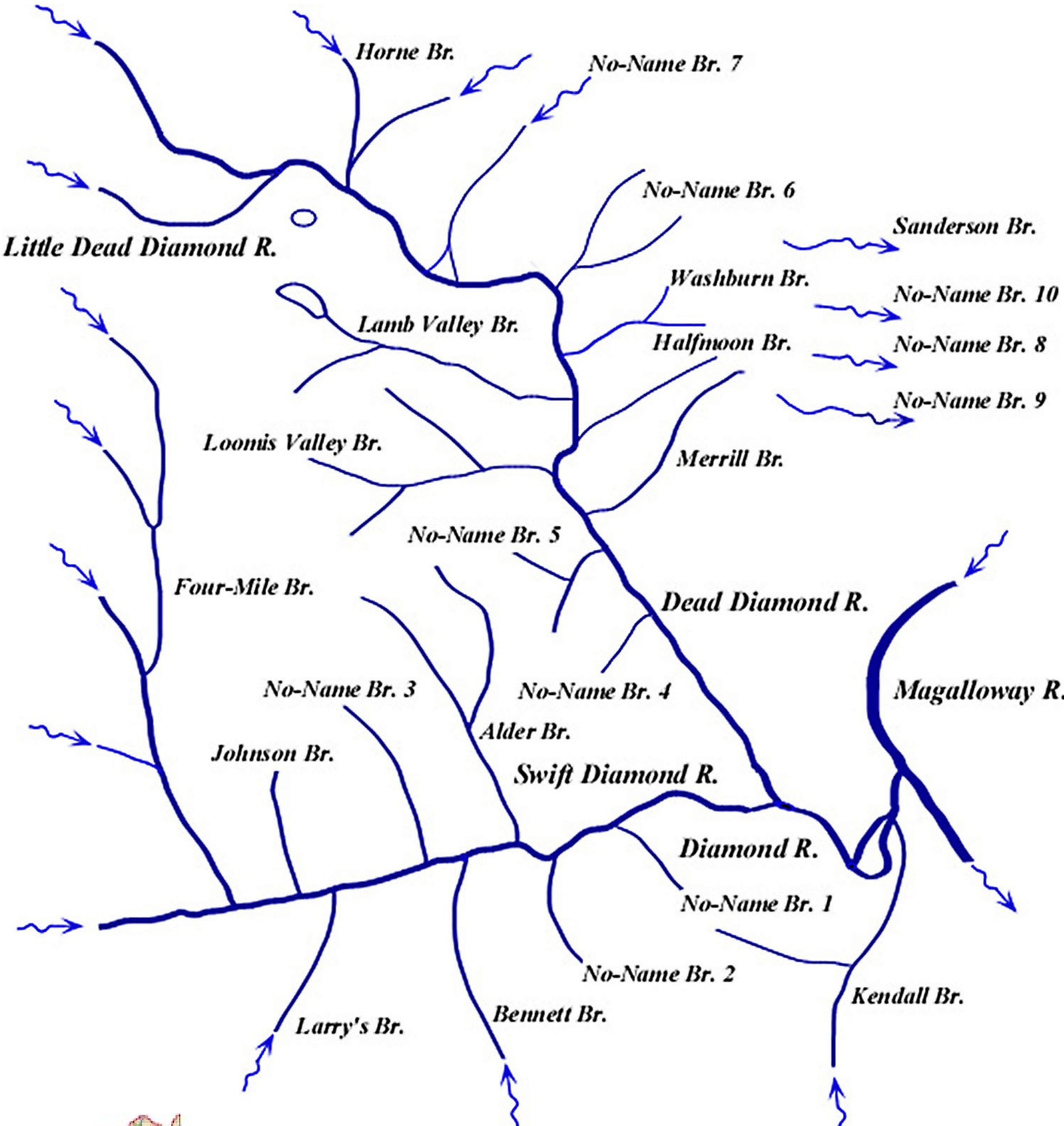
Some natural history highlights from Second College Grant

