the composition of bones [Klepinger 1984]. Calcium and phosphorus are the most important elements in the bones, which were the main components in the formation of hydroxiapatite [Janus et al. 2008]. Oudadesse et al. [2004] reported that the main elements are calcium, phosphorus and magnesium in the bones. Smaller calcium and phosphorus contents cause smaller hydroxyapatite content in the bones which may cause more porous structure in the bones [Janus et al. 2008]. The Ca/P, Ca/Mg and the Zn/Ca rate are also important characteristics to be measured in bones (Busetto etal., 2008). Normally the Ca/P ratio is 2:1, but the optimal Ca/P ratio can not be reached with vitamin D deficiency, which leads to unhealthy bones [Nestler et al. 1948]. The optimal value of the Ca/Mg ratio is around 2:1,it is important for the calcification of the skeletal tissue [Nielsen 1973]. Zinc is necessary to produce the main organic components of bone matrix for normal calcification, the Zn/Ca ratio is higher than 0.5 in bones [Busetto et al. 2008],.However, if zinc is present in too high concentrations, it can interfere with hydroxyapatite crystal growth and lead to accelerated bone resorption [Kenney and McCoy 1997]. Bones are mineralized tissues so they may have high storage capacity of metals such as barium, lead, strontium and zinc [Linder and Grillitsch 2000]. Flyaks and Borkin [2004] studied the elemental concentration of femur of *Rana ridibunda*. Their result showed that iron (220 + 5 mg kg-1), zinc (88 ± 2 mg kg-1), manganese (6.8 ± 0.2 mg kg-1), copper (30 ± 1 mg kg-1), lead (150 ± 1), nickel (16 ± 1 mg kg-1) and cadmium (17 ± 2 mg kg-1) could accumulate in relative high concentrations in bones from the area where chemical and metallurgical factories released their run off waters [Flyaks and Borkin 2004]. In other studies strontium and barium concentrations were detected in bones [Klepinger 1984; Busetto et al. 2008]. These results show that bones may be applied as indicator organs to assess the environmental load.

New Method to Assess Environmental Load on Frogs and Toads

Current analytical methods are relatively well developed to assess the effects of environmental load on amphibian populations. Nevertheless, in certain cases the available amount of sample is small. With the proposed micro analytical method different organs may be analysed without the need for killing live animals (Simon et al 2010). For our study toe bones of frogs and toads were chosen. The elemental analysis of toe clipped bone samples has several advantages: there is no need to kill the animals, the analysis has moderate chemical reagent demand and a high number of samples can be analysed by this method. Toe clipping is a commonly used standard method to identify individuals, particularly frogs and toads [McCarthy and Parris 2004]. This method is simple, safe and the toe clipped sample is applicable for histological examinations [Kriger etal. 2006, Hyatt et al. 2007], genetics [Noonan and Gaucher 2006, Amour and Lesbarréres 2007], or amphibian skeletochronological age determination [Bruce et al. 2002, Takashi and Masafumi 2009]. Hartel and Nemes [2006] reported that toe clipping is an acceptable method from a conservation viewpoint as it usually does not cause any serious effects. In our earlier study [Simon et al. 2010] the trace element concentrations in *Rana esculenta* frog bones were investigated and a method was invented to estimate the elemental concentrations of frog bones based on phalanges. Before the elemental analysis of bones hydrogen peroxide may be used to clean the bones for two days. This period is enough to clean the bones from conjunctive tissue and it still does not cause elements to leach out from the bone tissue. There were good correlations between the elemental contents and dry weights of the bones: phosphorus ($r2= 0.96$), calcium ($r2= 0.95$), magnesium ($r2= 0.97$), sulfur ($r2= 0.91$), sodium ($r2= 0.89$), manganese ($r2= 0.73$), barium ($r2= 0.63$) and zinc ($r2= 0.57$). It means that the elemental contents of bones were commensurable to their weights. This correlation suggests that the concentration of trace elements was similar in the phalanges and in large bones. To test the usefulness of the method the measured elemental contents of phalanges were compared to the estimated elemental contents. Based on the tibiafibula and metatarsalis bones, front and hind limb digits, the measured and the estimated elemental contents of phalanges did not differ considerably.

These results indicated that the elemental contents of phalanges reliably represented the elemental contents of tibiafibula, metatarsalis bones and digits. Thus, toe phalanges represent the other parts of the skeletal system and in spite of the small size of the phalanges; the elemental concentrations can be measured appropriately in them. To test the developed new technique the effects of urbanization on the elemental concentration of the toad's skeletal system were investigated. The concentrations of trace elements in bones were higher in toads from the urban pond than from the rural ponds. Both calcium and phosphorus were significantly higher in samples collected at the rural ponds.

Smaller amounts of boron and zinc were present in the toe bones from the rural ponds than from the urban one. These results demonstrated that different habitats may cause marked differences in the elemental contents of *B. bufo* toe bones. Although physiological differences and morphological deformities were not found in the toe bones, the concentrations of the main elements in the bone were markedly lower at the urban pond than at the rural ponds. In spite of the small size of toe bones, the elemental concentrations could be measured reliably. Thus, the developed technique based on toad toe bones may be useful for the assessment of contamination in pollution studies without killing frog and toad individuals.

Conclusion

Micro analytical methods give a new opportunity for using anurans as bioindicators. Small toe bones provide an appropriate amount of tissue sample for estimating the elemental composition of bones. Our results showed that the elemental composition of toe bones and large skeletal bones were in good correlation. Anthropogenic activity in urbanized areas has an effect on the elemental composition of toad toe bones. The concentration of major elements (Ca, P, Mg) was higher in the toe bones in rural sites, while Zn concentration was the highest at urban sites. The analysis of the anuran's toe bones is a new non-destructive method, which could be applied on live specimens without seriously harming their health. It may open further ways in environmental load assessments facilitating further monitoring to assess the effects of environmental pressure both on amphibians and their habitat.

Tiny Water Flea's Promising Role: Environmental Monitor

Stephanie Pappas

LiveScience

updated 2/3/2011

Researchers: shape-shifter is high-tech version of canary in a coal mine

When the water flea senses predators in its environment, it suits up, growing tail spines, a pointy helmet and other armour. Now, researchers have sequenced the genome of the water flea, providing hints about its shape-shifting ability and opening the door for environmental research using the crustacean as a model.

The project was 10 years in the making and involved the efforts of 67 researchers, plus at least 200 more who have conducted companion studies using the water flea genome data. The results, reported today in the journal Science, reveal that the minute creatures boast the largest genome of any animal studied. The findings could make the near-microscopic water flea a "modern, high-tech version" of a canary in a coal mine, said study author John Colbourne of Indiana University.

With the information provided by the water flea's genome, "you don't have to wait for the whole ecosystem to show that there's something wrong," Colbourne told LiveScience. "You simply ask a vitally important component of that ecosystem, 'Hey, how are you doing?'"

Many genes, many shapes

The water flea (also known by its scientific name, *Daphnia pulex*) got its moniker because early observers kept running across blood-red versions. The colour, combined with a pointy snout, made the water flea look like a bloodsucking flea. In fact, D. *pulex* is a filter feeder and a crustacean, not a flea. The early specimens were red because of the animal's amazing ability to alter its body in response to its environment. The red water fleas weren't bloodsuckers; they were producing more hemoglobin, the protein that binds oxygen and turns blood red, because they lived in low-oxygen ponds.

D. pulex can also switch back and forth between sexual and asexual reproduction, and when reproducing asexually, it can decide whether to have all-male or all-female offspring. But perhaps the most impressive example of the water flea's adaptability is its armor. When *D. pulex* senses chemicals in the water given off by predators such as fish, it starts growing defenses, including long tail spines, a pointy helmet, and tooth-like neck spikes.

This adaptability is part of what makes the water flea so intriguing as a research animal, Colbourne said. He and his team sequenced the water flea genome and found that is has at least 30,907 genes – more than any animal examined so far. (Humans have about 23,000 to 25,000 genes.)

This gene overload is caused by two factors. First, many are duplicates, and *D. pulex* seems to duplicate its genes at about three times the rate of other invertebrate animals. Second, D. pulex doesn't dump old genes. It keeps them around three times longer than other invertebrates.

Complicating matters, about a third of the animal's genes are unique to the *Daphnia* lineage. And for many of these exclusive genes, the water flea carries two copies.

"We don't know what their function is," Colbourne said "Many of the genes that are the most highly duplicated tend to be the genes that fall into the class of unknown genes. So the puzzle for us then is, 'How do we assign function to those genes?'"

The Swiss Army knife of crustaceans

Not satisfied with simply sequencing the genome, the researchers decided to crack that gene-function puzzle. Using cutting-edge techniques, they were able to find out how the water flea genome reacts to various environmental stresses. The major discovery, Colbourne said, was that the unknown genes are the most eco-responsive. That means they change their activity in response to outside influences.

In a second breakthrough, the researchers found that the duplicated genes are what Pfrender called "born-to-be-different" genes. The assumption is that duplicated genes only become useful when a lucky mutation makes them that way, a process that's hit-or-miss. But the water flea's duplicated genes can take on new functions much quicker than previously thought. That gives *D. pulex* a big toolbox to pull from when something in the environment changes.

"It's almost as if the *Daphnia* genome is like a Swiss Army knife," Colbourne said. "They're all knives, they all cut, but each is a particular shape well-suited for the task."

Testing the waters

Because of this adaptability, the researchers hope to use *D. pulex* to test water quality and measure environmental change.

"Consider the basic fact that there are roughly 80,000 man-made chemicals in our environment right now," Colbourne said. Less than 10 percent are subject to toxicological testing, he said: "That means for the vast majority of our chemical environment we have no idea what it's doing to animal populations, and we have no idea what happens to human health."

Water fleas have another trick up their exoskeletons that make them good toxicology testers, Colbourne said. When they reproduce sexually, embryos go into a state of arrested development and can stay dormant in lake sediment for decades before waking up and developing. That means 20-year-old *Daphnia* populations can be resurrected and compared with modern hatchlings. Even after the dormant eggs are no longer viable, Colbourne said, their DNA remains for hundreds or thousands of years. By linking genetic changes over time with environmental changes, researchers would have a picture of what Colbourne called "the ghost of the lake."

"If we could identify those genes in the genome that are linked to the ecological success of this organism, we would have this incredible resource of seeing evolution take place," Colbourne said.

The next five years will likely see a host of research dedicated to uncovering the *Daphnia* genome, Pfrender said – that is, linking genomic changes to environmental influences. From there, the researchers envision using lab populations of *D. pulex* to test environmental chemicals. Wild *D. pulex* populations could be monitored for large-scale genomic change.

There are numerous reasons why *Daphnia* is chosen for genomic study

The globally distributed zooplankton *Daphnia* (commonly called the water flea) is the first crustacean to have its genome sequenced. *Daphnia* has fascinated biologists for centuries because of its importance in aquatic ecosystems, its amenability to both field and laboratory study, and because of its remarkable ability and flexibility to cope with environmental challenges. These new genomic data will enhance studies in the wide variety of disciplines that make use of *Daphnia* for research - including crustacean biology, ecology, physiology, toxicology, population genetics, and evolution - and will promote greater understanding of the complex interplay between genome structure, gene expression, individual fitness, and population-level responses to environmental change. The availability of a *Daphnia* genome sequence will help create a new model system for ecological and evolutionary genomics.

1. Daphnia is a keystone species in both ponds and lakes. They are typically the principal grazers of algae, bacteria, protozoa, and the primary forage of fish. Because of their pivotal position in food webs, they are widely utilized as an indicator species to assess the response of ecosystems to environmental change.

2. Daphnia has been used for decades as a standard organism for toxicity testing, and its toxicological reactions to environmental pollutants are well characterized. Of the nearly 500,000 records in the ECOTOX database, water fleas represent 8% of all experimental data for aquatic organisms - second only to the rainbow trout.

3. Daphnia is already a widely used model system for quantitative and ecological genetics.

4. The reproductive cycle of *Daphnia* is ideal for experimental genetics. Generation time in the lab ranges from 5 - 10 days, making it possible to examine genome regulatory changes throughout its ontogeny.

5. Distinct lineages of *Daphnia* have independently colonized radically different environments (deep permanent lakes vs. shallow temporary ponds) on multiple occasions. These evolutionarily independent radiations provide an opportunity to evaluate whether similar environmental challenges are countered in genetically consistent ways.

6. Daphnia is a natural outgroup for comparative genomic studies among the arthropods, by appropriately rooting the phylogenetic tree of the model insect species. Crustaceans and insects have diverged from a common ancestor; therefore genomic characteristics are either derived or preserved, in reference to the *Daphnia* genome.

Terrestrial snails as indicators of the health of the decomposer part of the ecosystem in Parks in Alberta.

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Abstract: Land snails are a part of the decomposer group of organisms in the upper part of the soil which is normally ignored when considering Parks management. The land snails consist of a relatively small number of species that entered the area after the last glaciation, following the northward migration of the boreal forest, and also a second even rarer group of species that entered the area during the Hypsithermal event. Ecologically, the snails can be divided into four groups, viz., the turf species, the duff species, the wetland species and the generalists. They can only survive along the galleria forest along the main rivers, and in areas with trees or tall grass prairie up to about 1900 m elevation. Frequent ground fires largely destroy the terrestrial molluscan fauna in the grassland sites. Duff faunas are less affected. During revegetation, generalists may invade the area together with the duff specialists that will become dominant after a suitable organic layer has become established on the forest floor. Wetland species often survive fire. Other major threats are destruction of habitat, introduction of non-native vegetation, development of recreational parks, urban and resource development and agriculture.

Introduction.

An ecosystem is a balanced group of plants and animals making up the biota in a given microenvironment and interacting with the abiotic features of that microenvironment. Many members of the biota produce organic matter that falls to the ground, thus providing sustenance for other members that specialize in decomposing it. This decomposition goes on in the upper layers of the soil that is referred to as the litter (L), fermentation layer (F) and humus (H) at the surface of the mineral soil in Canada. The decomposers consist of a large number of small plants and animals, and one of the minor groups is the terrestrial snails. Most of the decomposers can only be studied by rather laborious methods, whereas the snails are rather easier to work with, and involve a reasonable number of taxa.

Parks in Alberta

Jasper is the largest and most northerly Canadian rocky mountain national park

Elk Island National Park of Canada protects the wilderness of the aspen parkland, one of the most endangered habitats in Canada.

The Parks in Alberta include those termed "natural areas" where the area is supposed to be maintained in its natural state. Inevitably, there is also a need for recreation for people, and conflicts arise in which the natural area tends to lose out. Furthermore, even in National Parks, more attention is paid to the well-being of the more obvious species such as elk, bears, caribou, trees, fish, etc., than the health of the smaller, inconspicuous species including the decomposers, which are commonly ignored. This can have the effect of extirpating species and upsetting the balance in the ecosystem. This paper will examine effects of some common management practices on the terrestrial snails, which are also a good indicator of what may be happening to the other decomposer species.

Ecology.

The terrestrial molluscs are dependent on moisture conditions, availability of food and on climate for their survival. In general, the short grass prairies lack land snails except where permanent water bodies are found and along the major river valleys. The snails become more common and diverse as they are traced into the foothills and mountains, being particularly abundant in the areas with strong Chinook winds and warmer temperatures.

Vallonia parvula Sterki *Zonitoides nitidus Muller*

The snails can be divided into four groups. The turf specialists, e.g., *Vallonia parvula Sterki* (1892) and *Zonitoides nitidus Muller* (1774), that are found primarily in the grasslands, i.e., the areas of tall grass prairie, the parkland, and in the grassy openings in the outer portion of the mixed coniferous and deciduous forest. The duff specialists, e.g., the *Vertigo* species, live in the organic layers of the soil, eating organic matter, so they are mainly found in the lower parts of the forest below 1900 m. Along the margins of lakes and ponds and along the flood plains of the major rivers are found the wetland species including the species of the genera *Catinella* , *Oxyloma* and *Succinea*.

Catinella baldwinii *Oxyloma pfeifferi* *Succinea putris*

These can be found at wet sites throughout the area. Finally, there are the generalists that can survive under a wide variety of conditions, e.g., *Zonitoides arboreus Say* (1816). The generalists are seen to have the maximum altitudinal range, although terrestrial molluscs have not been collected on the upper mountain slopes.

Vertigo moulinsiana *Zonitoides arboreus Say*

Effects of disturbance of the ecosystem on the terrestrial snails.

Disturbances come in several forms, e.g., seral changes, fire, destruction of habitat, introduction of non-native vegetation and agriculture in its various forms. All these have occurred in the “natural area parks”. They will be dealt with here separately, though in practice, several of these may be involved in affecting the molluscan distribution in any given case.

1. Seral changes.




of lodgepole pine *spruce* *alpine fir* *trembling aspen*

Vegetation goes through a series of changes to reach the final equilibrium stage for a given environment. Any major disturbance such as fire causes a new vegetation cover to grow. This vegetation also goes through a series of stages until it reaches an equilibrium condition. In the boreal forest in Alberta regeneration after fire commences with the growth of lodgepole pine and a small number of shrubs and herbs. This provides suitable nursery conditions for other shrubs and herbs as well as spruce and alpine fir. In theory, the pine dies off after about 80 years to be replaced by a cover of spruce and fir. In practice, the lodgepole pine along the Bow valley is surviving longer than predicted by the theory, and it now appears that an infestation of pine bark beetle may be necessary to cause the switch to the spruce-fir climax forest. In the tall grass prairie, the grasslands owed their existence to frequent fires, low precipitation and to grazing. When such areas are used for cattle ranching or Parks with suppression of fires, the grasslands gradually change to Parkland and even mixed deciduous and coniferous forest. The generalist and duff snails will be the first species to colonize the new environment, with the duff species becoming dominant when there is a suitable litter layer. The floristic composition of the forest affects the results since snails are particularly abundant in the litter beneath trembling aspen. There is reason to think that the species composition and species of the land snail fauna changes with the changes in the vegetation. Unfortunately, there are no quantitative studies of these changes in Alberta.

2. Fire.

Vallonia costata, Muller

Vertigo pygmaea

Fire is a serious threat to the decomposers in the soil. It is most damaging in the case of ground fires in tall grass prairie grasslands, where 72% of the species were found to be negatively affected in the Central American grasslands. Fire was always an important factor in the maintenance of the prairie grasslands, but it is also the reason that they were largely lacking in land snails. Quantitative studies show that fire produces a decrease in overall snail abundance, snail diversity and composition, which is closely related to depth of litter. Fire removes the surface soil organic layer, and has been implicated in the reduction in numbers of both land snails and numerous other native prairie invertebrate species.

The quantitative studies by Nekola in northwestern Minnesota and northeastern Iowa, showed that out of 72 species collected, 32 showed a significant reduction in occurrence after fire, while only six species showed a positive response. Of these, only one was a turf specialist in that area (Vallonia parvula, Sterki, 1892), while two were generalists (Vallonia costata, Muller, 1774, and Vertigo pygmaea, Draparnaud, 1801).

