Chapter 7 ~ Pasture Biodiversity and Riparian Management

Pasture Biodiversity

Pastures as Unique Ecosystems

In a pasture ecosystem, the plant and animal biodiversity depends critically upon the level of grazing. Too much grazing may lead to land degradation and the loss of biodiversity. Too little grazing may lead to the change from grassland to woodland and the loss of grassland habitat. The timing and frequency of grazing and the animal species involved are also important factors (Watkinson and Ormerod 2001).

Several challenges exist for the farmer to develop and maintain a balanced pasture ecosystem. The proper use of fertilizers, drainage and reseeding will increase herbage production but it may lead to a decrease the plant diversity.

Balancing stocking rate with pasture productivity is important. Higher stocking rates without the appropriate grazing management may result in land degradation and invasion of weed species (Watkinson and Ormerod 2001).

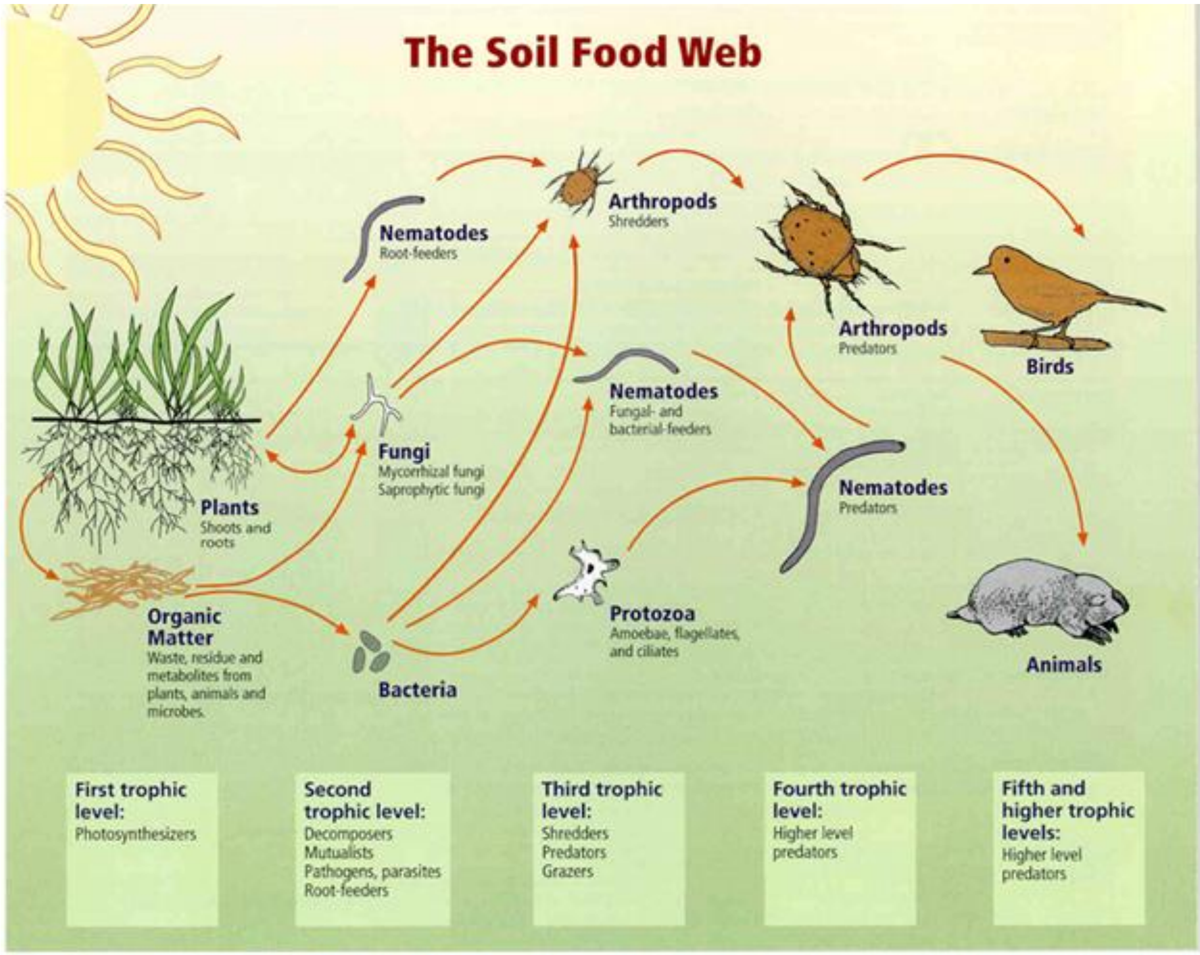
Current research is examining the biodiversity resulting from the interaction of such factors as manure and fertilizer application and livestock behavior such as defecation and grazing patterns. Biodiversity's value exists both intrinsically and through its contribution to ecosystem stability and processes. In a pasture system, where conservation and production can be at odds, careful management can build a bridge between economic production and ecosystem protection.