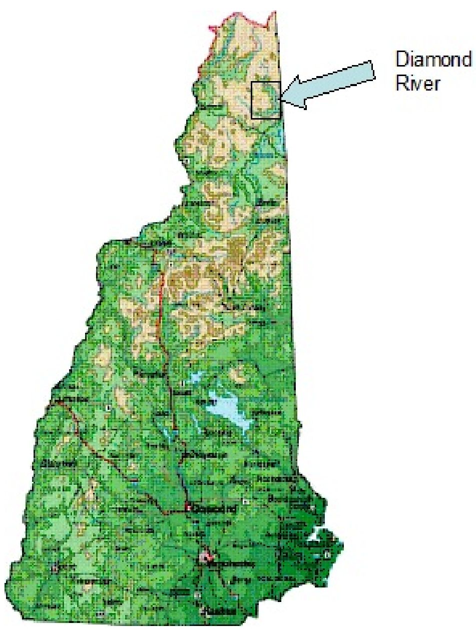
The Diamond River is the largest uninhabited watershed in NH. It has high natural biodiversity because of its geographic position near an ecological transition from northern hardwoods and pine forests to boreal forests. Consequently, it contains many species of plants and animals that are uncommon or absent from the southern 2/3 of state, although it still retains numerous southern species that are at the northern edge of their distribution. There are records of about 150 bird species, including ospreys, bald eagles, peregrine falcons, wood ducks, goldeneyes, mergansers, spruce grouse, black-backed woodpeckers, red-breasted nuthatches, boreal chickadees, >20 species of warblers, scarlet tanagers, rose-breasted grosbeaks, redpolls, snow buntings, and golden-crowned kinglets (a star of *Winter World* by Bernd Heinrich). There are several dozen mammal species within the Second College Grant. Common residents include moose, black bear, beaver, fishers, otters, and coyotes. Furthermore, the area provides potentially suitable habitat for marten, wolves, and mountain lions, which previously resided there but have been extirpated during the last century. It provides important wintering habitat for whitetail deer in the region (mature spruce/fir forest provides relief from heavy snow cover). There are thriving, unstocked, populations of brook trout and at least five other fish species. The Dead Diamond River supports what is probably the only native population of Brook trout left in NH or VT (see theses by Hogan '00 and Kelson 2012). Merrill Brook harbors a large population of the rare spring salamander, *Gyrinophilus porphyriticus*, which has been the subject of Ph.D. research by Winsor Lowe (Dartmouth Biology), and two undergraduate theses (Aucoin '00, Shannon '00). The streams harbor a remarkably productive and diverse community of aquatic insects (probably several hundred species of mayflies, stoneflies, caddisflies, beetles and true flies). Bryan Brown ('04 Ph.D. at Dartmouth) studied the effects of hydrological disturbance on these insect communities. Lauren Culler ('12 Ph.D. at Dartmouth) is studying relations between air and water temperature. Other elements of the flora and fauna are also rich but still await detailed natural history exploration. The Jesup Herbarium in our Life Science Center has a recently re-discovered plant collection from the Second College Grant.

Some observations on recent field trips have included sow bear with very young cubs, moose, fishers, white-tail deer in winter "yards", mixed species flocks of winter resident birds, flocks of nomadic crossbills, pileated woodpeckers, early migrant waterfowl, ospreys, bald eagles, hobblebush buds starting to expand while the ground is covered with snow, red squirrel middens, calling owls, active salamanders in icewater, beech bark disease, browsing patterns by deer and snowshoe hares, beaver activity, plastic leaf morphology in balsam fir, effects of historic spruce budworm outbreaks on forest understory community, effects of selective logging growth on remaining trees, red squirrel middens, active benthic insects beneath frozen rivers, rich communities of fungi and invertebrates within inner bark of recently dead trees, huge numbers of active Collembola on snow surface, tree architecture that has evolved to withstand snow loads, marcescent beech, vole tunnels within subnivean space, diverse lichens...