The short grass prairie areas generally lacked molluscs, except around water bodies and along the floodplains of the major rivers where the generalists and duff specialists could thrive. It seems likely that land snails and other native grassland invertebrate groups in the pre-settlement landscape may have been able to survive regular fires by recolonizing the burned areas from source pools in adjacent unburned areas. However the recolonization may take more than twelve years under present climatic conditions. In the southern Plains grasslands of the United States, recovery of the organic detritus to pre-fire levels takes at least 5 years. In more northern locations, the recovery takes much longer. Given the fragmentation of suitable source areas by agricultural, urban, recreation and forestry development, it is likely that turf specialists will continue to decline in numbers and diversity.

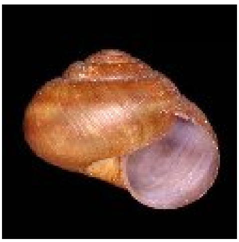
In wetland prairie communities in Oregon, Severns (2005) found that fire decreased species richness, but the abundance of individuals increased to above pre-fire numbers after about three years. Monadia fidelis was extirpated but Catinella rehderi Pilsbry (1948) and Vertigo modesta Say (1824) were indicator species of burning. Both the latter species are common in Alberta.

Fire was found to be least damaging in the case of forests in Minnesota, where 67% of the molluscan species were not obviously affected. The snails live in the upper 5 cm of the duff, and if that survives, then the effects of heat may be limited. If the duff burns, the biota living in it will be incinerated, including all the snails. Rate of recolonization after fire in Alberta is unknown. The generalist and duff woodland taxa may be protected by the mass effect of the snail population in the surrounding forest, which may aid in the recolonization process. In all environments, fire most strongly impacts the rarest species, which may become extirpated by frequent use of prescribed burns.

3. Destruction of Habitat.

This is now becoming the greatest threat to the survival of terrestrial molluscs. One of the most widespread causes is logging of timber. This removes the habitat, which will cause the extirpation of all but the most resilient generalists of the fauna in the affected area. Scarification of the surface soils, soil erosion and burning of the trash alter the microenvironment, resulting in the bare soils becoming drier and hotter. Unfortunately there do not seem to be any published studies of the changes. This is important in the areas of widespread logging of the slopes of the Rocky Mountains.

When Alberta Parks establishes Provincial Parks away from the mountains, the sites selected are usually along streams or on the shores of lakes. At Elkwater Lake, the south shore was largely relandscaped, resulting in a severe loss of habitat for the molluscs that used to inhabit the shore. This has resulted in the loss of those species from that area. A similar fate would appear to await the rare snails inhabiting the area to be developed as a major holiday resort in the Crowsnest Pass. The area is the main location for Anguispira kochi occidentalis Pfeiffer (1821), Oreohelix strigosa Gould (1846) and Oreohelix subrudis Reeve (1854) in Alberta, although some isolated occurrences of these species may be present along the foothills south to Waterton National Park.



Anguispira kochi occidentalis Pfeiffer (1821)

Oreohelix strigosa Gould (1846)

Oreohelix subrudis Reeve (1854)

Fortunately, these species also occur in Montana and in southern British Columbia.

Other causes of loss of habitat include development of areas for housing, open-pit mining, and the grazing of cattle in the Foothills. The first two causes result in complete loss of the habitat, whereas cattle grazing results in changes to the vegetation and may also cause losses by logging of timber. There is a tendency for areas cleared of timber to be used for grazing. The cattle chew the young coniferous trees and tend to prevent or seriously modify reforestation. Where coniferous trees are replanted, they tend to be of a single, fast-growing species which alters the microenvironment. Any modification of the architecture of the top 5 cm of the soil profile, e.g., by scarification, will cause problems for the duff specialists.

4. Introduction of non-native vegetation.

The native fauna evolved together with the native vegetation and is adapted to co-existing with it. In Little Bow Provincial Park, there has been replacement of several hectares of native vegetation by exotic grasses. The native molluscs had evolved to co-exist with the native vegetation, and the changes have resulted in the local extirpation of the terrestrial molluscan fauna. The change to a highly manicured camping area together with the changes in vegetation have resulted in the extirpation of most native terrestrial molluscan species in that area.

5. Agriculture and development.

These changes result in fragmentation of the natural environments making recolonization of any damaged areas difficult, if not impossible for terrestrial molluscs. Just as the patchy protection of the eastern slopes of the mountains is disrupting migration corridors for large mammals, the former extensive areas of forests and prairie grasslands have been chopped up into little isolated patches.

Large areas of the prairies have been modified by farming of various kinds. Probably the least intrusive use is ranching since the cattle generally have free range as did the buffalo bison several decades earlier. The main differences are the choice of food by the cattle, the intensity of use, and the planting of exotic grasses periodically to improve the pasture. Ploughing and reseeding have a similar effect to growing crops, except that nutrients are not removed as they are with arable farming. However intensive cattle ranching may result in changes in the available nutrients such as nitrogen. The use of herbicides and pesticides makes the land inhospitable for molluscs, and these chemicals may travel away from the point of application, either in the wind or in surface or subsurface waters. This has resulted in the extirpation of snails from considerable areas of the floodplains of the major rivers, which is particularly important for the rare species that entered the area during the Hypsithermal period. Thus Gastrocopta similis Sterki (1909) can only be found at one of the three sites where it had been collected previously, although it can still occurs at one relatively inaccessible site along the North Saskatchewan River in Saskatchewan. In the case of Fort Normandeau Provincial Park, it is unclear whether the introduction of exotic grasses or the use of chemicals is the cause of the extirpation of this species. A major migration of terrestrial mollosca up the river floodplains in the event of climatic warming is now virtually impossible.

At least as important is the alteration of the prairie by irrigation farming. This has occurred in large areas of southern Alberta, and results in flooding of some formerly dry areas together with reduced flows on the rivers. In general, the new associated wetlands increase the available environments for the snails that live alongside water, provided the water is not too saline. The building of dams can cause cessation of periodic flooding of the flood plains that is essential for the Cottonwood trees to flourish. Their demise along the Milk River is altering the ecosystem and this may cause loss of species. Similarly, the use of water for habitations along the major rivers such as the Bow River alters its chemical composition which can result in problems for the biota.

Conclusions.

The terrestrial molluscs are but one of a whole group of relatively inconspicuous organisms that are important in decomposing organic matter, reducing the fuel that makes forest fires more intense, and bringing about a recycling of the nutrients locked up in decaying organic matter. Since they can readily be monitored, they are convenient indicators of the health of the decomposer part of a given ecosystem. If that part is not functioning well, then there will be problems with the build-up of fuel that will make forest fires more intense and potentially more frequent. In addition, the lack of attention being paid to this group of organisms may result in their irreversible extirpation from the ecosystem. For these reasons, managers should pay more attention to the effects that their management practices may have on the decomposers in the ecosystems that they are dealing with.

Algae as Bioindicators of Water Quality of the Lakes

Edward G. Bellinger and David C. Sigee

3.1 Bioindicators and water quality

Freshwater algae provide two main types of information about water quality.

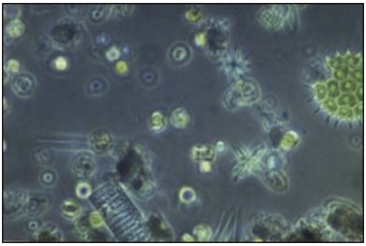
Long-term information, the status quo.

In the case of a temperate lake, for example, routine annual detection of an intense summer bloom of the colonial blue-green alga *Microcystis* is indicative of pre-existing high nutrient (eutrophic) status.

Microcystis is the genus of freshwater cyanobacteria which includes the harmful algal bloom Microcystis aeruginosa.

Short-term information, environmental change. In a separate lake situation, detection of a change in subsequent years from low to high blue-green dominance (with increased algal biomass) may indicate a change to eutrophic status. This may be an adverse transition (possibly caused by human activity) that requires changes in management practice and lake restoration. In the context of change, bioindicators can thus serve as early-warning signals that reflect the 'health' status of an aquatic system.

3.2 Lakes



Phytoplankton is tiny microscopic plants - algae

The use of algae as bioindicators of water quality is influenced by the long-term retention of water in lake systems and also by the age of the lake. Retention of water can be quantified as 'water retention time' (WRT), which is the average time that would be taken to refill a lake basin with water if it were emptied. WRT for most lakes and reservoirs is about 1 to 10 years, but some of the world's largest lakes have values far in excess of this – including extreme values of 6000 and 1225 years respectively for Lakes Tanganyika (Africa) and Malawi (Africa). Characteristics of lake hydrology and age result in:

Phytoplankton dominance. In moderate to high nutrient deep lakes, phytoplankton populations are able to grow and are retained by the system (not flushed out). Their dominance over non-planktonic algae and macrophytes means they are routinely used as bioindicators.

Long-term exposure. In many lakes, planktonic and benthic algae have relatively long-term exposure to particular conditions of water quality and relate to specific chemical and physical characteristics over extended periods of time (weeks to years).

Endemic species. Some of the world's largest lakes have existed over a long period of time – including Lakes Tanganyika (Africa: 2–3 million years [My]), Malawi (Africa: 4–9 My) and Baikal (Russia: 25–30 My). Long-term evolution within these independent and enclosed aquatic systems has led to the generation of high proportions of unique species (endemism), with over 50% endemic fauna and flora in Lakes Tanganyika and Baikal. The presence of substantial levels of endemism in these large water bodies, together with the fact that even non-endemic species may have unique adaptations, means that conventional bioindices will need to be adjusted to suit particular situations.

3.2.1 Contemporary planktonic and attached algae as bioindicators

Both planktonic algae (present in the main water body of the lake – pelagic zone), and attached algae (occurring around the edge of the lake – littoral zone) have been used to monitor water quality.

Phytoplankton: general water quality

Most studies on lakes have used the phytoplankton (rather than benthic) community for contemporary environmental assessment, since it is the main algal biomass, is readily sampled at sites across the lake and many planktonic species have defined ecological preferences. Analysis of the phytoplankton community from a number of sites across the lake also provides information about aquatic conditions in general, and is the basis of broad categorization of lakes in relation to water quality, particularly trophic state.

Attached algae: localized water quality

Although there have been relatively few studies using attached (benthic and epiphytic) algae to assess water quality, analysis of non-planktonic (mainly littoral) algae can provide useful information on general ecology and local water quality.

Local water quality

Various authors have analysed benthic or epiphytic algal populations in relation to water quality, including the extensive periphyton growths that occur in the littoral region of many lakes.

These algae are particularly useful in relation to local water conditions (e.g. localized accumulations of metal toxins, point source and diffuse loading at the edge of the lake), since their permanent location at particular sites gives a high degree of spatial resolution within the water body.

Localized metal accumulations Cattaneo studied periphyton growing epiphytically in macrophyte beds of a fluvial lake in the St Lawrence River (Canada), to see if they could consider periphyton communities in relation to water quality (toxic and non-toxic levels of mercury) under differing ecological conditions (e.g. fine versus coarse sediment). The periphyton, composed of green algae (40%), blue-greens (25%) diatoms (25%) and other phyla, was collected from various sites and analysed in terms of taxonomic composition and size profile. Multivariate (cluster* and biotic index) analysis of periphyton communities gave greatest separation in relation to physical ecological (particularly substrate) conditions rather than water quality. The authors recommended that the use of benthic algae as aquatic bioindicators should involve sampling from similar substrate sites to eliminate ecological variation other than water quality.

Point source and diffuse loading at the edge of the lake

Water quality in the littoral zone may differ considerably from that in the main part of the lake.

This is partly due to the closeness of the terrestrial ecosystem (with inflow from the surrounding catchment area) and partly due to the distinctive zone of littoral macrophyte vegetation, making an important buffer zone between the shore and open water. Analysis of littoral algae, either by multivariate analysis or determination of bioindices, has the potential to provide information on water quality at particular sites along the edge of the lake in relation to point discharges (stream inflows, industrial and sewage discharges) and diffuse loadings. The latter include input from surrounding agricultural land, discharges from domestic areas, traffic pollutants and loading from local ecosystems such as forests and peat bogs.

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3.2.3 Water quality parameters: inorganic and organic nutrients, acidity and heavy metals

A wide range of chemical parameters can be considered in relation to general lake water quality– including total salt content (conductivity), inorganic nutrients (nitrogen and phosphorus), soluble organic nutrients, acidity, heavy metal contamination and presence of coloured matter (caused particularly by humic materials).

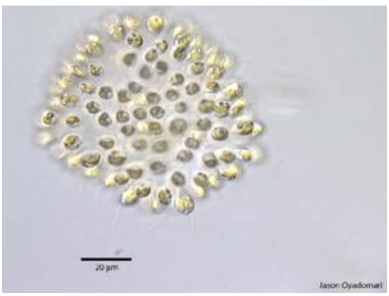
Algae as bioindicators of inorganic trophic status

Planktonic algae within lake surface (epilimnion) samples can be used to define lake trophic status in terms of their overall productivity and species composition. Species composition can be related to trophic status in four main ways – seasonal succession, biodiversity, bioindicator species and determination of bioindices.

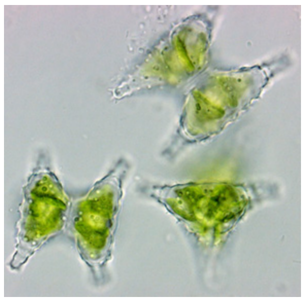
1. Seasonal succession.

In temperate lakes, the development of algal biomass and the sequence of phytoplankton populations (seasonal succession) directly relate to nutrient availability. In all cases the season commences with a diatom bloom, but subsequent progression can be separated into four main categories.

Oligotrophic lakes. In low nutrient lakes the spring diatom bloom is prolonged, and diatoms may dominate for the whole growth period. Chrysophytes* (Uroglena) and desmids* (Staurastrum) may also be present, and in some lakes Ceratium and Gomphosphaeria may be able to grow in the nutrient depleted waters by migrating down the water column to higher nutrient conditions.

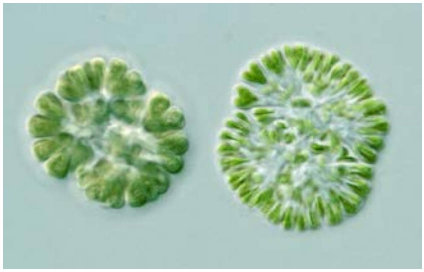


Chrysophytes (Uroglena)



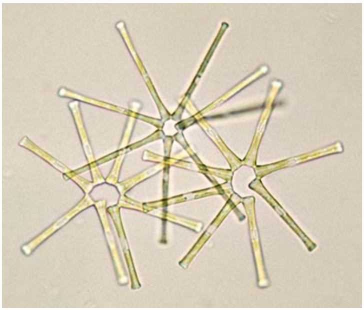
Staurastrum

Ceratium



Gomphosphaeria

Mesotrophic lakes. These have a shorter diatom bloom (dominated by *Asterionella*), often followed by a chrysophyte phase then mid-summer dinoflagellate*, blue-green and green algal blooms.



Asterionella

Eutrophic lakes. In high nutrient lakes, the spring diatom bloom is further limited, leading to a clear water phase (dominated by unicellular algae), followed by a mid-summer bloom in which large unicellular (*Ceratium*), colonial filamentous (*Anabaena*) and globular (*Microcystis*) blue-greens predominate.

Anabaena

Hypertrophic lakes. These include artificially fertilized fish ponds and lakes with sewage discharges, and are dominated throughout the season by small unicellular algae with short life cycles. The algae form a succession of dense populations, outcompeting larger colonial organisms which are unable to establish themselves.

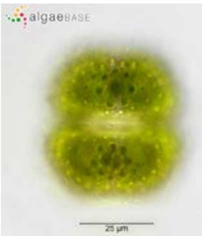
2. Species diversity.

Bioindices of species diversity can be derived from species counts and dispart into three main categories – species richness (Margalef index), species evenness/dominance (Pielou index, Simpson index) and a combination of richness and dominance (Shannon–Wiener index).

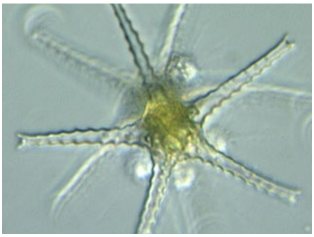
During the summer growth phase, species diversity is typically low in oligotrophic lakes, rising progressively in mesotrophic and eutrophic lakes, but falling again in some eutrophic/hypertrophic lakes where small numbers of species may outcompete other algae.

3. Bioindicator species.

Some algal species and taxonomic groups show clear preferences for particular lake conditions, and can this act as potential bioindicators. In a broad comparison of oligotrophic versus eutrophic waters, desmids (green algae) tend to occur mainly in low nutrient waters while colonial blue-green algae are more typical of eutrophic waters.



Cosmarium meneghinii



Staurastrum spp

Cladophora

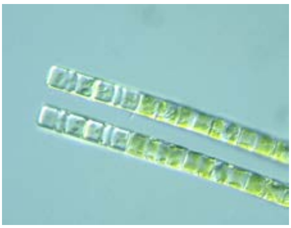
Such generalizations are not absolute, however, since some desmids (e.g. *Cosmarium meneghinii*, *Staurastrum* spp.) are typical of meso- and eutrophic lakes, while colonial blue-green algae such as *Gomphosphaeria* are also found in oligotrophic waters. Although it is not possible to pin-point individual algal species in relation to particular trophic states, it is possible to list organisms that are typical of summer growths in different standing waters.

Identification of such indicator species, particularly at high population levels, gives a good qualitative indication of nutrient state. In addition to phytoplankton bioindicators, the trophic status of the lake is also reflected in extensive growths of attached algae such as *Cladophora* and in the dense periphyton communities that occur in the littoral reed beds.

Eutrophic lake

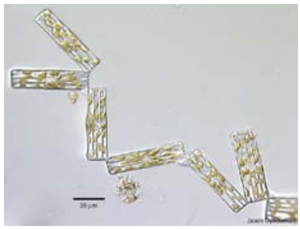
The high nutrient status of the lake is indicated by water analyses (mean annual total phosphorus >50 µg l−1), high productivity (maximum chl*a* concentration typically >60 µg l−1) and characteristic bioindicator algae. These include planktonic blooms of *Anabaena*, *Aphanizomenon*, *Microcystis* (colonial blue-greens) plus various eutrophic algae. Attached macro algae (*Cladophora*) and periphyton communities are also well-developed.

Analysis of lake sediments indicates increased eutrophication in recent historical times, with higher proportions of the diatoms *Asterionella formosa* plus *Aulacoseira granulata* and marked decreases in *Cyclotella ocellata* and *Tabellaria flocculosa* (more typical of low-nutrient waters) over the last 50 years.



Aulacoseira granulate

Cyclotella ocellata



Tabellaria flocculosa

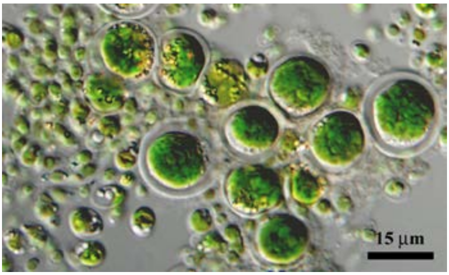
Although individual algal species can be rated primarily in terms of trophic preferences, they are also frequently adapted to other related ecological factors:

• *Acidity*: oligotrophic waters are frequently slightly acid with low Ca concentrations, and vice versa for eutrophic conditions.