The Soil Food Web and Biologically Active Soil Environment

The soil food web is a network of dynamic interactions among soil organisms as they decompose organic materials and transform nutrients. Soil organisms include a variety of species ranging from bacteria to earthworms as outlined in Table 7.1 (Bellows 2001). These soil organisms are responsible for:

- decomposing organic matter
- forming soil aggregates
- solubilizing mineral nutrients
- adjusting soil pH
- fixing Nitrogen
- nitrification
- phosphorus uptake through mychorrizae
- degrading soil minerals
- forming plant hormones

The soil organisms form the soil food web as in Figure 7.1.



Relationships between soil food web, plants, organic matter, and birds and mammals. Image courtesy of USDA Natural Resources Conservation Service (http://soils.usda.gov/sqi/concepts/soil_biology/images/A-3.jpg).

Figure 7.1 Food web of grassland soil

Table 7.1 Soil Organisms in an Acre of Living Soil (Bellows 2001)

Organism	**Function**
Bacteria	•Decompose simple or nitrogen-rich organic matter. •Nitrogen fixation. •Soil aggregate formation. •Detoxify pollutants.
Fungi	•Mycorrhizae form extensions on roots that improve take up of nutrients and water. • Transportation of nitrogen from legumes to grasses.
Protozoa	•Feed on bacteria. •Stimulate of the growth/multiplication of bacteria. •Help stimulate the adhesion of soil aggregates.
Nematodes	•Decompose organic matter. •Prey on fungi that cause plant disease. •Form parasitic galls on plant roots/stems which cause plant disease.
Earthworms	•Decompose organic matter. •Move organic matter through soil.
Other Species	•Facilitate nutrient cycling. •Includes dung beetles, sowbugs, millipedes, centipedes, mites, slugs, snails, springtails, ants and birds.

Once established, a healthy food soil web must be managed to maintain a healthy soil environment. The management schemes necessary for maintaining a healthy soil food web are outlined below in Table 7.2.

Table 7.2 Maintaining a Healthy Soil Food Web (Bellows 2001)

Provide soil organisms with a balanced diet.	•Adding organic material such as manure to perennial pastures provides food for soil organisms. •Nitrogen-rich materials decompose faster than older, woodier, materials with less nitrogen.
Provide soil organisms with a favorable environment.	•Soil is well aerated. •Moist, near neutral pH, easily decomposed materials are available to decomposer bacteria. •Acid, moderately dry, carbon-rich, complex organic materials are available to decomposer fungi. •Continuous plant growth takes place (active roots provide a nutrient rich habitat for soil organism growth).
Use practices that favor the growth of soil organisms.	•Maintain balance between intense grazing and adequate rest or fallow time. •Encourage grazing animals to move across pastures to feed, to distribute manure evenly and to break up manure patties. •Maintain a diversity of forage species to provide a variety of food sources and habitats for a diversity of soil organisms. •When required, the addition of lime to help acidic soils move toward a more neutral state.
Avoid practices that kill or destroy soil organism habitat.	•Avoid the use of Ivomectin deworming medications, soil-applied insecticides and concentrated fertilizers (i.e. anhydrous ammonia and superphosphate) •Minimize tillage and cultivation practices •Minimize practices that compact the soil (i.e. extended grazing practices, grazing wet soils.)