The Second College Grant has been owned and managed by Dartmouth College since 1807. Its large size (~ 30,000 acres), in combination with its unique land use history, gives it special value for recreation and biodiversity. Since the 1960s, the Second College Grant has been subject to an unusual system of multiple use management that simultaneously promotes aesthetics and recreation value (fishing, hunting, hiking, birding, etc.), maintenance of biodiversity, and timber harvest. It provides a model for forest management that could, and probably should, be applied more widely. As it is, this contrasts with an unfortunate polarization of forest management practices in most of North America towards either unsustainable overharvest or "zero-cut" practices. In addition to the research projects already mentioned, continued refinement of ecologically sound management practices at the Second College Grant have been aided by undergraduate theses in Biology (Mooney '98, Novello '99, Bier 2010, Kelson 2011), Geography (Jolyon Rivoir-Pruszinski '00), and Earth Sciences (Miller '95, Lawrence '96, Borkowska '99, David Reeder, Ph.D. '02). The Second College Grant provides excellent opportunities for further ecological research by Dartmouth students (including honor's theses and independent research). Some of the numerous broad possibilities include:

- Biodiversity surveys of birds, small mammals, woody plants, herbs, lower vascular plants, mushrooms, stream insects, and butterflies and other terrestrial insects. This could include systematic searches for threatened and endangered species.
- Mapping of key trout habitat features including spawning habitats, fry nurseries, thermal refuges. Genetics of brook trout. Movements of brook trout.
- Tests for ecological consequences of variation in water chemistry and thermal regimes among tributaries.
- Ecological surveys of old growth stands.
- Studies of how land use and climatic patterns inside and outside of the College Grant influence stream flow and water quality; Mapping of subsurface hydrology.
- Establishment of long term plots to study forest dynamics.
- Mapping of growth patterns in tree species, and studies of tree responses to stand thinning.





Above. Schematic of Diamond River watershed with Second College Grant. Arrows indicate direction of flow. The main rivers are the Dead Diamond and Swift Diamond, which join near the SE entrance to the College Grant, descends through a gorge, and drains into the Magalloway River. We will stay at the Management Center cabins, which are about 1 km above confluence of the Dead and Swift Diamond Rivers.

Left. Location of Diamond River watershed within NH.

Water conductivity in stream environments

Background. Conductivity, a meaure of electrical current flow through a solution, is expressed in units of microSiemens (uS). Conductivity is the reciprocal of electrical resistance (ohms). Because conductivity increases nearly linearly with increasing ion concentration, we can use conductivity measurements to estimate ion concentrations in solutions. Seawater conductivity is approximately 5000 µS, campus tap water is about 110 µS, and distilled water is near 0 µS. College Grant streams have low conductivities (between 12 and 47 µS) and thus have low concentrations of dissolved ions. Conductivity can tell us a lot about the nature of a stream. For example, low-conductivity streams typically have less groundwater input than high-conductivity streams, i.e., they are "precipitation-dominated." Thus, they also have more dynamic flow and temperature regimes. Conductivity also indicates the degree to which a watershed's bedrock and mineral soil resists erosion. The Little Dead Diamond River has the highest conductivity value of the streams we regularly monitor (see Table) indicating that it has relatively high levels of groundwater input; this is also supported by cool summer water temperatures, numerous iron seeps, and easily detected groundwater input.

Measurement. Water conductivity is measured by the diminution of electrical current passed through a water sample. Higher concentrations of electrolytes in the sample solution permit a larger fraction of the current emitted by one probe to reach the sensor probe, and produce a higher the conductivity measurement (greater µS). Conductivity is influenced by temperature (µS can change by up to 3% per °C) so measurements are sometimes temperature compensated to correspond to µS at 25° C. The meter can provide either raw conductivity measurements or measurements compensated according to the effects of temperature on conductivity of KCl in solution. Calibration of the conductivity sensor with reference solutions of known conductivity is critical to obtaining good measurements.