• *Nutrient balance*: mesotrophic waters may be nitrogen-limiting (high P/N ratio), promoting the growth of nitrogen-fixing (e.g. *Anabaena*) but not non-fixing (e.g *Oscillatoria*) colonial blue-green algae.

Oscillatoria

• *Long-term stability*: In hypertrophic waters, domination by particular algal groups may vary with the long-term stability of the water body. High-nutrient lakes, with established populations of blue-greens and dinoflagellates, often have these as dominant algae during the summer months. Small newly formed ponds, however, are often dominated by rapidly-growing Chlorococcales* (green algae) and Euglenoids*.

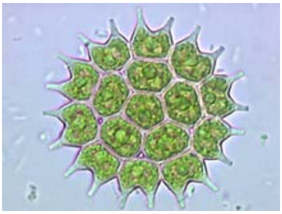


Chlorococcales

Euglenoids.

The latter are particularly prominent at high levels of soluble organics (e.g. sewage ponds), using ammonium as a nitrogen source. Some of the most hypertrophic and ecologically-unstable waters are represented by artificially fertilized fish ponds.

In addition to considering individual algal species, taxonomic grouping (assemblages) may also be useful environmental indicators. Reynolds considered species assemblages in relation to seasonal changes and trophic status, with some groupings (e.g. *Cyclotella comensis*/*Rhizosolenia*) typical of oligotrophic waters and others typical of eutrophic (e.g. *Anabaena*/*Aphanizomeno*/*Gloeotrichia*) and hypertrophic (*Pediastrum*/*Coelastrum*/*Oocystis*) states. Consideration of algae as groups rather than individual species leads on to quantitative analysis and determination of trophic indices.



Pediastrum

Coelastrum

Oocystis

4. Phytoplankton trophic indices.

In mixed phytoplankton samples, algal counts can be quantitatively expressed as biotic indices to characterize lake trophic status. These indices occur at three levels of complexity.

Indices based on major taxonomic groups which are used major taxonomic groups that were considered typical of oligotrophic (particularly desmids) or eutrophic (chlorococcales, blue-greens, euglenoids) conditions. Although such indices provided useful information, they tended to lack environmental resolution since many algal classes turn out to be heterogeneous – containing species typical of oligo- and eutrophic lakes. Problems were also encountered in some of the early studies with sampling procedures, where net collection of algae resulted in loss of small sized (single cells or small colonies) species. Such algae are often dominating elements in the plankton community, and their loss from the sample meant that the index was not representative.

Indices based on indicator species are based simply on the recorded presence of eutrophic and oligotrophic indicator species

More complex indices are based on quantitative rating of individual indicator species.

Organic pollution

According to Palmer, organic pollution tends to influence the algal flora more than many other factors in the aquatic environment such as water hardness, trophic status, light intensity, pH, DO (dissolved oxygen), rate of flow, size of water body and other types of pollutants. Organic pollution resembles trophic status in relating to nutrient availability, but differs in being soluble organic rather than inorganic nutrients. The terms oligo-, meso- and eutrophic are used specifically for inorganic nutrients and not soluble organics. The use of algae (and other organisms) for monitoring organic pollution was originally pioneered by Kolkwitz and Marsson. Palmer carried out an extensive literature survey to assess the tolerance of algal species to organic pollution, and to incorporate the data into an organic pollution index for rating water quality. Algal genera and species were listed separately in order of their pollution tolerance, and included a wide range of taxa (euglenoids, blue-greens, green algae and diatoms) as well as planktonic and benthic forms. The species organic pollution index developed by Palmer uses the top 20 algae in the species list. Algal species are rated on a scale 1 to 5 (intolerant to tolerant) and the index is simply calculated by summing up the scores of all relevant taxa present within the sample. In analyzing the water sample, all of the 20 species are recorded, and an alga is considered to be 'present' if there are 50 or more individuals per litre. Care should be taken in applying this index, since many sites with high organic pollution (e.g. soluble sewage organics) also have high inorganic nutrients (phosphates, nitrates), and algae characteristic of such sites are typically tolerant to both.

Acidity

Acidity becomes an important aspect of lake water quality in two main situations – naturally occurring oligotrophic waters and in cases of industrial pollution. Algal bioindicators have been important for monitoring lake pH change both in terms of lake sediment analysis and contemporary epilimnion populations.

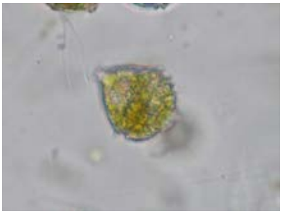
Oligotrophic waters

The tendency for oligotrophic lakes to be slightly acid has already been noted in relation to inorganic nutrient status, and for this reason many algae typical of low nutrient waters – including various desmids and species of Dinobryon* – are also tolerant of acidic conditions. Acidic, oligotrophic waters tend to be low in species diversity. In a revised classification of British lakes proposed by Duker and Palmer, naturally acid lakes include highly acid bog/heath land pools (group A), acid moorland pools and small lakes (group B) and acid/slightly acid upland lakes (group C).

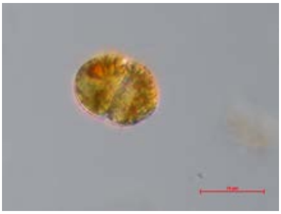
Industrial acidification of lakes

Industrial atmospheric pollution during the last century led to acid deposition and acidification of lakes in various parts of central and northern Europe.

Central Europe. In Central Europe, regional emissions of S (SO4)and soluble inorganic N (NO3, NH4) compounds reached up to ~280 mmol between 1940 and 1985, then declined by ~ 80% and ~35% respectively during the 1990s. This atmospheric deposition led to acid contamination of catchment areas and the resulting acidification of various Central European mountain lakes, including a group of eight glacial lakes in the Bohemian Forest of the Czech Republic. Studies on chronically acidified Bohemian Forest lakes have demonstrated some recovery from acid contamination. This is now beginning, about 20 years after the reversal in acid deposition that occurred in 1985, with some lakes still chronically acid – but others less acid and in recovery mode. Chronically-acid lakes have low primary productivity, with low levels of phytoplankton and zooplankton and domination by heterotrophic bacteria. Lakes in recovery mode have a higher plankton standing crop, which is dominated by phytoplankton and zooplankton rather than bacteria. Phytoplankton species composition is characterized by acid-tolerant oligotrophic unicellular algae. Lakes in recovery mode are still acid, and have a phytoplankton composition closely similar to chronically acid standing waters. These are dominated by two dinoflagellates* (*Peridinium umbonatum*, *Gymnodinium uberrimum*) and a chrysophyte (*Dinobryon* sp.), which serve as bioindicators. Other algae present in the Czech acid lakes included many small unicells (particularly chrysophytes and cryptophytes). Diatoms were not present, presumably due to the chemical instability of the silica frustule under highly acid conditions.



Peridinium umbonatum



Gymnodinium uberrimum

Dinobryon sp.

Northern Europe Acidification of lakes in southern Sweden follows a similar pattern in terms of algal species, with domination of many acid lakes by the same bioindicator algae seen in Central Europe – *Peridinium umbonatum*, *Gymnodinium uberrimum* and *Dinobryon* sp.

In addition to atmospheric pollution, lake acidification has also been caused by industrial effluents – where it is frequently linked with heavy metal pollution.

<u>Heavy metal pollution</u>

Planktonic algae are considerably influenced by heavy metal pollution, which can arise in a variety of ways – including sewage discharge, resuspension of toxic sediments and industrial effluent discharge.

Cattaneo studied the response of lake diatoms to heavy metal contamination, analysing sediment cores in a northern Italian lake (Lake d'Orta) subject to industrial pollution.

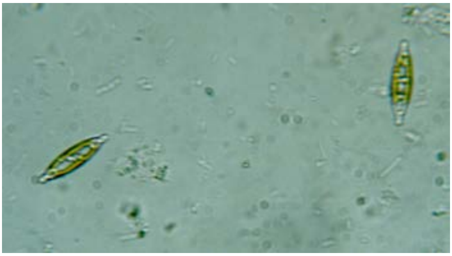
Environmental changes Lake d'Orta had been polluted with copper, other metals (Zn, Ni, Cr) and acid (down to pH 4) for a period of over 50 years – commencing in 1926 and reaching maximum pollutant levels (30–100 μgCu l^{-1}) between 1950 and 1970. Lake sediment cores collected after 1990 were analysed for fossil remains of diatoms, all of which showed a marked reduction in mean size during the period of industrial pollution.

Diatom response to pollution The initial impact of pollution, recorded by contemporary analyses, was to dramatically reduce populations of phytoplankton, zooplankton, fish and bacteria. Subsequent sediment core analyses of diatoms showed that heavy metal pollution caused a marked decrease in the mean size of individuals.

The decrease in mean diatom size was caused primarily by a change in taxonomic composition from assemblages dominated by *Cyclotella comensis* and *C. bodanica* to populations dominated by *Achnanthes minutissima*.

The change in mean size was also caused by a shift in the size within a single taxon – *Achnanthes minutissima*. The mean length of this diatom decreased significantly from about 14 μm before pollution to a minimum value of 9 μm during 1950–1970.

Achnanthes minutissima as a bioindicator



Achnanthes minutissima

Dominance of Lake d'Orta under conditions of heavy metal pollution by *A. minutissima* is in agreement with the known ability of this diatom to withstand strong metal stress. Other studies have shown it to be dominant in streams subject to heavy metal contamination. The diatom is cosmopolitan, however, often common in benthic assemblages of neutral waters, and its domination of a particular environment is not therefore directly indicative of heavy metal pollution. In spite of this, the presence of dominant populations (coupled with a decrease in mean cell size) is consistent with severe environmental stress – and would corroborate other environmental data indicating heavy metal or acid contamination.

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Euglenoids - (or euglena) are one of the best-known groups of flagellates, commonly found in freshwater especially when it is rich in organic materials

Flagellates - are organisms with one or more whip-like organelles called flagella.

Chlorococcales - unicellular green algae that reproduce by spores

Dinobryon - is a type of microscopic algae. It is one of the 33 genera of *Chrysophyceae* (Golden Algae).

Chrysophyte - the golden algae - a large group of algae, found mostly in freshwater.

Desmids - any of a group of one-celled, microscopic green algae characterized by great variation in cell shape.

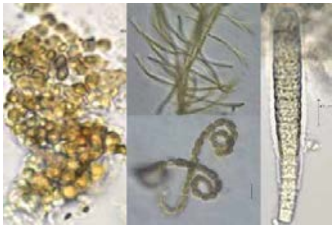
Dinoflagellate - any of numerous one-celled, aquatic organisms that have two dissimilar flagella and characteristics of both plants (algae) and animals (protozoans).

Cluster sampling is a sampling technique used when "natural" but relatively homogeneous groupings are evident in a statistical population.

Algae

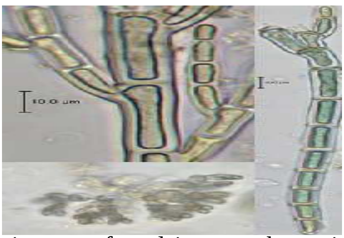
Algae are a complex and diverse group of mostly aquatic organisms that obtain their energy from sunlight through the process of photosynthesis. Algae can be found in macroscopic forms that are easily visible to the naked eye, as well as in microscopic forms that live free-floating in the water column and on rocks, wood, sand, and aquatic plants. Algae that float in the water column are called phytoplankton. Algae that live on rocks, logs, and sand are called periphyton. Algae that grow on aquatic plants and mosses are called epiphytes. The Biological Monitoring Program collects algal species from the following groups:

Cyanobacteria (formerly called Blue-Green Algae)



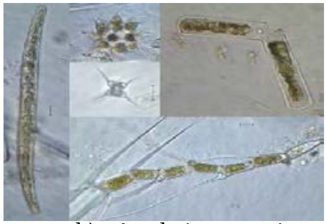
Cyanobacteria are primitive algae that are largely responsible for the Earth having an oxygenated atmosphere. Cyanobacteria are not plants and are more similar to bacteria. Unlike plants and animals, cyanobacteria do not have a cell nucleus. Cyanobacteria lack many of the advanced photosynthetic pigments found in other algae. Different species may appear blue-green (cyan) but may be other colors depending on which photosynthetic pigments they contain. Cyanobacteria can be unicellular, colonial, or form filaments and their cells are often much smaller than other algae. Some cyanobacteria are ecologically important because they convert atmospheric nitrogen into forms that can be used by organisms. Some cyanobacteria produce toxins that damage human liver and nervous systems.

Red Algae (Rhodophyta)



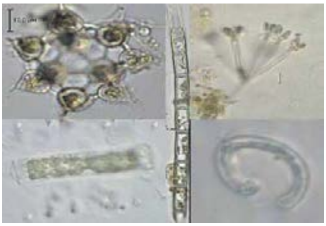
Red algae are thought to have evolved from a primitive, unicellular organism that engulfed and incorporated a cyanobacteria into its cellular structure. Red algae have a nucleus and their chloroplasts are bounded by two membranes thought to be the remnants of a food vacuole and a cyanobacterial cell. Chloroplasts of red algae retain some of the structure and pigments found in cyanobacteria. As their name implies, red algae are often red colored but are sometimes darkly colored. Different types of red algae may have unicellular, colonial, sheet, or filamentous forms. Some species have complex life cycles in which different phases might look completely different. There are few freshwater red algae in Maine . Most red algae live in salt water and some red seaweeds are commercially important for food (e.g., Porphyra), agar (e.g., Gracilaria), and carrageenan (e.g., Chondrus, Kappaphycus). Carageenan is used as a thickening agent for many foods.

Green Algae (Chlorophyta)



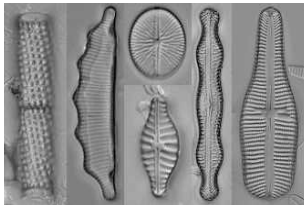
Similar to red algae, green algae are thought to have evolved from a primitive, unicellular organism that engulphed and incorporated a cyanobacteria into its cellular structure. They have a nucleus and and two membranes around their chloroplasts. Green algae are similar to plants because they share similar chloroplast structure, photosynthetic pigments, and metobolic storage products (e.g. starch). As their name implies, most green algae are green but there are exceptions. Different types of green algae may have unicellular, colonial, sheet, or filamentous forms. Some species have complex life cycles. Unlike red algae, there are many types of freshwater green algae in Maine.

Yellow-Green Algae (Tribophyceae)



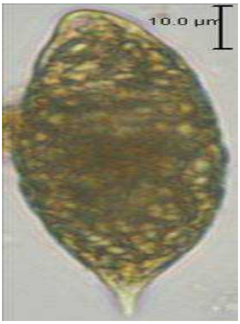
Yellow-green algae are a family of Brown Algae (Ochrophyta). They are thought to have evolved from a primitive, unicellular organism that engulphed and incorporated a red algae into its cellular structure. Each chloroplast is surrounded by four membranes that are thought to represent the original two membranes surrounding the red algae's chloroplast, the red algae's cell wall, and the membrane from the primitive organism's food vacuole. Brown algae chloroplasts contain chlorophylls *a* and *c* along with other photosynthetic pigments that give them a brownish color. Some yellow-green algae can be confused with green algae, however they do not produce starch. The starch in green algae turns a dark color when stained with iodine, but yellow-green algae do not produce starch and do not stain. Different types of yellow-green algae can have unicellular, filamentous, or siphonous forms. Vaucheria is a common yellow-green algae in Maine streams and is siphonous in form. A siphonous algae has long filaments that are hollow inside. Imagine a small straw inserted into a larger straw. All the cellular material is contained between the larger and smaller straws, while the area within the smaller straw is empty. A filament of Vaucheria has no cell walls. Technically, it is all one cell and the many nuclei, chloroplasts, and other cellular structures that flow throughout the filament.

Diatoms (Bacillariophyceae)



Diatoms are a family of Brown Algae (Ochrophyta) and share many characteristics with the yellow-green algae. The structure of diatoms is quite different, however. Diatoms have hard shells made of silica, which are formed by a top valve and a bottom valve that fit together. Diatom valves have many small holes in them that allow transfer of materials through the valves. Although they come in many shapes and sizes, diatoms are divided into centric forms (which are circular and radially symmetrical) and pennate forms (which are bilaterally symmetrical). Like many other algae, diatoms produce a gel-like substance called mucilage that helps them stick to surfaces and stick together to form colonies or filaments. Mucilage helps protect cells by keeping other things from growing on them. Some diatoms have slits in the valves, called raphes, which allow them to expel mucilage and move over surfaces. Some diatoms are tiny while others are huge in comparison. Diatoms are the most diverse group of algae in most Maine streams, rivers, and wetlands.

Euglenoids (Euglenophyta)



Euglenoids are more animal-like than other algae. They are thought to have evolved from unicellular organisms that engulphed and incorporated a green algae. Their chloroplasts have three membranes and have photosynthetic pigments similar to green algae. Some euglenoids photosynthesize and others have lost their chloroplasts completely and are predatory. Euglenoids have helical strips of semi-stiff material, called pellicles, inside their cell walls which give them a firm but flexible structure. They have a tail (flagella) for swimming and a red “eyespot” that is sensitive to light. Euglenoids cannot produce vitamins B1 or B12 on their own and are often restricted to nutrient enriched environments. Euglenoids, which are unicellular, are typically among the largest algal cells.

Dinoflagellates (Pyrrophyta)

Most dinoflagellates are covered by plates of “armor” and have two flagella to help them swim. Dinoflagellates are more animal-like than other algae. About half of the dinoflagellates lack chloroplasts and are predatory. The other dinoflagellates are thought to have acquired chloroplasts by engulphing and incorporating a variety of other algae, including green algae, cryptomonads, diatoms, chrysophyceans, and haptophytes. Dinoflagellates, which are unicellular, are typically among the largest algal cells. Some dinoflagellates are thought to produce toxins.

Algae are an important component of the ecosystem in rivers, streams, and wetlands, making them a valuable indicator of water quality. Algae serve as a food source for invertebrates and small fish and play an essential role in nutrient and energy cycling. Algae strongly influence oxygen levels in the water column through photosynthesis and respiration. They are highly sensitive to a range of environmental stressors, including nutrient enrichment, changes in pH, and increased concentrations of some dissolved chemicals and contaminants. Some species of algae are more sensitive to changes in water quality than macroinvertebrates or fish. Since algae have rapid growth rates and respond quickly to changes in their habitat, they often provide an early warning of changing environmental conditions which may not be detected by other methods.

Algae can also tell biologists about the historical condition of waterbodies. A group of algae called diatoms creates cell walls that consist of silica, a glass-like material which persists in sediments over long periods of time. These cell walls can be collected from the sediment even after the organism inside them is gone, and can give scientists information about how an algae community has changed over time in response to changing pressure from environmental stressors.

