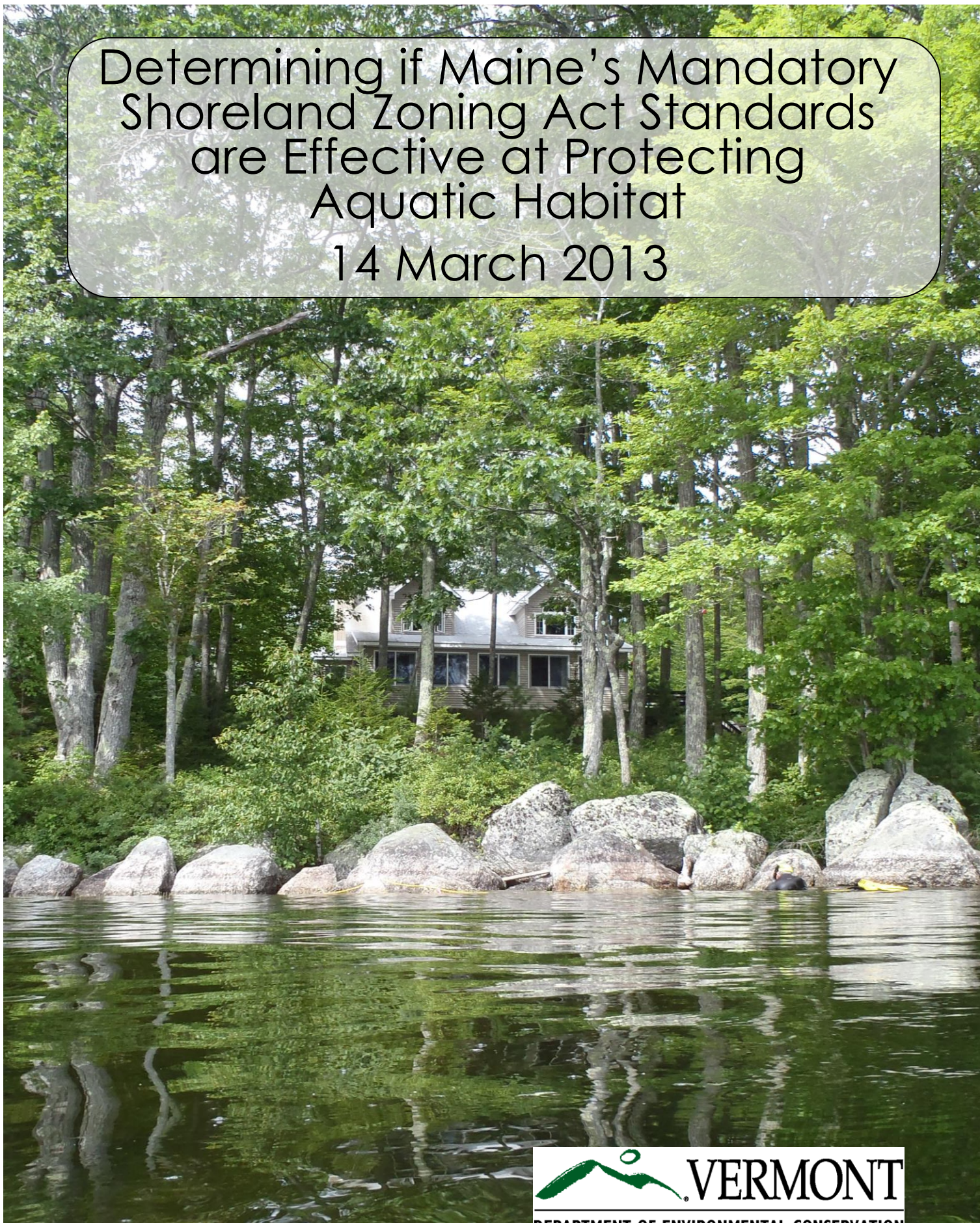


# Determining if Maine's Mandatory Shoreland Zoning Act Standards are Effective at Protecting Aquatic Habitat

14 March 2013





# Determining if Maine's Mandatory Shoreland Zoning Act Standards are Effective at Protecting Aquatic Habitat

A joint study conducted by the Vermont Department of Environmental Conservation and the Maine Department of Environmental Protection

Vermont Department of Environmental Conservation  
Kellie Merrell, Jeremy Deeds and Mark Mitchell

Maine Department of Environmental Protection  
Roy Bouchard, Retired (2011)