Biological relevance. Organisms in precipitation-dominated streams, indicated by low conductivity, must be able to withstand floods, dry downs, and scouring by anchor ice. Many have adaptations to persist through stressful periods in a state of quiescence or to seek refuge in protected microhabitats. Most animals in low-conductivity streams must also maintain high internal ion concentrations relative to those in the surrounding environment. Conductivity is linearly related to osmolarity (mOsm / liter = 5.79 + 0.0734 µS for NaCl). Thus, the waters of the Diamond River watershed have ionic concentrations of only 6-10 mOsm / liter compared to 200-300 mOsm / liter for typical freshwater invertebrates. Because these animals are extremely hyperosmotic to their environment, there is a tendency for uptake of water and loss of ions, especially across respiratory surfaces, which are necessarily permeable. Therefore osmoregulation involves the elimination of water, the retention of ions, and active transport of ions from the external medium into the animal. Freshwater animals exhibit numerous structural and physiological adaptations to minimize the costs associated with osmoregulation. Nonetheless, it has been estimated that osmoregulation accounts for >30% of the total energetic expenditures of some aquatic organisms. It is possible, but untested, that the aquatic communities of the Diamond River watershed are shaped in part by differential abilities among species for osmoregulation and that the energy budgets of residents are strongly influenced by the costs of osmoregulation.

Water conductivity (µS) at Second College Grant during

Stream	Low	High	Mean
Diamond River	14	47	34
Dead Diamond River	13	45	16
Little Dead Diamond River	23	46	32
Loomis Valley Brook	13	27	24
Horne Brook	13	26	20
Swift Diamond River	13	45	28
Alder Brook	14	33	27
Johnson Brook	14	34	30
Bennett Brook	22	38	33

Water pH in stream environments

Background. The relative concentrations of free hydrogen and hydroxide ions in aqueous solutions can vary considerably, but the total pool of these ions remains the same size. pH is a measure of the hydrogen component of this pool. It is the negative logarithm of hydrogen ion concentration (high pH = low hydrogen ion concentration). A solution in which half of the free ions in this pool are hydrogen ions and the other half are hydroxide ions is referred to as neutral pH (pH = 7). When acids dissociate in water, hydrogen ions are liberated which increases the relative concentration of hydrogen ions (lowering pH). Bases accept (bind with) hydrogen ions and can dissociate to increase hydroxide concentrations (increasing pH).

Measurement. pH can be measured with portable sensors that are constructed around a pH-electrode containing a membrane of pH-selective glass. When the electrode is immersed into the solution, an electrical charge caused by H-ions (H+) generates a cell voltage between the glass membrane and the solution. This electric voltage is recorded with reference to a reference electrode, located around the pH-glass electrode. The cell voltage of the combination electrode is directly proportional to the pH-value. Most pH sensors are temperature compensated to account for the effects of temperature on pH. If so, recorded measurements correspond to pH at 25° C. Frequent calibration of the pH sensor with reference solutions of known pH is critical to obtaining good measurements. The pH electrode is ruined by dessication.