Air Pollution Damage to Plants

Edward J. Sikora, Extension Plant Pathologist, Professor, Entomology and Plant Pathology; and Arthur H. Chappelka, Professor, Forestry and Wildlife Sciences, both at Auburn University

Symptoms of Air Pollution Damage to Plants

The effects of pollution on plants include mottled foliage, “burning” at leaf tips or margins, twig dieback, stunted growth, premature leaf drop, delayed ma¬turity, abortion or early drop of blossoms, and reduced yield or quality. In general, the visible injury to plants is of three types: (1) collapse of leaf tissue with the development of necrotic patterns, (2) yellowing or other color changes, and (3) alterations in growth or premature loss of foliage. Injury from air pollution can be confused with the symp¬toms caused by fungi, bacteria, viruses, nematodes, insects, nutri¬tional deficiencies and toxicities, and the adverse effects of tem-perature, wind, and water.

Dark necrotic leaf margins on white mulberry.

Yellowing of leaves of Senegal. date palm

Twig dieback of blueberries

Factors Influencing Air Pollution Injury to Plants

Plant injury caused by air pol¬lution is most common near large cities, smelters, refineries, electric power plants, airports, highways, incinerators, refuse dumps, pulp and paper mills, and coal-, gas-, or petroleum-burning furnaces. Plant injury also occurs near industries that produce brick, pottery, ce¬ment, aluminum, copper, nickel, iron or steel, zinc, acids, ceramics, glass, phosphate fertilizers, paints and stains, rubbers, soaps and detergents, and other chemicals. Damage in isolated areas occurs when pollutants are spread long distances by wind currents.

Factors that govern the extent of damage and the region where air pollution is a problem are (1) type and concentration of pollutants, (2) distance from the source, (3) length of exposure, and (4) meteorological conditions. For some pollutants, damage can occur at levels below Environmental Protection Agency standards.

Other important factors are city size and location, land topography, soil moisture and nutrient supply, maturity of plant tissues, time of year, and species and variety of plants. A soil moisture deficit or extremes of temperature, humidity, and light often alter a plant's re¬sponse to an air pollutant.

Damage caused by air pollu¬tion is usually most severe during warm, clear, still, humid weather when barometric pressure is high. Toxicants accumulate near the earth's surface when warm air aloft traps cooler air at ground level. This is called air inversion.

Sulfur Dioxide

The exposure of succulent, broad-leaved plants to sulfur dioxide (SO2) and its by-product sulfuric acid usually results in dry, papery blotches that are generally white, tan, or straw-colored and marginal or interveinal. On some species, chronic injury causes brown to reddish brown or black blotches. Both the upper and lower leaf surfaces are affected. The leaf veins normally remain green. Chlorosis (yellowing) and a gradual bleaching of the surrounding tissues are fairly common. Injured grass blades develop light tan to white streaks on either side of the midvein. A tan to reddish brown dieback or banding occurs on conifer leaves, with adjacent chlorotic areas. Growth suppression, reduction in yield, and heavy defoliation may also occur. Middle-aged leaves and young plants are most sus¬ceptible to sulfur dioxide. Sulfur dioxide injury can be severe 30 miles or more from its source. Injury, however, is usually greatest in the vicinity of the source (less than 1 to 5 miles away). Sources of sulfur dioxide include electric power plants, copper and iron smelters, oil refineries, chemi¬cal factories, and other industries that burn soft coal, coke, or high-sulfur oil as fuel.

Interveinal chlorosis of London plane tree.

Reddish discoloration on Eucalyptus

Interveinal chlorosis of leaves on red maple.

Fluorides

Fluorides are compounds con¬taining the element fluorine (F). The typical injury by gaseous or particulate fluorides is either a yellowish mottle to a wavy, red¬dish brown or tan “scorching” at the margin and tips of broad-leaved plants or a “tip burn” of grasses and conifers.

Fluorides are produced by glass, aluminum, pottery, brick, and ceramic industries and by refineries, metal ore smelters, and phosphate fertilizer factories.

Tips of needles on this conifer exhibit reddish "burns."

Chlorine

Injury caused by chlorine (Cl2) is somewhat similar to that caused by sulfur dioxide and fluorides, in that it is marginal and interveinal. On broad-leaved plants, necrotic, bleached, or tan to brown areas tend to be near the leaf margins, tips, and be¬tween the principal veins. Injured grass blades develop progressive streaking toward the main vein in the region between the tip and the point where the grass blade bends. The streaking usually oc¬curs alongside the veins. Middle-aged leaves or older ones are often more susceptible than the young ones. Bleaching and tis¬sue collapse can occur. Conifers may show tip-burn on the current season’s needles.

Hydrogen chloride and chlo¬rine are emitted from the stacks of glass-making factories and refineries. These gases are also produced by incineration, scrap burning, and spillage, such as from chlorine storage tanks. Chlorine-injured vegetation is often observed near swimming pools, water-purification plants, and sewage-disposal facilities.

Ozone

Ozone (O3) is probably the most important plant-toxic air pollutant. It is a very active form of oxygen that causes a variety of symptoms on broad-leaved plants: tissue collapse, interveinal necrosis, and markings on the upper sur¬face of leaves known as stipple (pigmented yellow, light tan, red brown, dark brown, red, black, or purple), flecking (sil¬ver or bleached straw white), mottling, chlorosis or bronzing, and bleaching. Ozone stunts plant growth and depresses flowering and bud for¬mation. It also causes marginal rolling and scorching of leaves on lilac. Affected leaves of certain plants, such as tobacco, commonly wither and drop early.

Conifers frequently show a yellow to brown mottling and tipburn, or a yellow to brown or orange-red flecking and band¬ing of the needles (Figure 8). Ozone usually attacks nearly ma¬ture leaves first, progressing to younger and older leaves. Young plants are generally the most sensitive to ozone; mature plants, relatively resistant. Ozone-killed tissues are readily infected by cer¬tain fungi.

Ozone is brought down from the stratosphere by vertical winds or produced during electrical storms; more importantly, it is produced when sunlight reacts with nitrogen oxides and hydro¬carbons formed by refuse burn¬ing and combustion of coal or petroleum fuels, especially the exhaust gases from internal-combustion engines.

Damages on conifer needles and necrotic spotting on maple leaves due to ozone toxicity.

Peroxyacetyl Nitrate (PAN)

The most plant-toxic oxidant, next to ozone, is PAN. PAN causes a collapse of tissue on the lower leaf surface of numerous plants. The typical leaf marking is a glazing, bronzing, or silver¬ing that commonly develops in bands or blotches. On some plants, such as petunia, Pinto bean, tomato, and tobacco, the collapse may be through the en¬tire thickness of the leaf blade. In grasses, the collapsed tissue has a bleached appearance, with tan to yellow, transverse bands. Conifer needles turn yellow. Early maturity, chloro¬sis, moderate to severe stunting, and premature leaf drop may also occur. PAN is most toxic to small plants and young leaves. The very young and most mature leaves are highly resistant.

Like ozone, PAN is produced when sunlight reacts with various exhaust gases.

Ethylene

Damage caused by ethylene (H2C-CH2) is often associated with PAN and ozone in urban areas. Ethylene modifies the ac¬tivities of plant hormones and growth regulators, which affect developing tissues and normal organ development, without causing leaf-tissue collapse and necrosis. Injury to broad-leaved plants occurs as a downward curling of the leaves and shoots, followed by a stunt¬ing of growth. Ethylene also causes “sleepiness” (an inward petal-curling and failure of buds to open) in narcissus; color-breaking and blasted buds in roses; and the shelling (early drop) of azalea. More-resistant, broad-leaved plants and grasses may only be stunted. Conifers drop their needles and young cones. New needle growth is stunted, and cone development is poor.

Ethylene is one of the many products of auto, truck, and bus exhaust. Ethylene also results from the incomplete combustion of coal, gas, and oil for heating and is a by-product of polyeth¬ylene manufacture. Ethylene is a problem in fruit, vegetable, and cut-flower storage rooms and greenhouses where manufactured gas is still used.

Conclusion

Visible plant responses to air pollution make them good bioindicators are helpful in the following ways:

- Establishing the early presence of air-borne contaminants.
- Determining the geographical distribution of the pollutants.
- Estimating the concentration of pollutants.
- Providing a passive system for collecting pollutants for chemical analyses later.
- Obtaining direct identification of different air pollutants on the basis of plant species and variety affected.

Biomonitoring of Airborne Heavy Metal Contamination

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1. Introduction

During the last few decades, heavy metal contamination of biotic component of environment has attracted the attention of many investigators. The main reason of these researches based on the heavy metal concentration may have a potential hazard in our food chain after a long period of procrastination. Using biological materials in the determination of environmental pollution as indicators is a cheap and reliable method.

Various types of plant such as lichens, mosses, bark and leaves of higher plants have been used to detect the deposition, accumulation and distribution of metal pollution, as some plants are greatly affected by physical and chemical environmental conditions. If conditions become altered, the exposed plant community can accurately reflect these changes (Nash, 1988).

This chapter discusses the possibility of various types of plant usage as biomonitors for detection atmospheric heavy metal pollution in different conditions and factors that affect their accumulative potential.

2.5 Type of biomonitors

Pinus pinea L.

Nerium oleander L

As plants are immobile and more sensitive in terms of physiological reaction to the most prevalent air pollutants than humans and animals, they better reflect local conditions (Nali and Lorenzini 2007). For these reasons, plants are the most common used bioindicators in air quality biomonitoring studies (Balasooriya et al. 2009). Types of plant and their different parts have been applied in trace element air monitoring programs, such as lichens, mosses, ferns, grass, tree bark, tree rings, tree leaves and pine needles (Szczepaniak & Biziuk, 2003; Morselli et al., 2004). For all biomonitors used, the mechanisms of trace element uptake and retention are still not sufficiently known. For grass, tree rings, and ferns, substantial element contributions from other sources than atmospheric, such as the soil or the tree bole, have to be taken into account (Szczepaniak & Biziuk, 2003). Rossini Oliva and Mingorance (2006) reported that the accumulation pattern in the different parts of Pinus pinea L. and Nerium oleander L. was the following: wood $<$ bark $\leq$ leaves, because of metals are taken up by wood stem from the soil and soil water, while the outer part (leaves and bark) intercept metals also by deposition from the atmosphere (Rossini Oliva & Mingorance, 2006).

It is important to note that a unique species that can be a suitable bioindicator for biomonitoring of toxic metal pollution all over the world has not been found yet. But lower and higher plants use as suitable biomonitors world-wide.

Plants accumulate metals due to many factors, such as element availability, the characteristics of the plants (such as species, age), state of health, and type of reproduction, temperature, available moisture, substratum characteristics, etc (Conti & Cecchetti, 2001)

2.5.2 Biomonitoring by higher plants

Although mosses and lichens most frequently used for monitoring metal pollution, these lower plants are characterized by irregular and patchy distribution and their sampling should be done by specialists who can differentiate between similar-looking species. These limitations become more pronounced in industrial and densely populated areas, where severe anthropogenic pressure may cause scarcity or even lack of indicator species at some sampling points. For instance lichens are characterized by slow regeneration and relatively weak tolerance to the complex influence of mycophytotoxic pollutants, Therefore intensive sampling may lead to their reduced availability and even disappearance (Berlizov et al., 2007).

The use of higher plants, especially different parts of trees (leaves and barks), for air monitoring purposes is becoming more and more widespread. The main advantages are greater availability of the biological material, simplicity of species identification, sampling and treatment, harmless sampling and ubiquity of some genera, which makes it possible to cover large areas. Higher plants also exhibit greater tolerance to environmental changes which is especially important for monitoring areas with elevated anthropogenic influence (Berlizov et al., 2007), therefore higher plants have appeal as indicators in air pollution monitoring in highly polluted areas where lichens and mosses are often absent.

Higher plants not only intercept pollutants from atmospheric deposition but also accumulate aerial metals from the soil. Aerial heavy metal depositions are taken up from the soil by plants via their root system and translocated them to other parts of the plant (Mulgrew & Williams, 2000). Hence in the industrial and urban areas, higher plants can give better quantifications for pollutant concentrations and atmospheric deposition than non-biological samples (Markert, 1993).

Some plant species are sensitive to single pollutants or to mixtures of pollutants. Those species or cultivars are likely to be used in order to monitor the effects of air pollutants as bioindicator plants (DeTemmerman et al., 2005).

In general, it can be assumed two separated groups of higher plants for biomonitoring purposes including herbs/grasses and trees/shrubs. In both groups, aboveground plant tissues (leaf and bark) contribute in airborne heavy metal accumulation.

2.5.2.1 Herbs and grasses as biomonitor

Agropyron repens

Lolium multiflorum

Brassica oleracea acephala

Kovacs (1992) recommended the use of ruderal plants as bioaccumulative indicators due to their ability to accumulate metals in high quantities without visible injury (Kovacs, 1992). Agropyron repens is used for monitoring atmospheric metal because it is very hardy and at least visibly not affected readily by pollutants. Moreover, being a perennial grass, it constantly collects metals, although at different rates depending on the season. It is found generally on waste grounds and waysides and hence is likely to have suffered less human interference than in the case with the common species of garden grass. On the other hand the leaves of the stem of the grass, the spikelets are arranged alternately broadside поверхностью вверх on, which enhances the trapping of particles. Finally, the roughness of the leaves facilitates the adherence of particles.

Rye grass (Lolium multiflorum) is often used in agriculture as fodder (feed crop). It is an accumulation indicator representative for other food and feed crops and is often used for an estimation of load on natural vegetation. The grass is exposed during the growing season to register accumulation of airborne pollutants.

Rye grass contents indicate if there is a danger of contamination in the consumption of plants and crops in the study area.

Green kale (Brassica oleracea acephala) is a recognized standard plant for determining effects of organic airborne pollutants and is used routinely by local agencies. High frost tolerance allows it to be used in active monitoring during autumn and winter, when other plants cannot be exposed and airborne pollution increases. Green kale is especially suited for detecting organic pollutants because these pollutants are usually lipophilic (fat-soluble) materials and are accumulated greatly in the leaf wax layer.

Other herbs and grass species are also used in air quality monitoring.

2.5.2.2 Trees and shrubs as biomonitor

Pinus eldarica

Cupressus arizonica

Both coniferous and deciduous trees can be used in the detection of aerial heavy metal pollution, but coniferous trees indicate pollution over a longer time period such as, Pinus eldarica, Cupressus arizonica (Ataabadi et al., 2010a), Pinus brutia (Baslar et al., 2009), Cupressus semervirens (El-Hasan et al., 2002).

Betula pendula

Fraxinus excelsior

Sorbus aucuparia

Broad-leaved tree species regarded as sensitive to metal contamination include Betula pendula, Fraxinus excelsior, Sorbus aucuparia, Tilia cordata and Malus domestica (Mulgrew & Williams, 2000). Numerous bioaccumulative indicators exist; some tree examples include Ailanthus glandulosa, Celtis occidentalis, Salix alba, Tilia tomentosa, Sambucus nigra, Quercus robur, Fagus silvatica (Mulgrew & Williams, 2000) and Elaeagnus angustifolia (Akosy and Sahin, 1999). Also results of studies indicate that Robinia pseudoacacia (black locust tree) is appropriate species because of this tree is genetically homogeneous, easily identifiable and ubiquitously distributed (Kovacs, 1992b).

However, there are limited studies about biomonitoring by shrub species, but we could number some shrub species such as Nerium oleander (Ataabadi et al., 2010a; Rossini Oliva & Mingorance, 2006), Lantana Camara (Fernandez Espinoza & Rossini Oliva, 2005) Ligustrum vulgare, Photinia serrulata, Berberis vulgaris and Thuja orientalis (Ataabadi et al., 2010 a,b; Ataabadi et al., 2011).

For comparative studies, it is important that sampling is undertaken at the same time of the year to reduce variability. Chemical composition of foliage varies with season and rainfall (Taylor et al., 1990). For most deciduous species, suitable time is period of year when metal content in leaves will be highest. For instance standard sampling of heavy metal accumulation in Populus nigra in central Europe is carried out in August.

Metal content will vary depending on which part of the plant is sampled. The extent of accumulation in different plant parts will vary with species and the nature of the element.

It should be noted that using transplantation exercises are not common for higher plants (Mulgrew & Williams, 2000).

2.5.2.2.1 Plant leaves as biomonitor

Leaves of higher plants have been used for heavy metals biomonitoring since 1950s (Al- Shayeb eta l., 1995). The use of leaves as bioindicators of environmental pollution has been studied, more and more, to assess their suitability, to assess effect of a specific pollution source, to differentiate between background (unpolluted) and polluted sites and to monitor or assess the level of pollution in an area (Turan et al., 2011).

Rossini Oliva & Mingorance (2006) and Ataabadi et al (2010a), reported that pine needles can also be considered suitable biomonitor for atmospheric heavy metal contamination (e.g. Fe, Al, Pb).

Factors that affect efficiency of heavy metal accumulation on leaf surface

Particle (containing heavy metals) deposition on leaf surfaces may be affected by two different factors including plant-dependent factors such as morphological and structural properties of leaves contain orientation and size (Mulgrew & Williams, 2000) of leaves, cuticle thickness, cork existence, roughness, existence of surface waxy layer, specific leaf area (SLA), stomatal density (SD) and stomatal pore surface (SPS) (Ataabadi et al., 2011; Rossini Oliva & Mingorance, 2006; Balasooriya et al. 2008) and plant-free factors such as particle size and wind velocity (Mulgrew & Williams, 2000). Also the accumulation of heavy metals by higher plants depends on the binding and solubility of particles deposited on leaf surfaces (Mankovska et al., 2004).

The deposited particles may be washed by rain into the soil, resuspended or retained on plant foliage. The degree of retention is influenced by weather conditions, nature of pollutant, plant surface characteristics and particle size (Harrison and Chirgawi, 1989).

Leaves of evergreen species are considered to be better traps because of higher accumulation on a longer period of time (Turan et al., 2011).

2.5.2.2.2 Plant bark as biomonitor

The physiological function of bark is to protect the tree from mechanical injury, damaging agents and excessive evaporation. Bark quality varies considerably in different tree species and at different stages in the lifetime of a tree species. The outer bark of trees consists of the inner layer (phloem), the cork-forming layer (phellogen), and the outer layer (rhytidom or phellem) composed of dead cork cells (Prance et al., 1993). This dead cork layer has usually been employed in biomonitor studies. The chemical composition of the bark is specific to each tree species. For instance, the pH, electrical conductivity and ash content of the bark of coniferous trees are usually lower than those of broad-leaved species (Barkman, 1958).