14 March 2013

Cover Photo by MEDEP

## EXECUTIVE SUMMARY

The VTDEC is tasked with ensuring that Vermont's lakes are managed and protected in compliance with the Vermont Water Quality Standards (VWQS). The VWQS serve as the foundation for protecting all of Vermont's surface waters, and classify each waterbody, establish uses (e.g. swimming, fishing, aquatic biota, wildlife and aquatic habitat) that must be protected, and set minimum chemical, physical and biological criteria that must be met in all of Vermont's waters. The VWQS are intended to achieve the goals set out in Vermont's water quality policy (10 V.S.A. Section 1250), which include the prevention of degradation of high quality waters; the prevention, abatement and control of all activities harmful to water quality; the maintenance of water quality necessary to sustain existing aquatic communities; and to seek over the long term to upgrade the quality of waters and to reduce existing risks to water quality. These goals are supported through the surface water management objectives and criteria set forth in the VWQS.

Until the studies described in this report, VTDEC had not systematically measured the impacts of lakeshore development on aquatic habitat, biota and wildlife to determine if these impacts were in conflict with the Vermont Water Quality Standards and Vermont's water quality policy. In addition, VTDEC did not know if lakeshore development standards existed that could protect aquatic habitat, biota and wildlife consistent with the goals of the VWQS and Vermont's water quality policy.

By studying 234 reference lakeshore sites and 151 unbuffered developed lakeshore sites on 40 lakes in Vermont, VTDEC determined that the kind of development allowed on Vermont lakes is degrading aquatic habitat and biota in conflict with the Vermont Water Quality Standards (Merrell, Howe, & Warren, 2009) and Vermont's water quality policy. In comparison, VTDEC and MEDEP determined that at the site level the kind of development allowed on Maine lakes was not degrading aquatic habitat and biota and would protect Vermont's waters consistent with the VWQS and Vermont's water quality policy. This was established by studying 13 reference lakeshore sites and 36 developed sites that followed Maine's minimum mandatory standards on 5 lakes in Maine.

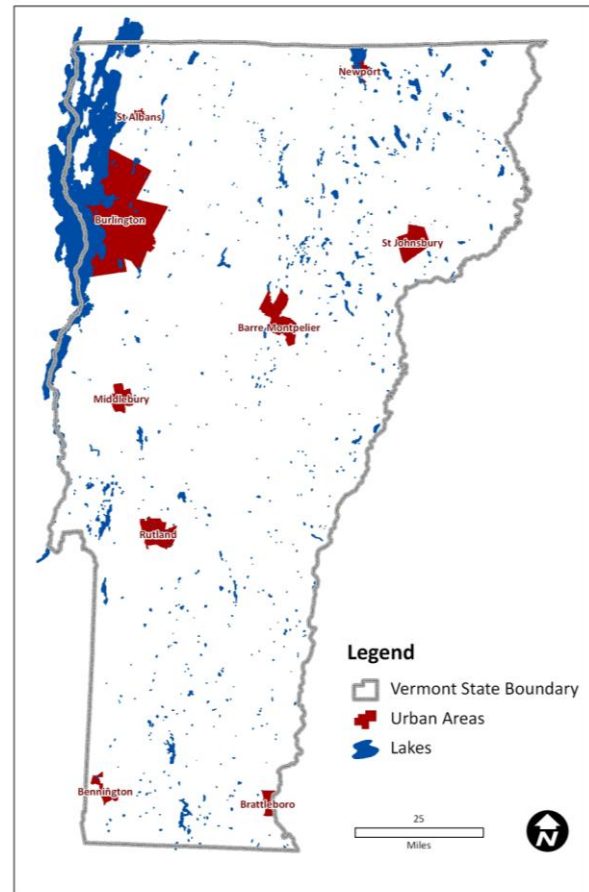
This study found that Maine's Mandatory Shoreland Zoning Act standards make it possible to both develop a lakeshore and protect aquatic habitat and biota.

## INTRODUCTION

Vermont and Maine have adopted different strategies for protecting their lakes from the negative impacts of lakeshore development. In 1971, Maine's legislature passed the Mandatory Shoreland Zoning Act (MSZA). The current law, as amended, requires municipalities to establish land use controls for all land areas within 250 feet of ponds. Towns adopt local ordinances that are at least as restrictive as the model ordinance developed by the state that outlines the minimum standards (MEDEP, 2003). Maine's law was modeled after the law Vermont passed in 1970. However, Vermont's law was passively repealed in 1975. Hence, Vermont has no statewide mandatory lakeshore protections or minimum standards; instead it leaves the stewardship of its lakeshores to each town and individual landowners. The vast majority of towns in Vermont lack ordinances deemed effective at protecting bank stability, water quality, aquatic habitat and wildlife by Vermont Department of Environmental Conservation's (VTDEC) Lakes and Ponds Management and Protection Section.