Pasture health should be monitored regularly with adjustments to management practices as needed to maintain healthy pasture soil. An index of pasture soil health (or a soil health card) is explained in Table 7.3, and is a tool to determine pasture soil health. While a given pasture may score low on some points and high on others, the purpose of the card is to get an overall score that will determine the state of biodiversity within the pasture's soil.

Table 7.3 Pasture Soil Health Card (Bellows, 2001)

Pasture Soil Health Indicator	Good Soil Health	Medium Soil Health	Poor Soil Health
Pasture Cover	Complete cover of forages and litter over entire pasture.	Limited bare patches; no extensive bare areas near drainage areas.	Extensive bare patches, especially near watering or other congregation areas.
Plant Diversity	Diversity of plant species including *forbs*, legumes and grasses; differences in leaf and root growth habitats.	Limited number of plant species and diversity of growth habitat; some invasive plants present.	Less than three different plant species, or invasive species are major components of the plant mix.
Plant Roots	Abundant vertical and horizontal roots.	More horizontal roots than vertical	Few roots, most are horizontal.
Soil Life (macro-organisms)	Many dung beetles and earthworms present.	Few dung beetles and earthworms present.	No dung beetles or earthworms present.
Soil Compaction	Wire flag enters soil easily; does not encounter hardened area at any depth.	Can push wire flag into soil with difficulty or encounters hardened area at 15-20cm depth.	Cannot push wire flag into soil.
Erosion	No gullies present, water running off pasture is clear.	Small rivulets present, water running off pasture is somewhat muddy.	Gullies present, water running off pasture is very muddy.
Soil Aggregation	Soil in clumps that hold together when swirled in water.	Soil breaks apart after gentle swirling in water.	Soil breaks apart within one minute after being in water.
Water Infiltration	Water soaks in during moderate rainfall, little runoff or ponding on soil surface.	Some runoff during moderate rainfall, some ponding on soil surface.	Significant runoff during moderate rainfall, much water ponding on soil surface.

CONSEQUENCES OF MANAGEMENT ON BIODIVERSITY

Wildlife Habitat

In the Maritimes, a wide variety of *ecozones* are present, ranging from cropland to mixed wood and coniferous forest to wetlands. The influence of agriculture on wildlife habitat is less here than in major agricultural ecozones. However in river valleys, where farmland is concentrated, wildlife is affected.

There are land management practices that favor wildlife use. These practices include rotational grazing systems, planting shelterbelts and hedgerows, management of riparian areas, conservation of wetlands and wetland buffers and conservation of remaining natural (native) lands.

The Kern Family Farm, in Granville Ferry, Nova Scotia is a local example of resource management and its effect on the environment and wildlife habitat. In 1994, an economical, gravity-driven watering system for cattle was installed. The system draws water from a pond and was installed in conjunction with the improvement of pastures in the pond area.

To maintain the pond's water quality and prevent erosion of embankments, the pond and traditional watering area were fenced off from livestock. On the inner slope of the pond *berm*, red fescue and birdsfoot trefoil were planted to control erosion. On the external slope of the pond berm, wildlife food and cover and natural vegetation were planted. These included white pine, red spruce, autumn olive, dogwood, nut and berry trees, honeysuckle, cranberry, oak and birch. Watercress was planted along the pond's edges and the pond was stocked with trout. Wildlife inhabitants included deer, bear, great blue herons, ducks, sandpipers, pheasants and songbirds (Kern 1994).

Practices to promote soil quality, control erosion and protect water quality are compatible with promoting wildlife use of agricultural habitats.

RIPARIAN ZONE MANAGEMENT

What is a riparian zone?

A riparian zone is the transitional area separating aquatic ecosystems (including lakes, rivers, streams, ponds and wetlands) and upland terrestrial ecosystems (Gregory et al. 1991, Cameron 2001). Riparian zones play diverse and valuable functions within an ecosystem. In general, a riparian zone protects the watercourse and increases its sustainability as an ecosystem and as a source of quality water. Several key functions include acting as a barrier to human activity, providing wildlife habitat and protecting the watercourse and water quality by filtering nutrients and bacteria (Cameron 2001).

Many land uses, including cultivation, timber harvesting, water management, urban development, and livestock grazing may produce negative effects on the ecological integrity of watercourses. Agricultural studies have shown that in comparison to the production of orchards, vineyards, corn, small grains, and hay, pasture is least damaging to watercourses (Clark 1998).