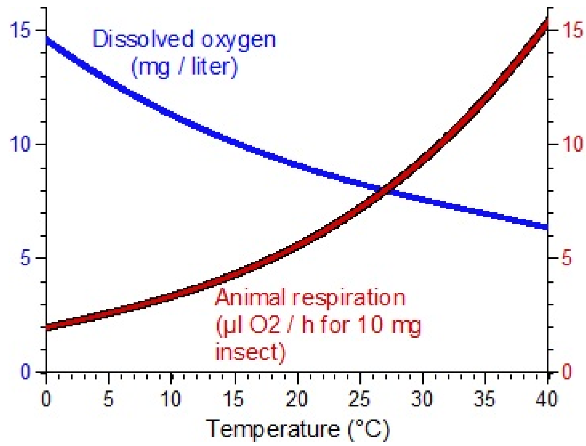
Biological relevance. Precipitation is naturally acidic (more free hydrogen ions than hydroxide ions, pH $\approx$5.6) due to the presence of carbonic acid formed when atmospheric carbon dioxide reacts with water. Acid precipitation refers to the deposition of rain, snow, and fog water that has relatively high concentrations of acids formed when air pollutants (principally oxides of nitrogen and sulfur) react with water to form strong acids. Precipitation in New England is frequently acidic. We have measured rainwater pH as low as 3.89 and snowmelt as low as 4.2 in the Diamond River watershed. This is notable because streamwater pH lower than 5.0, if persistent, is lethally toxic to most of the animals that live in College Grant streams and stressful if episodic. One way in which pH can impact the physiology of aquatic organisms is by altering the three dimensional conformation of enzymes, and therefore the kinetics of biochemical systems; pH can also impact gas exchange in aquatic organisms. Most pH values in the Diamond River watershed are well within the tolerance limits of native organisms due to the buffering effect of weathered bedrock and soil chemicals that increase pH (e.g. calcium). However, our data from 1997 indicate that acid stress is occasionally a problem in the Swift Diamond watershed (see table). It is possible that tributaries with chronically low pH, such as Bennett Brook, harbor different communities than they otherwise would because of differences among stream insects in their physiological responses to pH.

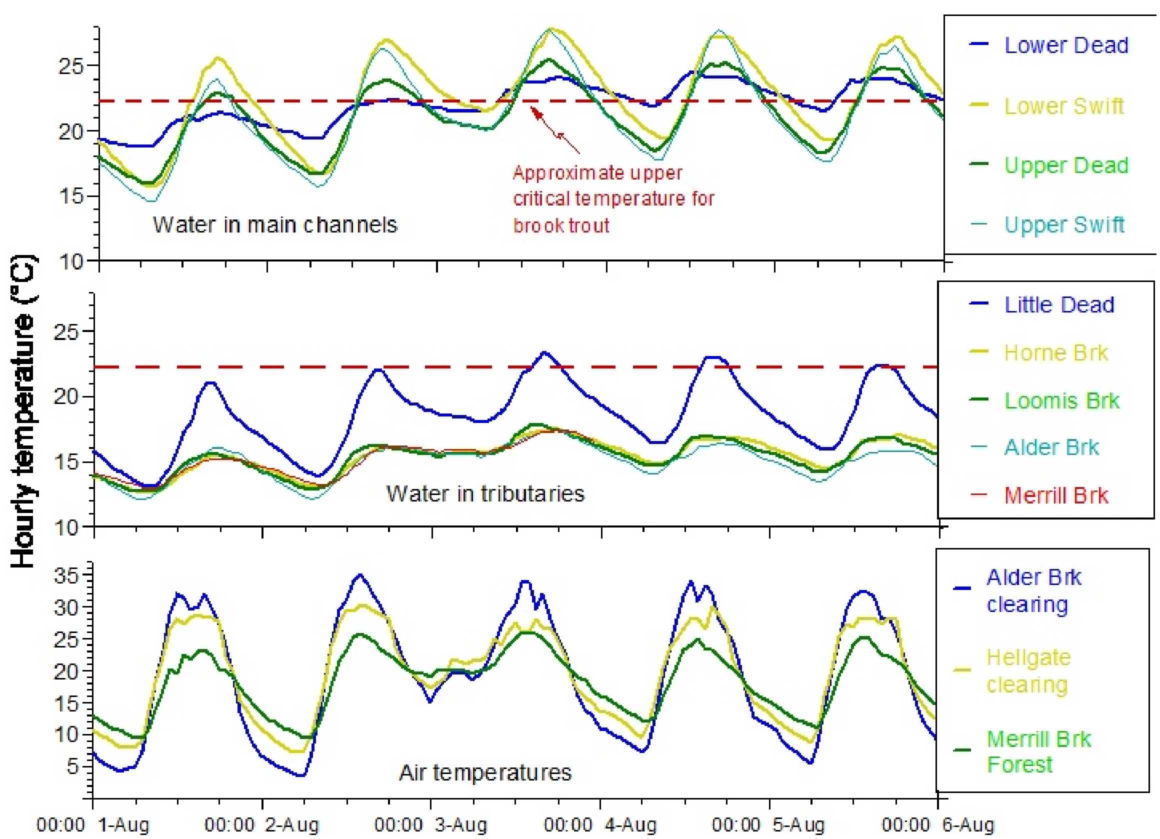
Summary of pH measurements at Second College Grant during 1997-98.