The lakeshore closest to the water's edge is important to the health of a lake. Yet, it turns out that roughly five percent of the residences in Vermont are located within 100' of a lake and that the average density of residential development of this area is twice that of all of Vermont's urban areas (Figure 1). The immediate lakefront zone, which makes up 0.3% of the land area of Vermont, so important to the health of Vermont's lakes, also happens to be some of the most heavily developed land area in the state (VTDEC, 2013). The majority of this development has no minimum standards

designed to dampen the negative effects residential development has on water quality, aquatic biota, wildlife and aquatic habitat.



**Figure 1. Vermont's urban areas and lakes. Using residential E911 locations, 5% of residences are located within 100' of a lake. Average density of development in the 100' lakefront zone is 402 residences per square mile. Average density of all the urban areas in the state is 198 residences per square mile, half that of the lakefront zone.**

The VWQS set forth both management objectives and criteria to protect different classes of waters. These include the objective to achieve and maintain waters in a natural condition compatible with the designated use

of aquatic biota, wildlife and aquatic habitat (Class A1 Ecological Waters); to achieve and maintain waters with a uniformly excellent character and a level of water quality that is compatible with the designated use of high quality aquatic habitat (Class B waters). The VWQS criteria that must be achieved for the aquatic biota and wildlife sustained by high quality aquatic habitat necessary to support their life-cycle and reproductive requirements (Class A2 Public Water Supplies); protection of aquatic biota, wildlife and aquatic habitat and to achieve and maintain a level of quality that fully supports the designated use of aquatic biota and wildlife sustained by high quality habitat, include: “change from the natural condition limited to minimal impacts from human activity” (Class A1 Ecological Waters); “biological integrity is maintained, no change from the reference condition that would prevent the full support of aquatic biota, wildlife or aquatic habitat uses” (Class A2 Public Water Supplies); and “no change that would prevent the full support of aquatic biota, wildlife or aquatic habitat uses” (Class B Waters).

Due to the lack of lakeshore zoning in Vermont, much of the development around Vermont lakes consists of removing all the vegetation to the water’s edge, leveling the lot, and adding impervious surfaces like roofs, driveways, patios, and decks in close proximity to the lakeshore. Vermont lakeshore residences usually use leveled lawns as the dominant feature to the post construction landscaping that often involve the installation of a seawall in order to secure the bank destabilized by the removal of the natural trees and shrubs.

From 2005 to 2008, VTDEC conducted a study looking at this form of development on 40 Vermont lakes to determine if it was negatively impacting the aquatic habitat and biota (Figure 2).

This study found that the conversion of treed shorelines to lawn, while seemingly harmless from the human perspective, causes significant changes to the biological and physical components of the nearshore aquatic environment that are in conflict with the management goals and criteria in the VWQS and Vermont’s water quality policy (Merrell, Howe, & Warren, 2009)(Figure 3).