When bark is exposed to air pollutants either directly from the atmosphere or from the rainwater running down the stem, the chemical composition of the surface layers of the bark changes, such changes can be utilised in investigating the extent of the area subjected to air pollutants. In this respect tree bark is a good bioindicator because it remains in place for an extended period of time, it is easily accessible and sampling does not damage the tree (Berlizov eta al., 2007). Retention of suspended particles is promoted by a moist, porous, rough, or electrically charged surface, making bark a highly effective collector (Panichev et al., 2004). Therefore bark has been widely employed as a passive monitor for airborne metal contaminations. The accumulation of atmospheric pollutants in bark is purely a physiological-chemical process. The pollutants either accumulate passively on the bark surface or become absorbed through ion exchange processes in the outer parts of the dead cork layer (Poikolainen, 2004). A number of air pollution biomonitoring studies have been performed using bark of different tree species include oak, elm, willow, poplar, pine, olive, cedar, eucalyptus etc. (Berlizov et al., 2007).

Metal accumulation in bark and plant foliage in urban and industrial areas can be considerable, with the greatest amount of the heavy metal burden located in the bark (Ceˆburnis & Steinnes, 2000; Watmough & Hutchinson, 2003).

Factors that affect efficiency of heavy metal accumulation on bark surface

Factors, in addition to atmospheric pollutants, that affect the chemical composition of tree bark are mainly the same as those for mosses and lichen, although the chemical reactions that occur in bark are somewhat different because bark is a non-living plant material. The concentrations in bark are mainly affected by bark quality, stand throughfall and stem flow.

The concentrations are highest in the surface layers of the outer bark, and decrease rapidly on moving towards the inner layers. Many different factors have an effect on the collecting of heavy metals in bark surface, such as heavy metal quantities in air, physiological and chemical properties of the bark, through fall, soil factors, contamination of other plants, climate factors, etc. A coarse and rough surface more readily accumulates atmospheric pollutants than a smooth surface (Poikolainen, 2004). Other factors include the bark texture and thickness (Poikolainen, 2004), the presence of epiphytic organisms, the time of exposure to the atmosphere and the depth of sampling (Bellis et al., 2001). Also bark acidity has an effect on the concentrations of some heavy metals. For instance, Bates and Brown (1981) found a clear negative correlation between bark pH and the Fe concentration in a study on the occurrence of epiphytic lichens on oak and ash. They concluded that this is due to the increased mobility of Fe with decreasing bark pH. There is no significant migration of elements from the bark surface through the cork tissue into the underlying wood, or vice versa. The migration of heavy metals from the soil via the roots into the bark as it is being formed is also usually insignificant. On the other hand, (Poikolainen, 2004). The study carried out by Szopa et al (1973) on lead concentrations along highways in the US indicated that the lead concentration in bark reacts rapidly to marked changes in lead concentrations in the atmosphere (Poikolainen, 2004).

3. Conclusion

Application of lower and higher plants as biomonitors seams to be a good way to monitor airborne heavy metal contamination, but the choice of proper phytomonitor for environmental studies depends on many factors such as availability of the biological material, contamination extent, study scale and etc. However lichen and moss due to their superior ability to accumulate elements and indicate them without interference with soil are reported the best bioindicators for the atmospheric heavy metal contamination, but in the urban and industrial areas, using aboveground parts of indigenous higher plants is recommended. Simplicity of species identification, sampling and treatment and ubiquity of some genera makes it possible to cover large areas. For the comprehensive conclusion, both of lower and higher plants should be studied simultaneously in the specific area and manifested with respect to their limitations and advantages.

Useful phrases for discussion and composition

http://www.rpn.ch/ljp/perso/devenogesS/docpub/ACTIVITIES/Usefulexpressionsessay.pdf

http://www.englishclub.com/speaking/agreeing-disagreeing-expressions.htm

When referring to the text:

As it is written in …

As one can read in.

This is indicated by

where it is said that …

This can be proven with

. (…) suggest(s) that …

as it is said that …

This word / phrase / expression refers to / underlines / emphasises / means / stands for

The author makes use of / employs …

the author/ the article says/claims/ proves/ argues/ stresses / puts emphasis on / emphasises / draws attention to / highlights/appeals to/implies that …

the author sets up (or ‘builds up’) the idea of

When analysing the structure of a text:

The text/story/speech can be divided into / is divided into / falls into / is composed of / contains / consists of […] parts / paragraphs / chapters / sections.

The first / […] / last part / paragraph / sentence constitutes / gives us / comprises the introduction / central problem / principal part / solution.

In the first / […] / last part the author varies the theme / changes the topic / goes into detail / passes from … to …

When referring to the text:

The text at hand / the given text is [an extract/excerpt from] … [a short story/speech/newspaper article/novel/poem a.s.o.] written by […] [and published in (the New York Times etc.) on [date] / in [year]. It is about / deals with / treats of / describes / is concerned with / presents … [topic = general topic, no details!].

The general/essential/main idea expressed is …

The [author/writer/speaker/poet] starts off by [+ gerund, e.g. stating that …].

He/She goes on by [+ gerund]…

He/She speaks about / discusses / gives his (her) opinion on … / expresses his (her) view concerning … / holds the view that … / comments on … / presents the thesis that … / draws (come) to the conclusion that …

Introduction and Stating something as a fact

first of all

to begin with

in order to decide whether.... or not

to outline the main points

First of all I'd like to point out...

The main problem is ...

To start with,...

The question of ...

As everyone knows ...

It is generally accepted that ...

There can be no doubt that ...

It is a fact that ...

It is common knowledge that ...

Nobody will deny that ...

Personal point of view

In my opinion ...

In my view ...

As far as I'm concerned ...

If you ask me...

to me…

I think/ assume/ feel/ fear that ...

I personally believe

I certainly think ...

I am quite sure ...

As far as I can see …

As I see it,

It seems to me that ....

I would also say that ....

Weighing up arguments

on the one hand..... on the other hand

to consider the advantages and disadvantages

arguments for and against

to discuss the pros and cons

in theory ... in reality

both... and....

not only ... but also

anyway / at any rate / in any case

in fact / actually / as a matter of fact

up to a point

so to speak

by no means / not at all

Presenting arguments

One justification often given for .... is that.................

Advocates/Proponents would claim that ....

Those who object to .... often argue that ....

Another objection is that ......

However, it should not be forgotten that ....

.... are opposed to .... on the grounds that ....

From the point of view of ....

According to ....

I am convinced that .... I am inclined to believe that .... There is no doubt in my mind that .... One of the drawbacks of .... is .... However, one of the benefits is that .... From my point of view, From my perspective It appears that I realize To my way of thinking I suppose I feel I understand I think that in my opinion/ in my view / to my mind this is a matter of opinion in my experience as far as I know as far as I am concerned to be aware / unaware of a problem to tell the truth the fact is that I am convinced that I firmly believe that I feel sth should be done about that	<u>Comparisons</u> compared to / in comparison with to draw / make a comparison between ...and similarly as well as In the same way, At the same time <u>Restrictions</u> however / though nevertheless whereas although / though / even though in spite of / despite unlike in contrast to / with sth. on the contrary sth is contrary to sth <u>Expressing pros and cons</u> There are two sides to the question ... An argument against ... is ... On the one hand ..., on the other hand ... An argument for ... is ... Some people think ..., others say ... An argument in favour of ... is ... but/ however/ yet/ still/ on the contrary/ nevertheless/ (al)though/ whereas

Asking for an opinon What's your idea? What are your thoughts on all of this? How do you feel about that? Do you have anything to say about this? What do you think? Do you agree? Wouldn't you say? Enumerating arguments in addition to / additionally besides / moreover / furthermore above all firstly, secondly, thirdly, finally / eventually - In the first place ... - Lastly ... - To begin with, ... - For a start/ To start with ... - One point I want to make is ... - also/ again/ too - Then/ Moreover/ In addition to that/ Another point/aspect is ...	Interruptions Can I add something here? Is it okay if I jump in for a second? If I might add something... Can I throw my two cents in? Sorry to interrupt, but... (after accidentally interrupting someone) Sorry, go ahead. *OR* Sorry, you were saying... (after being interrupted) You didn't let me finish. Agreeing I entirely / absolutely agree with that's exactly my own view I'm of exactly the same opinion that's perfectly true I'd like to support this view That's a very good point. That's how I feel (about it), too. I'm of the same opinion as ... probably/ possibly/ perhaps/ maybe No doubt about it. You have a point there. I was just going to say that. (agree with negative statement) Me neither.

Refering to

with reference to

regarding

as regards

as far as ... is concerned

according to (according to is used to introduce

someone else's opinion. Don't say "according to me")

Emphasizing

I’d like to point out that

I’d like to emphasize

Making exceptions

apart from

except

with the exception of

Generalizing

on the whole

in general / generally speaking

as a rule

to some extent

to a large extent / to what extent ?

in many ways

in all respects

in most / many cases

basically

Disagreeing

I partly disagree with

I don’t entirely agree with

I agree in principle, but

That’s not the way I see it

I see things rather differently myself

I’m not at all convinced that

I’m not absolutely sure

I don’t quite agree there.

You have to admit that ...

That argument just doesn’t stand up/hold.

I can’t accept the view that ...

If you believe that, you’ll believe anything.

I object to the thought ...

As far as I can see it is not right ...

I disagree with ...

Expressing doubt

I’m not sure if ...

I’m not convinced that ...

I doubt that very much.

... , however, ...

in spite of the fact

It is not very likely ...

Interest, Plans, Intentions

to be interested in sth / in doing sth

It interests me a lot

My main / particular interest is

I have the intention of doing

I am prepared to do sth

I am determined to do sth

I’m planning to do sth

I’m very keen on doing sth

Giving examples

for example / for instance

such as / including

in particular / particularly

to give you an example of what I mean

to illustrate this point by the fact that

what I mean is

et cetera / and so on / and so forth

that is to say / i.e

this is shown by the fact that...

to demonstrate/ to prove this, we can...

such as (e.g. words such as [quote], [quote], [quote] create the effect of')

- Here are some examples of ...

Giving reasons

because

as / since

because of

the reason for this is

the reason why

for some reasons or another

I have every reason to believe that

The reason for this is ...

This is due to ...

I base my argument on ...

as/ since/ because

One reason for this ...

This is why…

This is caused by ...

Lack of interest

I find … rather uninteresting / boring

I don't take any interest in

It's all the same to me whether

It means nothing to me

Summarizing and drawing conclusions

Finally, I would like to say ...

last of all

last but not least

in conclusion / to conclude

we can draw the conclusion

to sum up / to summarize we can say

all in all

in short / in brief / briefly

all things considered

the subject under discussion

I find it difficult to reach a conclusion but I'm tempted to say

It follows from this that ...

The obvious conclusion is ...

Last but not least ...

The only alternative left is ...

The only possible solution is ...

Thus/ And so/ In that case we are justified in saying that ...

There is only one conclusion to be drawn from this.

To conclude/ In conclusion we may say that ...

All in all/ In short/ In a/one word/ Briefly we may say that ...

Taking everything into consideration/ account we may say that ...

so/ therefore/ thus/ as a result/ consequently

<u>Consequences</u> therefore consequently / as a result/ hence/ thus for this reason / all these reasons	<u>To Compare and Contrast</u> On one hand, on the other hand; in comparison; similarly, likewise; in contrast; but; however; although; yet, nevertheless, despite this, (even though there are things to the contrary); even so, all the same.
<u>Addition</u> besides this (as well as this), furthermore (also), also, as well as, on top of this, foremost (most important, e.g. the foremost reason for the outbreak of war was...), firstly, secondly, thirdly, firstly, lastly, finally, likewise (in the same way).	<u>Modifying adverbs</u> totally / entirely / completely mostly / mainly / chiefly partly comparatively / relatively extremely / incredibly

<u>Conclusion expressing balanced considerations/opinion indirectly</u>

In conclusion,
On balance, I tend to believe that ....
All things considered,
Taking everything into account/consideration,
To conclude,
To sum up,
All in all it seems to me that ....
Finally/Lastly,
The obvious conclusion to be drawn is that ....
……………………. it can be said/claimed that …
……………………. it seems/appears that…
……………………. it would seem that…
……………………. it is likely/unlikely/possible/foreseeable that …
……………………. it is clear/obvious that…
…………………….. there is no/little doubt that …
…………………….. it is true to say that …
…………………….. although it must be said that …
……………………. it may be concluded/said that …

<u>Conclusion expressing opinion directly</u>

In conclusion,
On balance,
All things considered,
Taking everything into account/consideration,
To conclude,

To sum up,
All in all,
…………………………… it is my belief/opinion that …
………………………….. I (firmly) believe/feel/think that …
…………………………… I am convinced that …
…………………………… I am inclined to believe that …
…………………………… I (do not) agree that/with …

The world would surely be a better place to live in if ....

If people stopped ....ing, we would have/ we could look forward to a ....

The prospects for the future will be bleak/grim unless ....

<u>Location and summary statements:</u>

This fact is referred to in [source]

it is mentioned in [source] that

Table 1/Figure 1 shows/compares/presents/provides the nine measures of X./the experimental data on X./the results obtained from the preliminary analysis of X./the intercorrelations among the nine measures of X.

The results obtained from the preliminary analysis of X are shown/can be compared/ are presented in Table 1/in Fig 1.

As shown in Figure 12.1, /As can be seen from the table (above), /It can be seen from the data in Table 12.1 that/From the graph above we can see that the X group reported significantly more Y than the other two groups

The table below illustrates/ The pie chart above shows some of the main characteristics of the ...../the breakdown of ......

<u>Highlighting significant data in a table/chart</u>

It is apparent from this table that very few ......

This table is quite revealing in several ways. First, unlike the other tables ......

Data from this table can be compared with the data in Table 4.6 which shows ......

From the data in Figure 9, it is apparent that the length of time left between ......

From this data we can see that Study 2 resulted in the lowest value of ......

The histogram in Fig 1. indicates that ......

What is interesting in this data is that ......

In Fig.10 there is a clear trend of decreasing ......

As Table III shows, there is a significant difference (t = -2.15, p = 0.03) between the two groups.

The differences between X and Y are highlighted in Table 4

<u>Establishing the importance of the topic:</u>

One of the most significant current discussions in legal and moral philosophy is ....

It is becoming increasingly difficult to ignore the ....

X is the leading cause of death in western industrialised countries.

X is a common disorder characterised by ....

X plays an important role in the maintenance of ....

X is an important component in the climate system, and plays a key role in Y.

In the new global economy, X has become a central issue for ....

In the history of development economics, X has been thought of as a key factor in ....

Xs are one of the most widely used groups of antibacterial agents and ....

Xs are the most potent anti-inflammatory agents known.

X is a major public health problem, and the cause of about 4% of the global burden of disease.

X is an increasingly important area in applied linguistics.

Central to the entire discipline of X is the concept of ....

X is at the heart of our understanding of ....

A key aspect of X is ....

Establishing the importance of the topic (time frame given):

Recent developments in X have heightened the need for ....

In recent years, there has been an increasing interest in ....

Recent developments in the field of X have led to a renewed interest in ....

Recently, researchers have shown an increased interest in ......

The past decade has seen the rapid development of X in many ....

The past thirty years have seen increasingly rapid advances in the field of ....

Over the past century there has been a dramatic increase in ....

One of the most important events of the 1970s was ....

Traditionally, Xs have subscribed to the belief that ....

X proved an important literary genre in the early Y community.

The changes experienced by Xs over the past decade remain unprecedented.

Xs are one of the most widely used groups of antibacterial agents and have been extensively used for decades to ....

Highlighting a problem in the field of study:

However, these rapid changes are having a serious effect ....

However, a major problem with this kind of application is ....

Lack of X has existed as a health problem for many years.

Despite its safety and efficacy, X suffers from several major drawbacks:

However, research has consistently shown that first year students have not attained an adequate understanding of ...

There is increasing concern that some Xs are being disadvantaged ....

Despite its long clinical success, X has a number of problems in use.

Questions have been raised about the safety of prolonged use of ....

Highlighting a controversy in the field of study:

To date there has been little agreement on what ....

More recently, literature has emerged that offers contradictory findings about ....

One observer has already drawn attention to the paradox in ....

In many Xs a debate is taking place between Ys and Zs concerning ....

The controversy about scientific evidence for X has raged unabated for over a century.

Debate continues about the best strategies for the management of ....

This concept has recently been challenged by .... studies demonstrating ….

One of the most significant current discussions in legal and moral philosophy is ....

One observer has already drawn attention to the paradox in ....

In many Xs a debate is taking place between Ys and Zs concerning ....

The controversy about scientific evidence for X has raged unabated for over a century.

Questions have been raised about the safety of prolonged use of ....

The issue of X has been a controversial and much disputed subject within the field of ....

The issue has grown in importance in light of recent ....

One major theoretical issue that has dominated the field for many years concerns ....

One major issue in early X research concerned ....

Highlighting a knowledge gap in the field of study (for research):

So far, however, there has been little discussion about ....

However, far too little attention has been paid to ....

Most studies in X have only been carried out in a small number of areas.

The research to date has tended to focus on X rather than Y.

In addition, no research has been found that surveyed ....

So far this method has only been applied to ....

Several studies have produced estimates of X (Smith, 2002; Jones, 2003), but there is still insufficient data for ....

However, there have been no controlled studies which compare differences in ....

The experimental data are rather controversial, and there is no general agreement about ....

However, there is no reliable evidence that ....

X's analysis does not take account of .... nor does he examine ....

Focus, aim, argument:

This paper will focus on/examine/give an account of ....

This essay seeks to remedy these problems by analyisng the literature of ....

The objectives of this research are to determine whether ....

This paper seeks to address the following questions:

This essay critically examines/discusses/traces ....
The purpose of this paper is to review recent research into the ....
This paper will review the research conducted on ....
This chapter reviews the literature concerning the usefulness of using ....
The aim of this paper is to determine/examine ....
The aim of this study was to evaluate and validate ....
In this paper I argue that ....
In the pages that follow, it will be argued that ....
This paper attempts to show that ....
In this essay, I attempt to defend the view that ....

Outline of structure:

The main questions/issues addressed in this paper are: a), b and c).
This paper has been divided into four parts. The first part deals with ....
The essay has been organised in the following way.
This paper first gives a brief overview of the recent history of X.
This paper reviews the evidence for ....
This paper begins by ...... It will then go on to ....
The first section of this paper will examine .....
Finally, ...

Chapter 2 begins by laying out the theoretical dimensions of the research, and looks at how ....

Chapter 3 describes the design, synthesis, characterization and evaluation of ....

The last chapter assesses the ....

Explaining Keywords

While a variety of definitions of the term X have been suggested, this paper will use the definition first suggested by Smith (1968) who saw it as ....

Throughout this paper the term X will refer to/will be used to refer to ....

In this article the acronym/abbreviation XYZ will be used.

How to Render an Article

Headline /
Title of the article The article is headlined...
The headline of the article is...
The article goes under the headline...
The article under the headline... has the subhead...
The title of the article is...
The article is entitled...
2. Place of origin The article is (was) printed / published in...
The article is from a newspaper under the nameplate...
3. Time of origin The publication date of the article is...
The article is dated the first of October 2008.