Stream	Low	High	Mean
Diamond River	5.86	7.23	6.38
Dead Diamond River	6.00	7.32	6.38
Little Dead Diamond River	5.85	7.18	6.41
Loomis Valley Brook	5.29	7.12	5.74
Horne Brook	5.55	6.68	6.04
Swift Diamond River	4.46	7.36	6.24
Alder Brook	5.13	6.60	5.80
Johnson Brook	5.48	6.87	6.14
Bennett Brook	4.81	6.4	5.18

Temperature and dissolved oxygen in stream environments

Oxygen makes up about 21% of the atmosphere, but has very low solubility. Well aerated fresh water at 15° C contains only 34.1 ml O_2 / liter. The solubility of oxygen in water is strongly sensitive to temperature, with lower solubility at higher temperatures (see Figure). In the Diamond River and its tributaries, which have high turbulence and high contact with the atmosphere, dissolved oxygen content is consistently within 10% of saturation, which means that dissolved oxygen in mg / liter can be quite accurately estimated just by knowing water temperature (see Figure). Oxygen is essential as an electron receptor in the primary metabolism of nearly all organisms. Acquiring sufficient oxygen is a fundamental physiological challenge for aquatic organisms because of the low solubility of oxygen. Consequently, aquatic organisms display multifarious adaptations for meeting this challenge. Warm water temperatures can preclude the existence of many aquatic organisms because it increases respiration rate and oxygen requirements while simultaneously lowering dissolved oxygen content (see Figure). Brook trout begin to experience physiological stress at water temperatures of about 22 °C (72 °F) and are seldom found in water that regularly exceeds 22 °C. In the Second College Grant, water temperatures in the Dead Diamond, Swift Diamond, and Diamond rivers sometimes become inhospitably warm for brook trout. During the warm summer of 2001, maximum temperatures in these waters reached 26 - 29 ° C, and there were 272-438 hours when water temperature exceeded 22 °C. Even occasional summers such as this would likely be devastating for trout populations if they did not have access to the cool water refuges of Alder Creek, Loomis Valley Brook, and the Little Dead Diamond. See research by Lauren Culler ('12 Dartmouth Ph.D. in EEB). Remarkable numbers of trout can be found in these tributaries during warm-water events.





Publications of ecological research conducted at Second College Grant (links to some are available at: www.dartmouth.edu/~bio31)

Some undergraduate thesis research at Second College Grant

"Conservation Management for Brook Trout (Salvelinus fontinalis) in the Second College Grant: Analysis of the Genetic Structure of a Metapopulation", Suzanne Kelson '12 (advisor Ann Kapuscinski).

"Stream Temperature Modeling in the 2nd College Grant". Ben Bier '11 (advisor Matt Ayres).

"Balsam fir forest responses to management following insect infestation", Suzy Svatek '90 (advisor Laura Conkey, Geography).

"An Analysis of Factors Influencing Pixel Brightness Values in Satellite Imagery". K.T. Lawrence '96, (advisor, Dick Birnie, Earth Sciences).