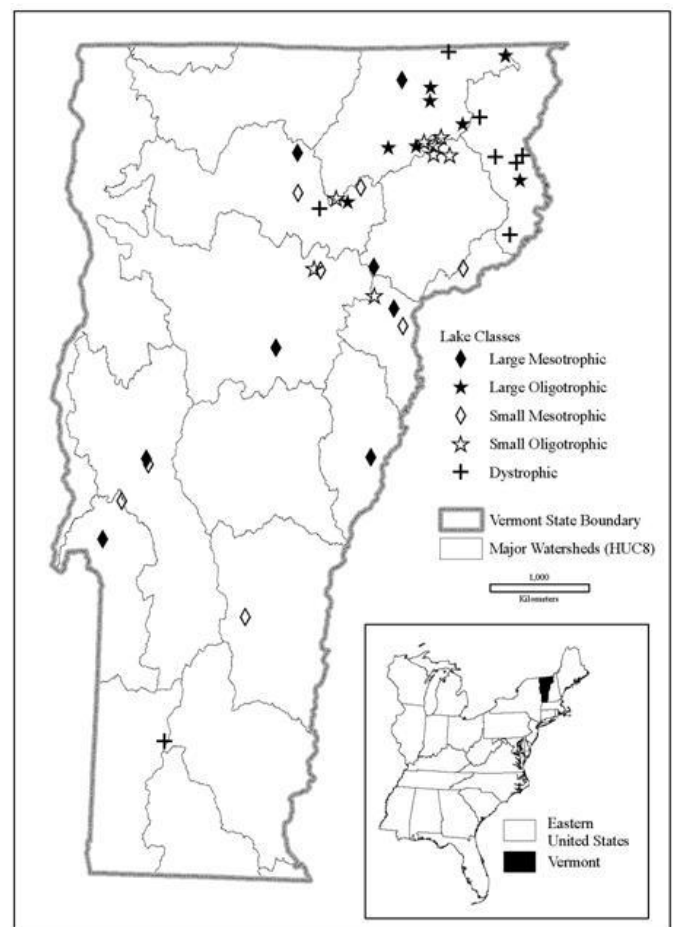
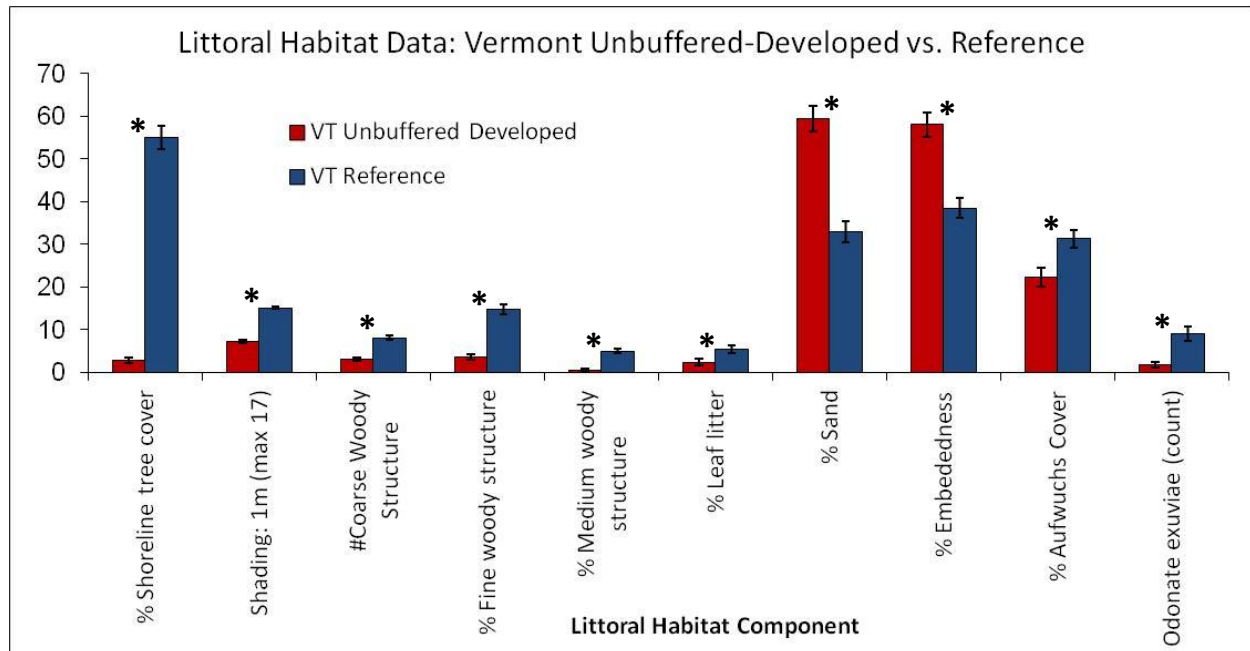


Figure 2. Location of 40 study lakes in Vermont



**Figure 3. Comparison of mean and standard error for aquatic habitat and biological parameters in the nearshore littoral zone off unbuffered developed and reference lakeshore sites in 40 lakes Vermont, (\*) denotes significance at  $\alpha=0.05$ . Unbuffered developed sites  $n=151$ , Reference sites  $n=234$  (Merrell, Howe, & Warren, 2009). Each habitat component's units - whether % cover, count or densiometer reading - are displayed with the biotope component name on the X axis. Hence, the Y axis is unitless.**