The article is printed on the second of October, 2008.
4. Author The article is written by…
The author of the article is...
The article is written by a group of authors. They are…
5. Theme / Topic
The article is about...
The article is devoted to...
The article deals with the topic...
The basic subject matter of the script is...
The article touches upon the topic of...
The article addresses the problem of...
The article raises/brings up the problem...
The article describes the situation...
The article assesses the situation...
The article informs us about… / comments on…
The headline of the article corresponds to the topic.
6. Main idea /
Aim of the article The main idea of the article is…
The purpose of the article / author is to give the reader some information on...
The aim of the article / author is
– to provide the reader with some information about...;
– to provide the reader with some material / data on...
– to inform about...;
– to compare / determine...;
7. Contents of the article
(a short summary of 3 or 4 sentences) + important FACTS, NAMES, FIGURES. The article can be divided into some parts.
The first part deals with...
The second covers the events...
The third touches upon the problem of...
The fourth part includes some interviews, dialogues, pictures, reviews, references, quotations, figures.
The article is written in the form of the monologue, from the first / third person narration.

Tapescripts

Pollution and its types.

http://www.youtube.com/watch?v=p6QLx7vEyIY

Have a look at this picture:

Nature at its exuberant best - Turquoise blue sky.- Eye full of green. - Sparkling waters. – … wilderness.

And what about this picture? - A land of vanishing beauty. - Shrinking open space of grey concrete. -

Sooty air. - Drying land. - Dirty waters. - And endangered wilderness.

This change which is called environmental degradation has become a major issue before the world.

Let's then begin with water pollution

Pollution is an undesirable change in the phisio-chemical or biological characteristics of air, water and soil due to addition of materials or energy in quantity and quality, which is harmful to living beings including man. The substances which contaminate air, water and soil are called pollutants.

Pollutants may be: Gases like carbon monoxide, sulphur oxides and nitro oxides. Metals like lead, zinc and mercury. Chemicals like aldehides, detergents, pesticides, herbicides and CFCs. Sewage. Radioactive wastes and so on.

Types of pollution The major types of pollution are:

Air pollution Water pollution Land pollution

Soil pollution Noise pollution Thermal pollution

Air pollution.

The major causes of air pollution are toxic gases and exhausts that are let out into the air by industries volcanoes jet planes automobiles forest fires burning of garbage etc.

These contain many harmful gases that cause diseases in human beings, destruction of vegetation and damage of the structure of Earth. These gases can also form acid rains.

Water pollution.

The effluents let into the water bodies from industries, sewage from towns and cities, washing clothes and cattle in the water bodies and such other reasons cause water pollution. The residue of fertilizers and pesticides carried into water bodies during rain also cause water pollution. The list of pollutants can be quite long. Oil spills in the oceans are another major cause that harms the marine life.

Land pollution

If you visit big cities you'll find heaps of solid wastes in and around. The sources of land pollution are mainly: Houses. Cattle sheds. Industries and agricultural fields. It includes: Household wastes. Glass. Fruit and vegetable waste. Dead bodies of animals. Old clothes. Paper. Plastic bottles. Cans. Excreta.

Chemicals. Wood pieces and so on. The heaps of solid waste provide breeding ground for germs. In addition to spoiling beauty and surroundings they emit fount smell.

Controlling land pollution.

Disposal of waste should be done very carefully and scientifically. It depends of the kind of solid waste.

1. solid waste organising from constructing material etc. is buried in urban areas as landfills.
2. solid waste like plastics, tin cans, metal scrap, paper etc. must be recycled.
3. wastes originating from plant materials and household organic material can be turned into manure.
4. biogas can be obtained from biodegradable wastes.
5. wastes from hospitals and nursing homes should be burnt in incinerators.

Soil pollution.

Pollution of soil is somewhat localized phenomenon as compared to air and water pollution which spread to long distances. Soil pollution occurs due to two main reasons: By pollutants that are washed down from the atmosphere because of rain; Insecticides and pesticides that are applied to the crops.

Both these alter the composition and quality of the soil.

Noise pollution

Noise can be defined as any unwanted sound. Sound is measured in a unit called decibel (dB). The lowest sound measured in this unit is 1 decibel and a sound of a rocket taking off is about 180 decibels. In between the two are various levels of sound. When we talk normally the sound level is about 16 decibels.

Noise is a pollutant because it produces several adverse effects on human beings and other animal life. The loudness and duration of noise is injurious to our physical and mental health. Sudden loud noise may cause acute damage to the ear drum; continued loud noise may cause deafness.

Noise lowers the efficiency of work, Disturb sleep, And causes irritability.

Thermal pollution

Thermal pollution includes release of any kind of heated gases or heated water repeatedly into the environment including the water bodies. If release in the atmosphere they warm up the air in the area and if release in water bodies they kill the aquatic life.

http://www.youtube.com/watch?v=tmhiglxga-4 – cartoon video to make transcripts

Keystone Species vs Indicator Species.

http://www.youtube.com/watch?v=a-5GCs9FeUo

0:00 – 1:56

Hi. My name is Mary Poffenroth and I'm an Adjunct Professor of biology and today we gonna be talking about keystone species vs indicator species. A keystone species is the species that has a huge impact on the environment even though its population number may be kind of low. Much like a keystone in an arch help support the entire arch a keystone species if removed from the ecosystem can cause a collapse. One example is the California sea otter. The California sea otter was almost hunted to extinction. When that happened scientists and fisherman started to see a collapse in this ocean environment. You see, sea otters are gonna be the only organisms that eat sea urchins, well, sea urchins eat kelp. No sea otters – the sea urchin population exploded. It started to eat all the kelp. So, what's the big deal? Well, kelp actually provides a place for protection as well as spawning for fish. So as the sea otters disappeared so did the fish. Luckily sea otters were brought back and the ecosystem of the coast of California are going much better.

Our next example is indicator species. An indicator species is a species that when they are absent, present or in relative abundance tell scientists a lot of something about what's going on in ecosystem. One example are lichens. Lichens are extremely sensitive to things like sulfur dioxide and ozone. If these things are in the air, you can tell because of the lichens won't be doing so good and possibly be absent from areas that they used to be in. So, that can tell scientists that there's probably an air pollution problem in that area.

Even though every species has an inherent right to live on our planet some species are just a little bit more important to the health and vitality of the ecosystem than others.

Why I Became a Biologist- Camille Parmesan

http://www.youtube.com/watch?v=6WY6wptkw_w&feature=related

I've always been interested in the natural world as my mother was a geologist and a botanist as well and took me out for walks ever since the time I was ..er.. ever since I could walk,..uh...and I learned …would learn all the rocks and all the plants and all the animals every time we'd go out on vacation.

But as an undergraduate I actually was a premeditated. I wanted to be a medical doctor because I wanted to ..sort of… do something good for a humanity. And then in my senior year I spent a summer doing field work up in the Sierra Nevada mountains with this butterfly, and spent three months camping out in the tent, waking up every morning to birds singing and then going out in the field and working …you know… with the earth, and with the caterpillars and the butterflies and I thought this is what I wanna do to the rest of my life.

I suppose the other big reason that I'm …I'm not a medical doctor but a field biologist is because even if you're doing a medical research which is probably what I would have gone into, you're stuck in a lab all day, so you're in that's what people think of as …as a scientist or in a lab with the white coat and beakers of things all around. That never did appeal to me.

My work on the other hand is very dirty I'm out in the mountains camping out in a tent for months at a time. I dig in the dirt, I lie in the dirt, I eat the dirt… it's and it's wonderful because it I don't think I could ever go back to working in a sterile lab environment after having been on the field, 'cause you really get to know the pulse of the species that you're working with, you get intuition for them, you get to know what makes them happy, what…what they like, what they don't like. And I think it'd be very difficult to interpret …well…the kind of work I do without having that intuition and you can't get that in the lab.

Global Warming: Impacts on Wildlife and Society

http://www.youtube.com/watch?v=RJxR4wVsR7Y

My name is Camille Parmesan and I'm at the University of Texas the Integrated Biology..

Very broadly what I'm interested in are what the impacts of climate change have been on wildlife. When you say "global warming" people think of absolutely everywhere getting hotter. And really in truth what's happening is that most places are getting hotter but some places are getting cooler and some places aren't changing. So now we talk about climate change. And what that means is that as we've had a rise in greenhouse gases and principally carbon dioxide which is what comes out of your cars. This is cause to the Earth to retain more heat and as it retains more heat globally this has big impacts on local and regional climates. One of the things that I study is what has been a response of animals and plants to that gradual rise in temperature over the years, over the past hundred years.

There are 2 main types of response that you can look at, and one of them is very intuitive and that's that the timing of events changes, so if you think of winter being warmer, which it has become warmer, than it is easy to imagine that spring might start earlier. And in fact that's what we're seeing: spring is about 2 weeks earlier now than it was 30 or 40 years ago. And that's due to this gradual rise in temperature. That is one of the big types of impacts that occur.

The other one is, perhaps, not as obvious to people until they think about it for a minute. And that's that where an animal exists, that the area that it occupies on this planet is often, usually driven by a climate. And so as climate change occurs, then the distributions of a lot of those animals and plants you might expect to move around. And we expect them to move in particular directions. As gradually North America warms a lot of species are gonna tend to move up towards Canada and up the mounts from the lowlands. So the second type of thing you can look for are these bigger changes in the distribution of plants and animals.

When I first got interested in this climate change I chose to work on this one species of butterfly that lives in the western USA all the way from Mexico up to Canada. And I chose it because it's… we know it's very sensitive to climate from a lot of research that people have done, and it doesn't move very much as an individual. So if it was going to change where it's living it would be a very gradual process which might match the sort of gradual increase in temperature that we've had. The western US has risen in temperature by about 1° F (Fahrenheit) over the last hundred years, and the question is has where this butterfly lives changed over the past hundred years.

And to get that information I went around to museums and look at museums specimens to see where people had recorded finding it in the early nineteen hundreds (1900). Once I had that, I had to figure out whether anything had changed. So I spent 4 and a half years going around to as many sites as I could documenting whether or not the population was still there. In some places it was, in another place the population's gone extinct even though the habitat actually looked fine. This butterfly was much more likely to have gone extinct at the southern edge of the range in Mexico and at low elevations, and in Canada and up at the highest elevations of Sierra Nevada it was doing really-really well. This is exactly what you'd expect as a response to the 1° F temperature rise as this butterfly is slowly shifting where it lives to more northerly and more higher elevation areas. It took me 5 to 6 years to actually come up with the answers to whether the climate change has effect to this butterfly. But when I did come up with it, it had a big impact, because it was the first solid documentation of the species the whole species that has been affected by recent global warming.

4:20 --

My research on the response of these butterflies to temperature rise is what we think of as being Basic Biology, basic research, but because it involves response to climate change it immediately becomes to attention of a lot of policy people and a lot of international organisations, and one of these, that I become involved with very soon after getting into the climate change field, is something called Intergovernmental Panel on Climate Change. That's the United Nations body, that's comprised of scientists that are come out with reports that are intended to be the global assessment of the state of climate science as well as the impacts of climate change on both natural biological systems as well as humans.

The aim of the Panel is not to present policy makers with specific recommendations but rather to present the science in order for the policy makers to come up with their own recommendations.

The last IPCC report came out in 2001 which I was involved in as a lead author. At that point a lot of nations were still debating whether or not to ratify the Kyoto Protocol which is an international agreement to reduce carbon emissions. When our report came out, when they saw that not only the climate science was at that stage, where the climate scientists were attributing the warming of the past 30 years to increases in carbon gases, but also that it was having huge biological impacts. Those 2 things together convinced many-many nations to start ratifying the Kyoto Protocol, and at this point out of the hundred eighty nations that are involved in it, all of them had signed and most of them had either ratified or started ratification procedures.

A second type of policy relevant work that I'm doing is work with the IECN; I'm chair of the task for some climate change impacts. The IECN is also called the world conservation organisation and their aim is really to provide information and assistance to managers and the conservation efforts around the world in order to preserve biodiversity.

So that's the big goals as we need to preserve biodiversity and they've come out with something called "red list of endangered species" which is widely used by many-many organisations in determining whether or not a species needs special protection.

Now, up to now they've really been focused on what we think of as the typical conservation problems: habitat lost, pollution, toxicity in the air and in the water. But recently they've realized they need to start including climate change as one of the things that are harming species on this planet.

What we are hoping to do is over the next 2 years come up with some very specific recommendations for conserving biodiversity in the face of climate change, and particularly for those regions of the Earth that had hot spots for biodiversity such as North-Eastern Australia, the Grate Barrier Reef, parts of Central and South America that have real hot spots for tropical species. And it's gonna be a very difficult task but it's one in which the scientists who are doing the ground work really need to be involved in because science is occurring so rapidly in this field. …*?* One, you can't wait till the publications come out but also it's very important to have the basic researchers working with the managers and the policy makers in order to get the science interpreted correctly, because this is one case in which it's really important to get it right and not just … kind of… wave your hands and try to do something approximate.

Adaptation of Butterflies -- Changing Planet

http://www.youtube.com/watch?v=bDOaUguTiG8

From Monarch to Checkerspot, from Swallowtait to Painted Lady

Butterflies are among the most beautiful and celebrated of all insects. But these tiny creatures add more than just colour to our Earth. They pollinate plants, add to the biodiversity of our planet and for scientists provide the vital information about how climate change impacts the environment.

Many butterflies are very-very good indicators of the health of the ecosystem at their end. They are very sensitive. So butterflies are often the fist just to start declining if their habitat is degrading before even the scientists noticed it.

Camilla Parmesan, Professor of Integrated Biology of the University of Texas, studies the impact of climate change on butterflies. She says over the last 30 years warmer temperatures have forced dramatic shifts in the places where butterflies live and breed as far as 126 miles or 200 km north and south towards cooler climates.

What we're seeing is that the area of residency is shifting. It's not really individual's moving, picking up and moving. It's the whole population's gone extinct on one boundary, that's gone, and a new population's formed at another boundary. And the net result is that the whole range shifts.

One example is the Edith's Checkerspot butterfly found in western North America. At the southern edge of the butterfly's range in Mexico, Parmesan says, about 75% of population has died off compared to less than 20 % along its northern edge in Canada. At the same time, she says, about 45% of population has died off at the elevation below 8000 FT and less than 20 % died off at the elevation above 8000 FT. This pattern of extinction tells Parmesan that population of Edith's Checkerspot shifted higher up and to the north.

The average location of the population is now about a hundred miles for the north than it used to be.

The reasons some butterflies shift and others die off has a lot to do with how adapted a butterfly population is to its habitat, and how much it relies on its host plant. The life cycle of a butterfly happens in four stages beginning with an egg attached to the leaf of its host plant. After a few weeks the egg hatches and a caterpillar is born. Once a caterpillar becomes fully grown it forms a pupa that undergoes the transformation called metamorphosis in which it re-emerges as a fully grown butterfly.

Parmesan says warmer temperatures cause some host plants to dry up earlier than usual which could have drastic consequences for butterfly reproduction.

By the time the eggs hatch most of the plants have dried instead most of the plants being green and a few being dry, so that in the ten days that those caterpillars have to feed the whole plant population is in this state – is drying up and none of them survive.

It's a problem that may only get worse. According to the 2007 consensus from the Intergovernmental Panel of Climate Change Earth's temperature is expected to increase by 3 to 7° F or 2 to 4° C over the next 100 years. Jessica Helmet, associate professor in the department of biological science at the University of Notre Dame, is studying how these temperature change could affect the eggs of Common Blue butterfly – the endangered species found near the Great Lakes.

So, we're literally simulating every day what it is typically like. And that are other changes which we're simulating: 2° warmer than that, 4° warmer than that and 6° C warmer than that.

In another experiment Helmet and her research students has it how well two populations of butterflies from Vancouver Island – the Propertius Duskywing and the Anise Swallowtail - fared given the warmer climate in California. Helmet found that Propertius Duskywing favoured the cooler weather in Vancouver Island over the warmer climate in California.

They didn't like the warmer winters. And so we think that if the climate becomes warmer in California and British..British Colambia in the future it's not necessarily gonna be a good thing for that particular butterfly.

Scientists call this preference for a place with specific climate local adaptation. Butterflies that are locally adapted are less likely to move and more likely to die off when the temperature changes.

If I were the betting person and I were standing a little bit to the north waiting to these butterflies to arrive from the south due to the climate change I think I might be waiting for them for a while.

But temperature is not the only factor impacting the butterflies. In the places like Chicago LA and New York huge urban sprawl now dominate the landscape and limits the number of places where butterflies can live.

Climate change may be the final nail but if humans were not around, if they still have lots of habitats I think they would have been OK even within the climate change we've had. But that on the top of habitat loss is too much.

To help that species get past these manmade barriers scientists are exploring the idea of managed re-location, moving species to the area with the more suitable climate within its range. If the amount of the available land continues to decline managed re-location may be the only way to keep some species of butterflies from going extinct.

That's what we are trying to prevent. Not so much prevent what's happening right this minute but we want to make sure that what we've got now will still be there a hundred years from now.

Making sure that wild species like the butterflies are around to maintain the health and beauty of our planet.

Biotic Index: Macroinvertebrates

http://www.youtube.com/watch?v=In1Foq4l43A

Peggy: Streams offer a variety of habitats that support many types of aquatic life. Macroinvertebrates are those organisms that do not have backbones, but are large enough to be seen without the aid of a microscope. Monitoring macroinvertebrates gives us an idea of water quality over time since they live all or parts of their lives in the water. This differs from parameters such as temperature which gives us just a snapshot of water quality at the moment of monitoring. Now here's Kris Stepenuck, volunteer stream monitoring coordinator, to tell you more about aquatic macroinvertebrates and their role in assessing water quality.

Kris: Our uses of the land affect the habitat and the quality of water in the stream which both affect the type of organisms that can survive in the water. An important factor for survival in a stream is the amount of oxygen available for aquatic organisms. The availability of oxygen in water is related to pollutants that reach the waterway. You can learn more about this in the "Dissolved Oxygen" portion of the DVD.

In relation to macroinvertebrates, it's important to understand that different types of macroinvertebrates have varying needs for oxygen. There are organisms which are sensitive, semi-sensitive, semi-tolerant, and tolerant to pollutants that affect oxygen levels in the water.

(1:16) A water quality rating or "Biotic Index Score" can be determined by sampling for macroinvertebrates, identifying them, and then assigning higher scores to sensitive organisms and lower scores to tolerant organisms.

(1:28) Before you can begin sampling though, you must assess your site to determine where to sample from. There are a variety of habitats within streams that provide food and offer shelter and attachment sites for macroinvertebrates. Riffles, rocky shallow water areas where water is flowing quickly, provide the greatest diversity in terms of available habitat for invertebrates with abundant oxygen supplies available and with many nooks and crannies between and on rocks for macroinvertebrates to attach to. Undercut banks are considered the next most diverse for macroinvertebrates in a stream with their many roots, rocks, or logs, and with overhanging vegetation offering an additional habitat. Snags and tree roots also provide habitat for macroinvertebrates. Another good site, though less diverse than the others, is a leaf pack which provides habitat for organisms such as these scuds (2:15).

(2:17) At your site, you should seek to collect as many kinds of macroinvertebrates as possible and sample from a minimum of two habitats to ensure accurate site assessment. Keep in mind that you should attempt to sample from habitats with the most diversity first. Generally, that means favor sampling from riffles but don't ignore the other habitats entirely. Later in this segment, we'll give you examples about how to plan sampling at your site, but first we're going to explain more about how to collect your sample.