"The effects of clearcut size on the bird community in the Second College Grant", Josh Mooney '98 (advisor, Dick Holmes, Biology). Showed that small clearcuts can enhance avian diversity but that large clearcuts tend to favor cosmopolitan species and reduce diversity. Has reinforced managment strategy favoring primarily selective logging with some small clearcuts.

Signature of a Young Forest: Detection of Spectral Change in Post-Clearcut Vegetation Using Landsat TM Data, Second College Grant, New Hampshire. A.A. Borkowska '99, (advisor, Dick Birnie, Earth Sciences).

"The impact of logging and suspended sediments on aquatic invertebrates", Mike Novello '99 (advisor, Matt Ayres, Biology). Showed potential for downstream impacts of logging via increases in sediment load. Contributed to decision that logging within the Grant will be restricted as much as possible to the winter, when sedimentation impacts on streams are minimal.

"Population biology of brook trout, *Salvelinus fontinalis*", inhabiting the tributaries of a boreal stream ecosystem", Dan Hogan '00 (advisor Matt Ayres, Biology). Showed that tributaries are critical habitat for watershed population of trout. Identified particular tributaries (e.g., Alder Brook, Loomis Valley Brook, Bennett Brook, and Little Dead Diamond) that are especially important trout habitat. Contributed to increased protection of tributaries from logging and roads.

"Stream salamander response to timber harvest and interstitial refuge selection", Cheryl Shannon '00 (advisor, Doug Bolger, Environmental Studies)

"Differential habitat use by *Eurycea bislineata* - the effect of stream salamander community and anthropogenic disturbance", Linda Aucoin '00 (advisor, Doug Bolger, Environmental Studies)

"Temporal and spatial variation in the geomorphic effectiveness of flooding Dead Diamond River, NH", Jolyon Rivoir-Pruszinski '00 (advisor Frank Magilligan, Geography)

Graduate research at Second College Grant

Brown, B. L. 2003. Spatial heterogeneity reduces temporal variability in stream insect communities. *Ecology Letters* 6:316-325. Advisor, Kathy Cottingham.

Lowe, W. H. 2005. Factors affecting stage-specific distribution in the stream salamander *Gyrinophilus porphyriticus*. *Herpetologica* 61:135-144.

Lowe, W. H., and D.T. Bolger. 2002. Local and landscape-scale predictors of salamander abundance in New Hampshire headwater streams. *Conservation Biology* 16: 183-193. (Advisor, Doug Bolger, Environmental Studies). Highlighted at web site of Society of Conservation Biology. This work along with undergrad theses of Shannon and Aucoin, identified Alder Brook, and especially Merrill Brook as high value habitat for salamanders. Accordingly, Merrill Brook is now given priority consideration in management decisions in the Second College Grant.

Lowe, W. H. 2002. Landscape-scale spatial population dynamics in human-impacted stream systems. *Environmental Management* 30:225-233.

Lowe, W. H. 2003. Linking dispersal to local population dynamics: a case study using a headwater salamander system. *Ecology* 84:2145-2154.

Lowe, W. H. and D. T. Bolger. 2002. Local and landscape-scale predictors of salamander abundance in New Hampshire headwater streams. *Conservation Biology* 16:183-193.

Lowe, W. H., K. H. Nislow, and D. T. Bolger. 2004. Stage-specific and interactive effects of sedimentation and trout on a headwater stream salamander. *Ecological Applications* 14:164-172.

Nislow, K. H. and W. H. Lowe. 2003. Influences of logging history and stream ph on brook trout abundance in first-order streams in New Hampshire. *Transactions of the American Fisheries Society* 132:166-171.

Miller, A. B., 1995, A Multitemporal Analysis of Land Cover in the Northern Forest of New England using Landsat MSS Data: M.S. Thesis, Earth Sciences (advisor, Dick Birnie).

David Reeder, Earth Sciences, Removing the Topographic Effect from Digital Satellite Data - studies made extensive use of the Grant's GIS data base (advisor, Dick Birnie)