Maine's MSZA requires structures to be set back at least 100 ft from the lake, keeping impervious surfaces and cleared areas away from the lake (MEDEP, 2008). Based on a point system<sup>1</sup>, within each 25' by 25' area between the structure and lake, the act requires that enough trees of sufficient diameter be retained to add up to 12 points (where points increase with increasing diameter at breast height (DBH)). Other requirements for the plots prohibit the cutting of vegetation less than three feet high in order that low growing plants and shrubs can intercept rainfall. The uneven spongy duff layer under the vegetation further retards the runoff of rainfall and allows it to be absorbed into the soil. This requirement also prevents two landscaping activities that lead to increased runoff to a lake: leveling of the ground and lawn creation (Graczyk, Hunt, Greb, & Buchwald, 2003). To ensure tree recruitment as older trees die or are removed, at least 3 saplings must be retained. In order to maintain an intact canopy important for dampening the eroding effects of rain, no canopy openings greater than 250 ft<sup>2</sup> are allowed. Trees in the buffer can be removed and pruned for views as long as the standards are still met. A six foot wide path can be cleared and maintained to provide access to the lake and the path should meander to prevent it from functioning like a floodway for runoff moving from the impervious surfaces in the developed portion of the property.

<sup>1</sup> The point system is for each 25' x 50' plot between the shore and the structure. To align best with the littoral habitat plot width, this study broke the area in half to 25' x 25'. Required point and sapling requirements were halved as well.



In 2009 and 2010, VTDEC attempted to determine if developed lakeshore sites meeting Maine's MSZA standards protect the aquatic habitat in a manner consistent with the management goals and criteria of the Vermont Water Quality Standards. Of the over 1,848 developed lakeshore lots on the 17 developed lakes in the Small Oligotrophic, Small Mesotrophic and Large Oligotrophic study lake classes in Vermont, only eight lots met Maine's MSZA standards. This sample size was not large enough to determine if Vermont sites meeting Maine's MSZA standards protect aquatic habitat. The lack of qualifying sites in Vermont illustrates that despite the efforts of VTDEC to educate the public about the importance of intact buffers to lakes, less than 0.5% of lakeshore residents develop their lakeshore voluntarily in a way that would comply with Maine's MSZA.

In 2011, Maine Department of Environmental Protection (MEDEP) and VTDEC lake scientists collaborated for one intensive week of sampling. Thirty-six buffered developed sites and 13 reference (undeveloped) sites on five lakes in Maine were visited. The sampling effort resulted in a sample size large enough to determine whether Maine's standards are effective for protecting aquatic habitat. The results are summarized in this report.



*Buffered developed site on Clearwater Pond, Industry, Maine (MEDEP)*

## METHODS

From 2005 – 2008 the VTDEC littoral habitat assessment study sampled 40 Vermont lakes representing 5 different lake classes with 8 lakes sampled in each class (Figure 2). Sampling activities take less time on oligotrophic lakes because they have lower plant densities than mesotrophic lakes. Since teams had only one week to perform the sampling in Maine, large oligotrophic lakes were chosen. Five lakes were sampled in Maine in 2011 (Figure 4).