The benefits of riparian buffer zones are diverse and far-reaching. First and foremost, riparian areas increase the water quality of a watercourse and extend its lifetime for sustainable use. Riparian areas also act as carbon sinks, with the vegetation storing carbon. Once well established, part of the riparian zone can provide a highly productive forage supply for livestock (Fitch and Adams 1998).

The various levels of vegetation within the riparian zone help to maintain water quality by trapping sediments and filtering out harmful pollutants. The same vegetation strengthens stream and riverbanks by binding soil with the roots, shielding banks from erosion, and repairing annual damage with sediment deposition (Thomas et al. 1979, Platts 1990 and 1991). Streambank vegetation stabilizes the streambank and helps prevent streams form widening or changing course (Bellows 2003). This also reduces the need for implementing expensive shoreline protection. The shade provided by the riparian zone plant life moderates water temperature increases from the sun on the water and runoff flowing through heated soils. Siltation from exposed soils is also minimized as plant roots reduce erosion (Lansky 2002).

Riparian zones can provide diverse wildlife habitat and increase the landscape biodiversity. Riparian vegetation provides habitat for wildlife species. Forested stream banks provide shade, maintaining the cooler water temperatures critical for fish. Overhanging grassy vegetation provides shelter for fish and other aquatic organisms. The contrast between the riparian area plant community and the surrounding upland range vegetation adds to structural diversity over the landscape (Thomas, Maser and Rodick 1979).

Keeping livestock away from the watercourse has a positive impact on animal health. When livestock are contained in pasture, out of riparian zones, they spend more time feeding and less time in muddy and wet conditions, which results in a reduced incidence of mastitis, fewer injuries and less foot-rot (Cameron 2001).

Healthy riparian areas are well-vegetated with a diverse group of plants that have a deep binding root mass and have the age classes of vegetation that allow for re-growth. The species found in a riparian zone vary depending on the location of the riparian zone and the water body on which it borders. The following factors are usually considered when designating a riparian zone are:

- the size and type of the water body

- the degree of shade near and around the water body
- the degree of soil disturbance nearby from roads, trails and yards
- landscape characteristics that influence exposure to light or tendency for erosion (such as orientation, slope, or soil types)
- what lies beyond the riparian buffer (opening size, degree of soil disturbance, roads, trails or development)

The health of a riparian zone can be measured through the number of native species growing in the zone, the abundance of shade providing trees, the presence of multi age plants, the presence of wooded debris and the lack of bare ground. Conversely, riparian zone health can also be measured by the lack of specific characteristics. AAFC (2003) has listed the characteristics of unhealthy riparian zones as outlined in Table 7.4.

Table 7.4 Unhealthy Riparian Zone Characteristics (AAFC 2008)

Characteristic	Cause	Effect
An abundance of weeds and non-native plant species.	Removal of native vegetation	• Less deep binding root mass • Stream banks become unstable and erode
A lack of shade providing trees.	Logging of trees	• Promotes greater sunlight penetration leading to warmer stream temperature and decreased capacity to hold dissolved oxygen • Increase algal growth • Decrease abundance of aquatic organisms
A lack of tree saplings.	Over-grazing	• Mature trees are not replaced
Large areas of bare ground.	Trampling by livestock	•Slumping and erosion of bare ground •Increases sediments in stream, reducing water quality
A lack of large wooded debris.	Removal of wooded debris	• Limits habitat for fish and other aquatic organisms

There is often more than one source that contributes to riparian degradation, and they tend to interact with one another, making it difficult to isolate what is causing the harm. Cultivation, timber harvest, water management, urban development, flood and erosion control, in addition to livestock grazing, may all negatively impact a water course.

Factors impacting the integrity of the riparian zone include (Clark 1998):

- climatic region
- frequency of storms
- landform factors (soil type, drainage)
- biophysical factors (tiling, channelization, flow velocity, vegetation)
- pasture and grazing management practices (fertilization, time-limited grazing, reinforced access points.