(2:46) To monitor the biotic index, you need several pieces of equipment. You need hip boots. You need your recording form and a pen. You need a magnifying glass. You need a spoon or other equipment you can use to sort macroinvertebrates from the sample debris. You need a white dish pan, a white ice cube tray, and D-frame net. The D-frame net is called that because it has one flat side that you place in the bottom of the stream and has a mesh net that will catch the macroinvertebrates that are dislodged from their habitat. You can use the D-frame net in a number of different ways depending on the habitat that you're sampling. First, you need to know how to collect a complete biotic index sample.

(3:27) A complete biotic index consists of three samples taken from three subsamples taken from different habitats in the stream. The tricky part is that if you collect in a riffle, you need to collect at both the downstream and upstream ends of the riffle and combine those samples together to make one subsample.

(3:45) When you're collecting from a riffle, you want to approach from the downstream end and move upstream placing your D-frame net on the bottom of the stream. Then, moving to the upstream side of the net, begin to kick the bottom of the stream to dislodge macroinvertebrates. You can also rub rocks so that the macroinvertebrates are dislodged from the rocks and flow into the net. You want to do this combination of kicking and/or rubbing rocks for two minutes. At which point, you'll scoop up your net.

Come over to the side of the stream and pour the contents of the net into the dish pan which has about an inch of water in it. You can rinse the net into the water. Then, check the net for any remaining macroinvertebrates which you can pick from the net and place into the dish pan. Once you've done this, you'll move to the upstream end of the riffle. Replace your net on the bottom. Kick for two minutes once again or rub rocks. Then, pour the contents of the net into the dish pan. Now that we've done riffle sampling, we're going to move onto other habitats.

(5:00) This habitat is an example of an "Undercut Bank". You can see a little bit about it by seeing the vegetation that's overhanging that bank. When you're sampling an undercut bank area, you're going to use the net a little bit differently than you did in the riffle. In this case, you'll take the D-frame net and put it underneath the undercut bank and scrape along the top of the undercut bank to dislodge macroinvertebrates. You'll do twenty jabs into the undercut bank to equal one subsample.

After you've done that, you'll take it out as before and you'll dump the contents of the D-frame net into the dishpan as you did in the riffle. Now that we're done with an undercut bank, we'll move onto another habitat.

(5:39) This is an example of a "Snag". It's a log that's entered the stream that's providing habitats for macroinvertebrates to attach to. Like an undercut bank, you use your D-frame net to jab underneath the

snag and scrape along the bottom of it to dislodge the macroinvertebrates. You'll do twenty jabs to equal one subsample at a snag. Once you've done the twenty jabs, like before, you'll take the contents of the net and dump them into the dish pan. Let's go check out one more habitat.

(6:12) The last habitat type we'll look at today is how to sample from a "Leaf Pack". To do this, you'll position your net downstream from the leaf pack and dislodge the leaves so that as many as possible flow into the net. Once you've done this, you'll do like before. Pour the contents of the net into your dish pan.

(6:31) To review, a complete biotic index sample consists of three subsamples combined together into one. For riffles, you'll kick for two minutes both at the downstream and upstream ends of the riffle. For undercut banks and snags, one subsample is equal to twenty jabs of the net into that habitat. The goal of leaf pack sampling is to collect as much of the leaf pack as possible in your net.

We'll now go through two examples to help you assess how to sample at your site.

(7:03) Riffles are lacking from this site, but you have both undercut banks and a snag to sample from. In order to sample from the most diverse habitat, you want to focus your attention on the undercut banks with two subsamples being collected from the undercut banks and your third subsample being collected from the snag.

(7:21) This site is dominated by riffles, but there's also undercut from which to sample. In order to focus your sampling on the most diverse habitat, you'll want to collect two subsamples from the riffles and do your third subsample from the undercut banks. Now that you know how to collect your sample and from which habitats, we'll show you what to do next.

(7:40) Now that you've collected your biotic index sample, the next step is to sort the macroinvertebrates from the sample debris. Mike and Adam are here to help with that and they've already started on one of the samples we've collected. There's a number of tools you can use including a paint brush to scoop up a number of the macroinvertebrates or a baster or a spoon, again to scoop up a number of the macroinvertebrates and to sort similar looking macroinvertebrates into different cubes of the ice tray. Once you've sorted your macroinvertebrates, you can use the biotic index recording form to circle the macroinvertebrates that you find. The index is based on a presence and absence. So, you don't need a total count of each organism. You record it the same whether you find one or a hundred. Let's do some sorting!

(8:25) Peggy: A biotic index assesses water quality based on the organisms living in the water. The Water

Action Volunteers Biotic Index is based on macroinvertebrates, that is, organisms without backbones that are visible without the aid of a microscope. The macroinvertebrates used in the biotic index were specifically chosen because:

1) They are ubiquitous; that is, they are found in streams and rivers all over the world.

2) They are not very mobile. So, they cannot escape pollution inputs very easily.

3) They live a portion or all of their life cycle in the water.

4) They utilize oxygen from the water to live not oxygen from the air.

(9:10)Kris

: So, Adam, what do you have there?

Adam: Damselfly.

Kris: So, Adam knows that this macroinvertebrate is a damselfly. If you don't know what you have in your sample, you can use what's called the "Key to Macroinvertebrate Live in the River" to figure it out.

The first question to ask is whether or not the macroinvertebrate has a shell or no shell. Because this doesn't have a shell, you see if it has legs or no legs. It has legs, so we find does it have ten or more pairs of legs, four pairs of legs, or three pairs of legs. This one has three pairs of legs. So, the next question is whether or not it has wings or no wings. It has no wings, so we find does it have no obvious "tails", one or two "tails", or three "tails". It has three tails. So, we look through the pictures and the words to decide which macroinvertebrate we have. As Adam told us, he has a damselfly. Once you've sorted and identified all of your macroinvertebrates, the last step to calculate your biotic index is to count the number of types of organisms that are circled in each group. Write that number in the box provided.

Enter each boxed number in the workspace for each group on the back of your recording form. Multiply the entered number for each group by the group value. Do this for each of the groups. Total the number of macroinvertebrates that are circled. Then, total the calculated values for all of the groups. Divide the totaled values by the total number of types of organisms that were found and record this number. This is your biotic index score.

(10:50) So to summarize, the key steps to remember when collecting and determining your biotic index score are:

- to collect three subsamples focusing on the most diverse habitats first
- sort your sample
- identify
- determine the biotic index score

(11:07)

Peggy: Many people find studying macroinvertebrates to be the most enjoyable part of volunteer monitoring. In addition, it provides valuable information for assessing water quality. Macroinvertebrates are an important part of the food chain, providing a source of food for fish and other organisms. Also, they live in the water for many months or a year or more. So, the water quality needs to be adequate throughout that time in order for them to survive. If you would like to learn more, view the macroinvertebrate section of this DVD series.

Lichens and air pollution

http://www.nhm.ac.uk/nature-online/life/plants-fungi/lichens-pollution/index.html

So in this survey we're looking for… specifically for lichens as indicators of air quality either good or bad. So you can find a twig and do it until it joins a main trunk, so just have a look along it and just take what's on it.

No fungus can make its own food it has to get it from somewhere else. Inside the lichen is an alga, and this green alga, a single celled alga, makes the food for the fungus. That is, it uses the sun, photosynthesis, and produces carbohydrates on which the fungus can live.

Actually the very interesting thing about Xanthoria which has a huge amount of sun screen in it, this is a chemical compound that the fungus make to protect the algal cells. And when it is in shady conditions, this compound doesn't develop so much so it's rather short of the yellow stuff which gives this sunscreen.

This bright yellow lichen here – leafy Xanthoria – the main indicator lichen for nitrogen. It grows in a lot of places in Britain. We've had to use common lichens because we need to put this survey together across the whole country, so this is one of the commonest lichens.

You've got one of your clean air lichens there, look. Evernia. White below, green on top. And it's only attached to the bottom. You've got your Parmelia which's got lots of little white lines on. And the last one we've got which is also, and this is greeny-brown one, which is now got a length, which is terrific. Melanelixia. In America they call it a cauliflower lichen. I think it's a good name, actually.

What is actually happening is that the twigs and the brunches are telling us about what's happening now, and the trunks are telling us about the history of air pollution in the past.

In this area of London, the south of London, with the main winds coming from the south-west, so I wouldn't have expected it to very polluted. And it's quite interesting today that we picked up some of the clean air lichens here. So it looks as though things are definitely improving.

Tree Lichen Monitoring

http://www.youtube.com/watch?v=Upjp7Y4iOKo

0:05 – 0:29 Meet Josh. Josh is concerned about his neighbourhood air quality. He doesn't have the money to do expert quality testing, however he does have options. Hey Josh, have you heard of lichen testing? Lichens? Do you know what they are?

0:30 – 1:00 Lichens are unique in a sense that they are not a plant or an animal. They are a composite of fungus and photosynthetic agent. There're 14 000 different types of lichens which are all ranging in colour, size and shape. They can be found everywhere from the poles to the tropics even on the backs of insects. You can measure them in 2 ways: by height and weight or by radius. Radius is easier. Since some lichens grow slowly between 2 to 3 mm per year, testing lichens growth only needs to be done annually.

1:01 – 1:14 Lichens are great biomonitors and have been used in several studies to monitor air quality. They have no roots, and no deciduous parts. Everything they used to grow comes from the air.

1:15 -1:45 This specific study utilizes the methodology of McMaster's Dr. George Soldier. Soldier found the relationship between the two types of lichens found on maple and ash trees, and between nitrogen dioxide and sulpher dioxide which are indicators of overall airborne pollution.

Essentially areas of high SO_2 and NO_2 have low levels of this lichen and areas of low levels of SO_2 and NO_2 have high levels of this lichen. Basically, the more of these two types of lichen is present the better the air quality.

1:46 – 1:50 So Josh! *Are* you ready to go to test some lichen?

1:51 – 2:04 Only two materials are required. First is a measuring device consisting of 4100 centimeter square quadrants glued together, second is a data recording sheet and pen.

Let's get started!

2:07 – 2:21 Planning your route is the first step. Create boundaries so you avoid missing streets or trees. This will keep you on track and help keep you safe.

2:23 – 3:16 Now it's time to find yourself some maple and ash trees. Either one will do the trick. You just need to know what to look for. What's the easiest way to tell – look up!

With the exception of horse chestnut maple and ash trees are the only trees in Ontario with opposite branching. Have a look! Can you see how the twigs have a mirror image of each other as they stem from the branch? That's we're looking for. Don't worry if not of them are opposite. As long as one trunk has an opposite pair you've got yourself a maple or an ash. Alternatively, no one intended, check off these other trees. See how the twigs alternating out of the branch *given* there's no opposite pairs to be found – these trees are not right for the study.

3:17 – 3:38 So now that you determine if it's a maple or an ash, ask yourself: "Is the tree suitable?" You want to avoid disease bark, acroshape trunks and trees within a hundred meters of the major road.

Found a good tree, Josh? Great. Record its exact location so you remember where it is.

3:41- 3:56 Hold up your measuring device to the tree lightly pressing it against the bark, make sure it's in the centre of the tree, and the bottom of the device is about 1 meter from the ground.

4:56 -4:14 Now let's look for a lichen. How much do you see? Feel free to get a closer look if you need to. Remember we're looking for both lichen species.

4:16 – 4:46 Grading how much lichen you see is really the key to the study. Starting at the top quadrant grade how much lichen you see for each species. Zero indicates no lichen, 1 indicates one or two colonies less than 1 centimeter wide, 2 indicates a few lichen colonies with less than ten percent quadrant coverage, and 3 indicates ten percent coverage or more in the quadrant.

Here some examples of *Millegrana* species – the gray-ashy one.

5:08 – 5:37 Record your answers.

Although this process can be subjective, trust yourself - it gets easier with practice.

Measurements need to be taken on all directions of the tree. With four quadrants per side of the tree you'll end up with sixteen measurements for each lichen type.

5:46 – 6:00 Are you done there, Josh? Great.

Send your results to Environment Hamilton. They'll take care of the simple data launching

And that’s it!

Are you liking lichen, Josh? – yeah!

Nature talks

http://www.youtube.com/watch?v=RM-cBkP3ME0

Hi, campers! Today I’m in the marsh.

Welcome to this addition of “Nature talks” - an opportunity where we get to go out and talk to nature.

I’ve been slapping around this marshal day and not one frog wants to talk to me!

But don't worry. Andy has a frog friend who always has an opinion.

So, check out this *frogbit* and meet me back at my tent.

Frogs are amphibians and have been around for hundreds of millions of years.

There are four thousand species of frogs in total around the world, making up around ninety percent of all species of amphibians.

In the last five years frogs have begun disappearing at an alarming rate.

Scientists believe this is because of climate change and human interference.

Lots of animals give us clues about the health of our planet but frogs are very special because they live on land and in water and can give us information about both systems.

All right, now it's time that talk to a frog.

Hey, campers! Welcome to my place. Now, let's see if we can get *Fraw Swa* on the line.

Hey, there he is.

Hey *fro swa*, can you hear me?

Oh, hello, Derik. Oh, you look nice. Oh you get that haircut, I love that shirt.

…. thanks Fraw Swa

Listen. We need to cut to the chase. These campers have questions and they need answers.

So, question number one.

- Are frogs really that slimy…

- excuse me, I’m sorry, what’d you say to me? I do not think so. You see, here’s the point. Frogs are not slimy beings at the whatsoever. The reason we look slimy is because we always in the water.

- Okay well that makes sense. Well let me ask you this question: are toads and frogs the same thing.

- Oh, no,no,no… or that is a common mistake. You see, frogs are like humans. They need water to survive. But toads do not. We’re also better jumpers than toads. They take small hops, while we take big, high jumps. We’re jumpers. And they’re hoppers.

Okay. I get it. I get to ask you this question. That's gonna be hard but… Do frogs give you warts?

I'm not even going to dignify that … answer.

- come on, Fraw Swa, do it for the kids.
- Okay, okay…. For the kids I will do. Yes, frogs and toads are bomby , yes, we admit it. but now way any frog ever gives someone warts. Now way.
- There you go. Now we all know - frogs do not give you warts. I have to ask you this, though. When I see a group of fish it's called the school. Is there any name for when you see a group of frogs together?
- Oh. Excellent, Derik. Finally a good question. A group of frogs is called an army.
- An army? Oh, you see, we have armies as well. Do you, guys, have ranks like captain, lieutenant…well…
- There's another fantastic question! As a matter of fact, yes. For example, I am a general.
- Oh…
- Next time you'll see me in the marsh, you'll salute!
- Yes, sir.
- One last question. Tell me something cool that I don't know about frogs.
- To tell you something cool about frogs? Have you seen us? For example, we are all ridiculously good-looking.
- Fran Swa, tell us something we don't know.
- Ok, Derik, you insist - I do. We've been around for millions and millions of years since the time of dinosaurs. Would you think of that? ….
- Holy cow! That's a long time!
- Or for example my great-great-grandfather was married to a brontosaur
- Fran Swa…
- I kid, I kid…I'm ….
- Ok. Thank you for being a good… meeting with us today
- Oh, no problem, no problem, Derik. You know I always have time for Andycampers.
- Thanks. And there we have it. Everything you needed to know about frogs. For more information check out Andycamper.com. see you next time at "Nature talks"

Disappearing frogs

http://www.youtube.com/watch?v=b3V04D3C4Lg.

0:25

[Narrator]

Herpetologists in California are on the trail of an increasingly elusive prey.

It's not that frogs, salamanders, and other amphibians are getting better at hiding; it's that with each passing year there are fewer of them to find.

We found red-legged frogs here in the past. We usually had pretty good luck. Oh, cool!

[Narrator]

Vance Vredenburg is an associate professor at San Francisco state. Recently he and his team have been studying mountain yellow-legged frogs in Sierra Nevada. What they're finding is alarming. A deadly disease is wiping out entire populations of frogs.

[Vance Vredenburg]

So, to be in the field and find hundreds and sometimes thousands of dead frogs piled all over the place, no-one's ever heard of this for hundred-plus years of herpetology. Suddenly is happening now, in our lifetime. What is it about?

[Narrator]

Right now it's unknown if the devastating disease that's killing the yellow legged frogs in Sierra is affecting their barrier cousins.

Today Vance's joined biologist *Karen Swain* to test native red legged frogs in one of carrying study areas near Pacific at California

[Vance Vredenburg]

One of the most sort of well-known species of amphibians here in California are these are the Californian red legged frog. This frog is very charismatic frog; they get really big, really cool. They call at night. You can hear them calling. We used to have found them all over the place. These frogs are pretty much anywhere in California Anybody worried who came up, they would be around.

[Narrator]

Depleted by development and other threats the need of red legged frog is facing a very uncertain future. And it is now a federally protected species.

[Bob Drewes]

When I was a kid I could go and find a red legged frog with ease. I could go into golden gate park and find things, with ease. All of a sudden they are gone.

[Narrator]

Frogs decline. It isn't just happening in California. Amphibians have been disappearing all over the world. Obviously over six hundred species known to science, more than one third are experiencing massive decline. It's a biological mystery.

[Vance Vredenburg]

It's really alarming; it's something like 40 % of all known amphibians are threatened with some level of extinction. It's unprecedented in terms of vertebrate group of animals. So scientists have been just you know banging a head …..what's going on?

….. I got them….. look at that! …..excellent

…. is beautiful….

And this is a tree frog. Has real corks, real disks on the tips of their toes. You can really see them

Locally tree frogs like this little pacific chorus frog seem to be doing okay *province* and carrying. The challenge is still to find and test a threatened red legged frog.

3’25

[Narrator]

This is not just a story about frogs. It’s a story it's a story about our shared world and some very specific hidden threats.

[Bob Drewes]

Well, so what? Who cares about frogs? I mean. Lots people love them, I do, most kids do.

Emn.. well

It is a frog, that’s not so much the frogs it's the environment.

I think that a lot of people tend to forget that we live here too.

Something is happening to the fundamental makeup of the globe.

I’m talking about water and I’m talking about soil.

If it is indeed, human generated a problem; this is a whole environmental health thing.

And we’re committing a suicide.

And our first warning, one of our earliest warnings is the frog populations.

4: 16

[Narrator]

Frogs unique physiology their ties to both the water and the land can tell us a lot about what's going on in the entire ecosystem.

[Bob Drewes]

Frogs are an ideal indicator of environmental health because they spend part of their life, their whole developmental part of their life in the water; most of them: as eggs or as gilled larvae.

But then they undergo metamorphosis to air breathing adults and because their skin is semi-permeable to the passage of the water.

Any problems with the ground there’re in or the water when they return to reproduce will affect them as adults.

[Vance Vredenburg]

Even though a frog does have lungs they can stay under water and totally be fine. They can breathe right through thief skin.

That’s a part of the reasons that we believe that amphibians in general are seen as sort of the sort of sentinel group of species, because they're very sensitive to any changes in their environment.