Allowing livestock free access to riparian zones can result in the following:

1. negative effects on stream channel form and structure, shape and quality of the water column and soil stability and structure in the riparian zone. The water column is altered by increasing water temperatures, the addition of nutrients and suspended sediments and by alterations in the timing and volume of flow. Soil compaction on the floodplain from hoof action decreases infiltration rates and leads to increased runoff, accelerated erosion and higher sedimentation rates.
2. decreased vigour and biomass of vegetation, an alteration of species composition and diversity and losses of some vegetation components, especially trees and shrubs.
3. a decrease in fish and wildlife species and numbers following overgrazing of riparian areas.

Much of the current literature on livestock impact on watercourses pertains to the arid and semi-arid zones of western North America. In regions with higher rainfall, herd behaviour may differ, such as the frequency of drinking, duration of lounging near a water source and the degree of reliance on the riparian zone (Clark 1998). A study done by Kathryn Bremner (2008) in Nova Scotia compared the effects of cattle having full access to water courses to the effects cattle had after special structures were put in place to limit their access to the water courses. Results varied with each situation and structure, however, they suggest that providing controlled access could reduce bacterial load to the water course, and only if the access location is properly sited, designed and managed. For more information, see the Soil & Crop Improvement Association of Nova Scotia and the Nova Scotia Environmental Farm Plan's factsheets titled "Providing Water with Limited Access Ramps", "Water Quality Impact of Cattle Access to Watercourses" and "Do Limited Access Ramps Improve Water Quality?"

The impact of livestock access on watercourse compared to other land uses may be dependent on landform. The soil texture and type, surface geology, topography and drainage influence the type of agriculture practiced and the type of pollution experienced (Clark 1998). Uncontrolled access by livestock to the riparian zone can damage the riparian zone integrity. However, the evidence suggests that the degree of damage is localized, site specific and manageable.

Recovery of Riparian Areas

Efforts to recover riparian areas may require temporary decreases in livestock use, periods of rest, and changes in the timing of the use. When recovery efforts have allowed riparian ecosystems to reach a new balance, careful grazing management strategies must be implemented to maintain these productive areas. Long-term grazing management strategies need to include the fundamentals specific to the riparian zone. If done on a landscape basis, in concert with careful upland grazing strategies, cows and fish can co-exist (Fitch and Adams 1998).

The Nova Scotia Department of Agriculture has defined minimum setbacks from watercourses to be five metres for spreading manure. Biologists suggest a setback of 10 to15 m if at all possible to create a healthy and biodiverse riparian zone.

Agriculture & AgriFood Canada has suggested the following management techniques for healthy riparian zones:

- use corridor or exclusion fencing in severely disturbed areas to allow regeneration of natural vegetation
- fence livestock out of watercourses
- avoid cropping to the edge of a water body and allow natural vegetation or appropriate planted forage to regenerate
- provide watering systems for livestock away from the riparian zone
- construct livestock crossings to reduce disturbance of the riparian zone
- alter livestock distribution by rotating salt and mineral locations, and using temporary fencing
- graze after the spring and early summer period
- reduce the intensity of grazing within the riparian area
- use alternative grazing management systems such as rotational grazing
- manage the riparian zone as a separate and unique pasture

PASTURES AS CARBON SINKS

Carbon-sequestering practices may enhance the profitability of farming systems by increasing yields or reducing production costs. Pastures can function as "carbon sinks" by storing excess carbon dioxide. By using conservation tillage or no-till practices when renovating pastures, soil is conserved and carbon dioxide can be trapped in the *humus* of agricultural soil, thus reducing the carbon dioxide released to the atmosphere. Improved farming practices can save one to three tonnes of carbon per hectare from the atmosphere for a 10-20 year period (AAFC 2003).

Cattle consuming high-fibre diets produce more methane per litre of milk than cattle consuming low fibre diets with less forage and a higher grain component. However, the production of higher quality pasture may result in giving lower emissions, along with lower fossil fuel use and increased sustainability (Fredeen et al. 2001). One indicator of sustainability is the efficiency of a production system.

Native and improved pasture ecosystems are compared to a corn system in Table 7.5. The table shows that while corn has a higher ability to use the sun's energy and also maintains a higher output, it still has the lowest total energy efficiency because of its high input needs.

Table 7.5 Energy Efficiency of Agroecosystems (10^9 Kcal/ha) (Fredeen et al. 2001)

	Corn	**Native Pasture**	**Improved Pasture**
Efficiency of Solar Capture (%)	1.7	0.03	0.08
Output	24.5	4.2	12.6
Input	8.4	0.1	1.1
Efficiency (output/input)	2.9	42	11.9

The impact of managing intensive grazing (MIG) on greenhouse gas emissions was examined using the Atlantic Dairy Sustainability Model which was developed by Mike Main in 2001. Three systems were compared for producing 500,000 kg fluid milk per year:

Seasonal MIG dairying: A novel system where cows are freshened in spring and fed entirely on Management Intensive Grazing (MIG) for almost 6 months, followed by confinement feeding through late lactation and the dry period. Almost no supplements are fed with an annual production of 5,800 kg milk /cow/y from a milking herd of 86.

MIG, high forage: Cows were fed on (MIG) for just over 5 months and about 85% of the milking herd diet is forage; annual production is 6,900 kg/cow/y from a milking herd of 73.

Confinement, high concentrate: Cows are fed entirely in confinement and only about 55% of the milking herd diet is forage; annual production is 10,300 kg/cow/y from a milking herd of 49.

Table 7.6 outlines the predicted carbon dioxide (CO_2) equivalent emissions per year.

Table 7.6 Greenhouse gas emissions and other sustainability measures of highly pasture based versus confinement feeding

	Seasonal MIG dairying	MIG, high forage	Confinement, high concentrate
CO_2 from fossil energy use	0.11	0.14	0.21
CH_4 emissions	0.77	0.70	0.53
N_2O emissions	0.21	0.24	0.36
N_2O from off-farm feed production	0.01	0.01	0.05
Soil C sequestration / loss	-0.28	-0.13	-0.04
Net total (kg CO_2 eq per kg milk)	**0.82**	**0.95**	**1.10**
Hectares needed	190	180	105
Grain fed (tonnes)	4	53	170
Chemical fertilizer	no	no	yes
Farm soil organic matter (% increase in 20y)	0.51%	0.23%	0.15%
Average nitrate leaching (N, kg/ha/y)	2.0	2.7	8.2
Net margin (uniform milk price)*	$83,000	$50,000	$47,000

**the Net Margin represents the profit after the cost of production (gross income minus total costs). The costs vary with cow numbers, total milk production, use of pasture, feed costs and crop inputs.*

In the overall analysis, it was found that high forage and pasture diets have lower net emissions because of lower emissions associated with energy use and nitrous oxide (N_2O) production, and because of CO_2 trapped in the higher soil humus content under forages. These factors more than offset the higher methane emissions from high forage diet. A recent New Zealand analysis has predicted the same results (Robertson et al. 2002). Greenhouse gas emission from Canadian milk production in 2001 has been estimated as 1.02 kg CO_2 eq per kg milk (Verge et al. 2007).

Soil carbon sequestration is important even though the % change in soil organic matter levels is quite small, since the mass of the soil is so large (2,000,000 kg/ha to 15cm depth). Also, forage crops typically have low nitrous oxide production or nitrate leaching losses, because, unless heavily fertilized, grass crops tend to scrub nitrate from the soil. However, if pastures are heavily fertilized with nitrogen, there can be large emissions of nitrous oxide, and/or nitrate leaching, because of nitrogen overload where cows urinate. Recent work at the Nova Scotia Agricultural College suggests this is not an issue under un-fertilized pastures. Also, when forage legumes are used as the main nitrogen source, much of the nitrogen is tied up in organic forms, and is less available for nitrous oxide production or nitrate leaching, until the land is tilled.

The analysis also suggests that high forage systems using MIG are more broadly sustainable than confinement systems. Fossil energy use is lower, nitrate leaching is lower, soil organic matter levels are higher, and it appears to be a more profitable approach. And, it is well known that soil erosion is a non-issue under forages. Of course, forage based seasonal milk production is not currently an option, but there are demonstrable efficiencies in this approach if future markets allow this. Meanwhile, there are clear benefits to forage based systems, especially when management intensive grazing is optimally used, and this will only become more important as grain prices rise.