5:10

[Narrator]

Frogs are being hit from all sides and there are multiple factors that may be contributing to this die off.

Worldwide amphibians are facing pollution, disease, habitat loss, climate change, competition and predation from invasive species, even the UV radiation effects from our depleted ozone layer.

5:35

Observing Daphnia Heart Rate

http://www.youtube.com/watch?v=HhOUwlOdxkA

Hi. I'm Mary Haugen, a biologist from Carolina Biological Supply Company.

Today I'll show you how to set up the popular heart rate measurement experiment using Daphnia magna.

We offer two types of Daphnia. Daphnia pulex are smaller and are often used in feeding studies, whereas Daphnia magna are larger and have a heart that is easier to view with a microscope.

To begin you'll need a few supplies: a light microscope, concavity slides, a pipette, scissors, a culture of Daphnia magna, a stopwatch and a diagram of daphnia anatomy.

To understand the effect temperature change has on heart rate you'll need a baseline for comparison.

First locate the heart on a diagram of daphnia anatomy.

Do not force large Daphnia through a narrow pipette tip.

If necessary use scissors to remove the end of the pipette at a 45 degree angle.

Use a pipette to capture a single Daphnia, place the Daphnia in a well of the concavity slide.

Do not use a cover slip as this will crush the Daphnia.

The Daphnia must have water around it to survive observation; however you can remove excess water with the pipette.

Turn on the microscope and using the lowest power objective locate the Daphnia on the side.

Increase magnification until the heart is located just under the anterior dorsal surface behind the *ice pop.*

Using the stopwatch count the heart beats for 15 seconds.

Multiply this number by four and you have the heart rate for one minute.

To make watching, timing and counting easier you can tap out the beats using a marker and a sheet of paper.

When measuring the effects of cold temperatures on Daphnia you'll need a few more supplies than you already have set up. Obtain a thermometer, ice, bottled spring water and 2 clean cups, so that one fits inside of the other.

Pour spring water into the small cup and add several Daphnia from the cultures jar using the pipette.

Place the thermometer inside the small cup noting the temperature. Add ice to the bottom of the large cup, then set the small cup inside at the larger cup.

Add spring water into the larger cup. We use spring water throughout this setup since tap water contains chlorine which is toxic to Daphnia.

Do not use the distilled water either.

Weigh and monitor the temperature as it decreases.

To prevent heating the cool Daphnia too quickly turn the microscope light off until you're ready to observe the heartbeats.

This process can be repeated for warmer temperatures.

Use a hot pot or microwave to heat the water till hot but not boiling, use caution when handling hot water and use heat proof containers.

If using different chemicals or liquids to observe the change in heart rate, simply apply a drop of the liquid directly to the Daphnia while it is on the slide.

If Daphnia are left for a long period of time in test substances that are not water, they may die before you're able to observe their heartbeat.

When finished, the culture can be poured down the drain and rinsed with hot tap water or you can feed them to freshwater fish in a classroom aquarium

There are many ways to conduct this experiment but we hope this gives you a good starting point

Visit Carolina.com/Daphnia to see all of our related products.

The Secret Life of the Snail

http://www.youtube.com/watch?v=KD2m6H3Rb18

The snail has four tentacles. The shorter two are for feeling the longer pair are eye stocks. Most snails move by gliding on their muscular foot. Which is lubricated with mucus. This motion is powered by succeeding waves of muscular contractions, they are moving on the snail’s foot.

A snails shell forms a logarithmic spiral. This special kind of spiral curve often appears in nature. Hurricanes, galaxies and snail shells all share this logarithmic design.

Land snails are Gastropods. They breathe by taking air into a visceral cavity that's richly supplied with blood vessels. The snail’s …….. They probe their environment for vegetation.

They have very poor eyesight and rely mainly on their sense of touch and smell to find food.

Snails feast on leaves and plant life with their powerful radula.

………….. with thousands of tiny teeth. When a snail is feeding the scrapping of its radula is sometimes audible if you listen closely.

What's in our water?

http://gallery.usgs.gov/videos/526

[USGS CoreCast Introduction]

[Steven Sobieszczyk] Hello and Welcome. This is the USGS CoreCast, I'm Steven Sobieszczyk. In this episode of the CoreCast we are actually going to be re-broadcasting a previously released video from the USGS Oregon Science Podcast. We figured the topic of water quality, as discussed in the video, was representative of the hydrologic research that the USGS, as a whole, does around that country. Therefore, it fit in really well with other CoreCast products. So, without further ado, this is, "What's in Our Water?"

[Intro Music begins]

[Steven Sobieszczyk] Water. Such a simple molecule. Just two hydrogen atoms and one oxygen. Small. Innocuous. Yet when combined with countless others, it has the power to reshape the entire planet. One of the basic building blocks of life, water is much more than just a simple liquid. Entrained in water is a whole world of microscopic materials. Sediment. Organisms. Dissolved minerals. Even harmful chemicals. In this episode, we are going to investigate more than just the substance - water. We are going to examine what is in our nations' water, how we at the U.S. Geological Survey monitor it, and what tools we have developed to aid those who want to explore more about our planet's most abundant resource. This is…the USGS Oregon Science Podcast.

[Steven Sobieszczyk] The term "water quality" covers a vast range of physical and chemical traits of water. It can refer to any number of characteristics of water, such as dissolved or particulate matter trapped in the water column. This may include materials like dissolved minerals (sodium and potassium, for example) or suspended particles like organic carbon (which is basically broken down leaf litter or other decomposing organic matter) or fine-grained sediment (such as dirt washed away from hillsides). In addition, those who investigate water quality may be interested in other water properties like acidity or conductivity. Or, in the case of greatest concern for most people, pollution. To help simplify this potentially overwhelming subject of water quality, we will focus on conditions in local streams here in Oregon.

[Stewart Rounds] So living here in the Pacific Northwest, we really are blessed with some great water resources. We have wonderful streams and lakes. Although, there are some places where people say, "I wouldn't want to swim or fish in that river! Oh, it's disgusting!" You know, let's think about this problem with a little bit of perspective. Back in the 1930s and 40s, boy, the Willamette was an open sewer. But, there was a big cleanup that happened in the 1940s and as we understood, a little bit more about some of the types of water-quality problems there were successive cleanups. There was another big cleanup in the 1970s and the 1990s. So, today, you can go swimming in the Willamette River. You can go fishing in the Willamette River and it's really in pretty good condition.

[Steven Sobieszczyk] Dr. Stewart Rounds is the USGS Water Quality Specialist in Oregon. As with most hydrologists, Stewart has always had a passion for water.

[Stewart Rounds] You know, water quality has always been something that has interested me. Ever since I was a kid. I wanted to know how things work. And I look at a river and I want to know more about it. I want to know where the water comes from, how good the water quality is, whether it's good for fish, what its carrying, where it's going to, how things change… Understanding processes in natural systems, it's just fascinating.

[Steven Sobieszczyk] Dr. Round's research focuses on water-quality monitoring of rivers and lakes, including water temperature, nutrient transport, and water-related concerns due to algae. What types of problems do algae cause in our local rivers? Well…that all depends on how much algae there is.

[Stewart Rounds] So, algae is an important thing that we study and it's not entirely a bad thing, right? Algae is the base of the food chain. If we didn't have algae than we wouldn't have anything for the zooplankton to eat. And if the zooplankton didn't eat anything than we wouldn't have any food for the fish. And if we don't have fish, well, you can take it from there. So algae is good in many ways because it's the base of the food chain. On the other had we don't want too much of a good thing because then it can lead to pH levels that are too high, which is not good for fish. Or when the algae are no longer growing, they can use up too much oxygen and cause problems that way.

[Steven Sobieszczyk] Algae is just one of many parameters, or characteristics, of water quality that the USGS monitors. Other parameters commonly measured include water temperature, pH (or acidity), and turbidity (which is the cloudiness or dirtiness of water). All of these data are collected and stored online in our National Water Information System, or NWIS, database. The water quality data are free, and can be accessed through the NWIS website, or through the online software package, USGS Data Grapher.

[Stewart Rounds] So the data grapher is set of online tools that allow users to create customized graphs and tables of a whole variety of time-series data that are served up by the U.S. Geological Survey. Let's start by looking at a time series graph from one site. In this example, let's take a look at some pH data from the Clackamas River near the mouth of that river at Oregon City. The results show you some of the inputs that you ask for and the graph, and you can see that the pH values in mid-summer can reach relatively high values near 9, and that the patterns in pH decrease when the streamflow goes up. Another way to visualize those patters in the pH data in the Clackamas River is to use a color map. The color map shows some interesting patterns that we saw in the time series graph. We had higher pH values at particular times in the spring and summer and we had lower pH values for a time between those peaks when the discharge was higher.

[Steven Sobieszczyk] As part of its overall mission, the USGS measures the quantity and quality of the nation's waters. This work is completed through the use of a network of over 7,000 stream flow gages. In Oregon alone, there are over 200 stream flow monitoring locations, many of which also continuously monitor different water-quality properties. Each year, scientists, like Dr. Rounds, continue to observe lakes and rivers, and through new tools they develop, help explore how water quality changes in the world around us. For more on what the USGS is doing through its National Water Quality Assessment Program or through other cooperative programs in the state, please visit our water resources information website at usgs.gov/water.

Determining amount of water pollution…

http://vimeo.com/1744819

Scientists in Israel have discovered a new way to test for water pollution. They listen to what the plants …… in water have to say.

The researchers shine a laser beam on the tiny particles of algae floating in water. They can hear sound waves that tell them the type and amount of contamination in the water.

Professor Zvy Dubinsky is an Aquatic Biologist. He developed the technique together with Dr. Julia Pinchenson. He says, the secret is to measure a plants ability to transform light into energy.

We use that microphone to detect the heat, the wasted heat, that the algae are unable to use in photosynthesis. Then, if we listen to this carefully, we can know the status of the water in which these algae live and to take action to direct it in the way we want - either to increase the number of the algae or to control their proliferation.

Dubinsky says that as water sources deteriorate worldwide the testing of algae could be used to monitor water quality faster, chipper and more accurately than techniques now are used.

With proper funding, Dubinsky says, a commercial product could be ready in about two years.

I hope we shall see many… a few hundreds of such instruments helping to preserve the purity of our waters which is so important in our times, and also to be able to follow the global climate change driven processes in the world's oceans, rivers and lakes.

…..

Plants Track Air Pollution

http://www.euronews.com/2013/06/03/biotechnology-to-fight-air-pollution/

[Narrator]

Using biotechnology to fight pollution. This is the challenge for a European Union research project. Under the spotlight – a specific kind of moss.

[Eva Decker]

We use moss, because, by mass, it has a huge surface area. You can see all the structures and it can clean the dirt particles out of the air.

You can see here that the moss has shoots or spores, and from one of these spores you can grow a new plant.

And using these spores we started to cultivate new plants in the lab.

[Narrator]

Monitoring the levels of nitrogen and sulpher oxides and also airborne heavy metals like cadmium, lead and nickel, is hard to achieve with existing technologies as they are either imprecise or very expensive.

In Freiburg University in Germany a team of biologists is growing the moss in a controlled environment.

[Eva Decker]

When we reach this stage, it's time to cultivate a larger amount of moss. So we use a bio-reactor because a volume of 5 litres while here we can only work with 200 millilitres. This means that we can produce more moss in a bio-reactor.

[Narrator]

Plants are already in use as biological indicators as they absorb pollutants. Mosses are very well suited as bioindicators for airborne contaminants as they have no roots and a very high surface to mass ratio. One innovation is the cultivation of huge amounts of peat moss under controlled laboratory conditions.

[Ralf Reski]

Thus we not only reduce the plant's genetic variability to the smallest possible level – one single genetic clone – but also through controlling conditions in the moss bio-reactor we can guarantee that the level of pollution in the moss, as well as its growth, are always identical. And you cannot obtain this consistency with material you have just collected from nature.

[Narrator]

These moss plans will be transferred to air-permeable bags, then moved to monitoring stations at a variety of different European locations. The technique is currently being tested in Santiago di Compostela, Spain.

[Carlos Brais Carballeira Brana]

Three different samples are exposed for three weeks in order to accumulate all the pollutants in the area, in this case from passing cars or industrial plant, but primarily it'll be general road traffic.

[Narrator]

Following exposure, the moss is dried, then powdered, then it's analyzed to measure the level of different pollutants in it.

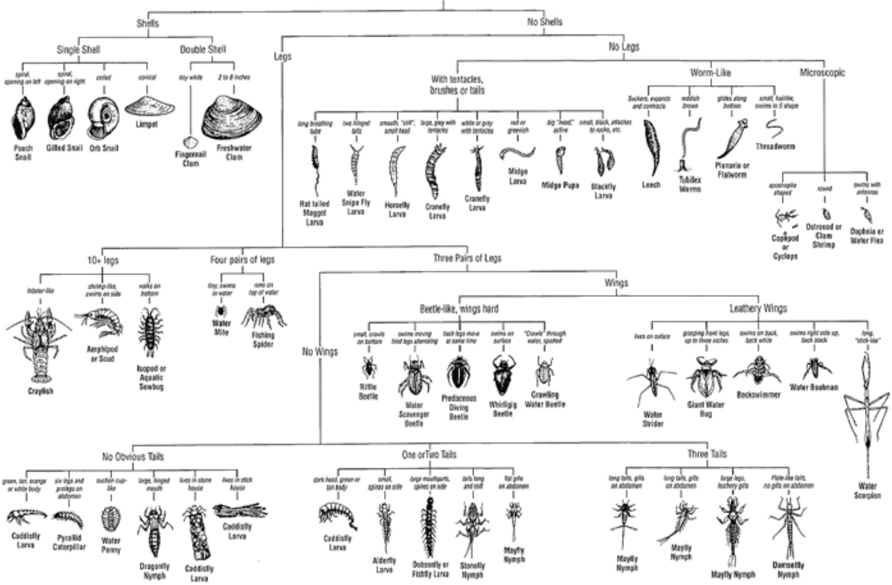
This approach, combining molecular biology and material sciences with ecology and bionics, could be, in the future, extended to other critical environmental contexts.

[José Angel Fernández Escribano]

We are planning to use this idea, this philosophy, in other places such as rivers, fields and industrial areas.

These contaminants can affect rivers, which then join the sea, and pollute the marine environment. It will be possible to develop these tools and to discover all the pollutants that are affecting the whole ecosystem.

Key to Macroinvertebrate Life in the River



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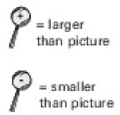
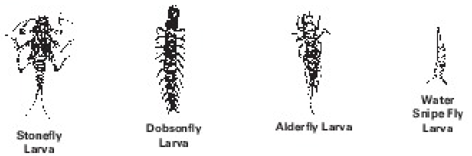
Relative Size Key:

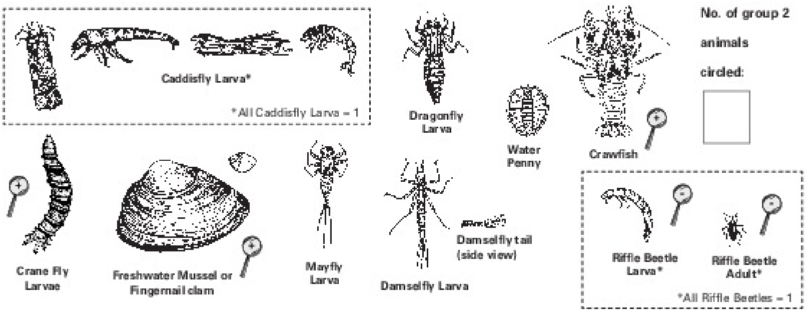


Group 1: These are sensitive to pollutants. Circle each animal found.



No. of group 1 animals circled:

Group 2: These are semi-sensitive to pollutants. Circle each animal found.



No. of group 2 animals circled:

Group 3: These are semi-tolerant of pollutants. Circle each animal found.

No. of group 3 animals circled:

Group 4: These are tolerant of pollutants. Circle each animal found.

No. of group 4 animals circled:

For more information, call (608) 265-3887 or (608) 264-8948.
Download and print data sheets from
watermonitoring.uwex.edu/wav/monitoring/sheets.html

Water Action Volunteers

Recording Form for the Citizen Monitoring Biotic Index

Name: ______________________________ Date: ____________

Stream Name: ______________________________ Time: ____________

Location: ______________________________ Site: ____________

(County, Township, Range, Section, Road, Intersection, Other)

At this point, you should have collected a wide variety of aquatic macroinvertebrates from your three sites. You will now categorize your sample, using the *Key to Macroinvertebrate Life in the River* to help you identify the macroinvertebrates found. **The number of animals found is not important; rather, the variety of types of macroinvertebrates and their tolerance to pollution tells us the biotic index score.** Before you begin, check off the habitats from which you collected your sample (see right).

- ☐ Riffles
- ☐ Undercut banks
- ☐ Snag areas, tree roots, submerged logs
- ☐ Leaf packs

1. You should have removed large debris (e.g. leaves, rocks, sticks) from your sample and placed this material in a separate basin (after removing macroinvertebrates from it).
2. Check the basin with the debris to see if any aquatic macroinvertebrates crawled out. Add these animals to your prepared sample.
3. Fill the ice cube tray half-full with water.
4. Using plastic spoons or tweezers, (be careful not to kill the critters – ideally, you want to put them back in their habitat after you're finished) sort out the macroinvertebrates and place ones that look alike together in their own ice cube tray compartments. Sorting and placing similar looking macroinvertebrates together will help insure that you find all varieties of species in the sample.
5. Refer to the *Key to Macroinvertebrate Life in the River* and the *Citizen Monitoring Biotic Index* to identify the aquatic macroinvertebrates:

   A. On the back of this page, circle the animals on the index that match those found in your sample.

   B. Count the number of types of animals that are circled in each group and write that number in the box provided. Do not count individual animals in your sample. Only count the number of types of animals circled in each group.

   C. Enter each boxed number in work area below.

   D. Multiply the entered number from each group by the group value.

   E. Do this for all groups.

   F. Total the number of animals circled.

   G. Total the calculated values for all groups.

   H. Divide the total values by the total number of types of animals that were found: TOTAL VALUES (b.) / TOTAL ANIMALS (a).

   I. Record this number.

   SHOW ALL MATH (Use space below to do your math computations)

No. of animals circled from group 1 ________ x 4 = ________

No. of animals circled from group 2 ________ x 3 = ________

No. of animals circled from group 3 ________ x 2 = ________

No. of animals circled from group 4 ________ x 1 = ________

________ TOTAL ANIMALS (a): ________ TOTAL VALUE (b):

Index score: ☐

How Healthy is the stream?

Excellent	3.6+
Good	2.6 - 3.5
Fair	2.1 - 2.5
Poor	1.0 - 2.0

Divide totaled value (b)_____by total no. of animals (a) _____for index score:

Report your results online at **www.uwex.edu/erc/wavdb** *or submit your data to your local coordinator.*
Call your local monitoring coordinator if you have questions about sampling or determining the Biotic Index Score.

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Беляева

ENGLISH FOR BIOLOGICAL MONITORING

Часть 2

Учебное пособие

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