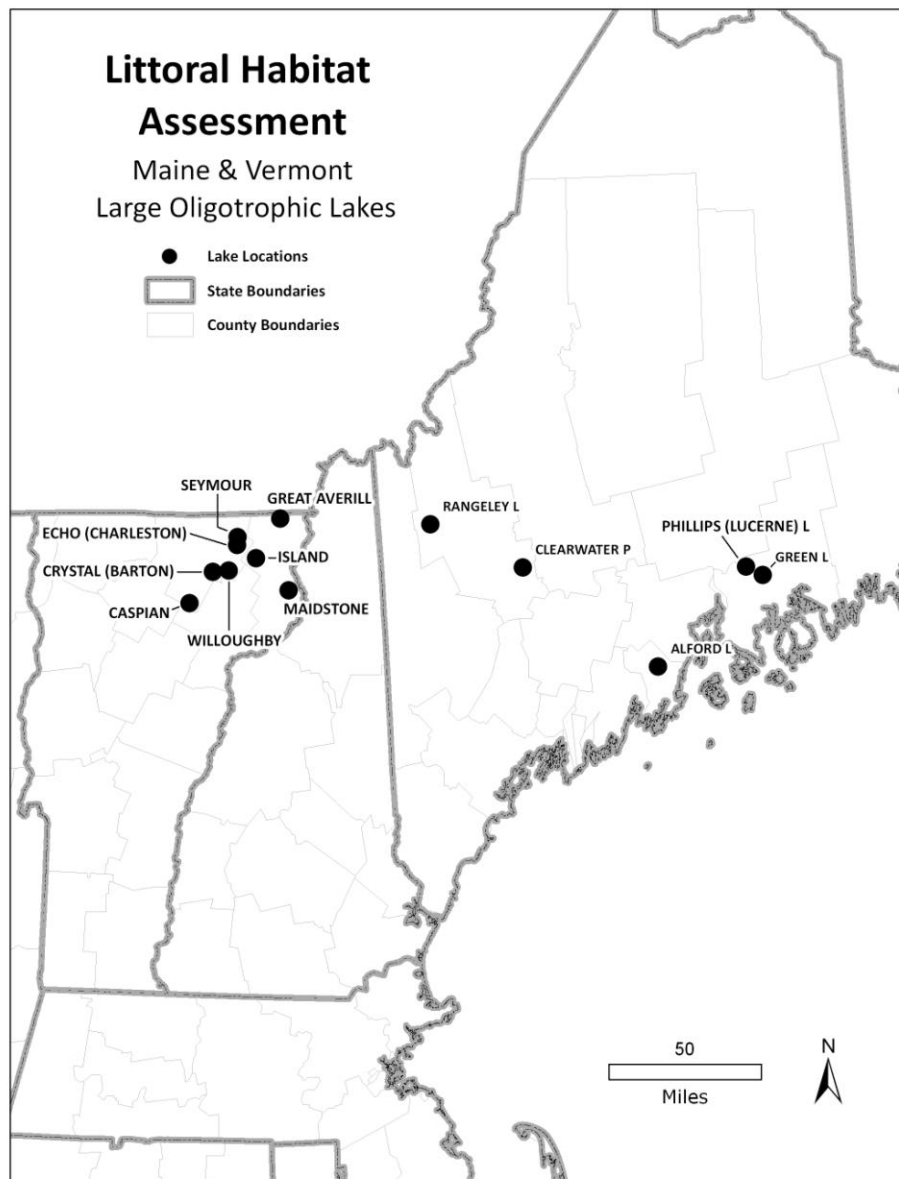


Figure 4. Location of large oligotrophic study lakes in Vermont (N=8) and Maine (N=5).



In Maine, sampling teams focused on collecting data that was missing from Vermont's study, namely data from buffered developed lakeshore sites that met Maine's MSZA standards. Of the 49 sites sampled in five Maine lakes, only 13 were reference undeveloped sites. At least two undeveloped reference sites were sampled on each of Maine's lakes.

Two crews of three scientists each performed the sampling. Each crew included two snorkelers and one forestry technician who took measurements within the terrestrial buffer. Snorkeler I focused on identifying the plants to species level and estimating their abundances. This snorkeler also estimated the percent cover of different sediment types, periphyton and aufwuchs (biofilm). Snorkeler II counted the pieces of large woody structure (> 10 cm diameter) and estimated the percent cover of medium (4-10 cm diameter) and fine (< 4 cm diameter) woody structure. This snorkeler measured shading using a densiometer at one and five meters from the waterline, and also estimated the percent cover of deciduous leaf litter and embeddedness of sediments. For a more detailed description of the methods used by the snorkelers see Merrell, Howe, & Warren, 2009. The forestry technician estimated the percent tree cover along the shore, measured the DBH of all trees greater than two inches in diameter within the 25' by 25' immediate lakeshore area and measured the distance to the nearest structure. Additional observations by the forestry technician included: canopy intactness, evidence that vegetation under three feet tall was not cut, percent cover of impervious surfaces, and the dominant ground cover. The forestry technician and snorkeler I or II collected all the dragonfly and damselfly exuviae skins along the two meter wide shoreline directly adjacent to the lake. The exuviae are the exoskeleton's shed by the adults when they emerge from the lake to transform into their adult stage.

Maine's law requires that the minimum standards be met in every 25' x 25' area plot up to 100 feet from the shoreline. In order to save time, DBH of all the trees was measured only in the 25' x 25' plot immediately adjacent to the lake along the stretch of shoreline adjacent to the in-lake snorkeler transects.



*Unbuffered Developed site on Seymour Lake, Vermont (VTDEC)*

### **Extent of Lakeshore Converted to Lawn at the Whole Lake Level**

In order to determine if there were differences between the extent of lakeshore that had been converted to lawn in Vermont and Maine, ten shoreline locations were randomly selected on the study lakes. Using 2012 high-resolution aerial imagery, it was determined whether lawn was present within the 25' x 25' immediate shoreline plot at each randomly selected site on the five lakes in Maine and the eight lakes of the same class (large oligotrophic) in Vermont.

All statistical comparisons were done using two-tailed t-tests, with significant values reported at  $\alpha=0.05$ .

## RESULTS

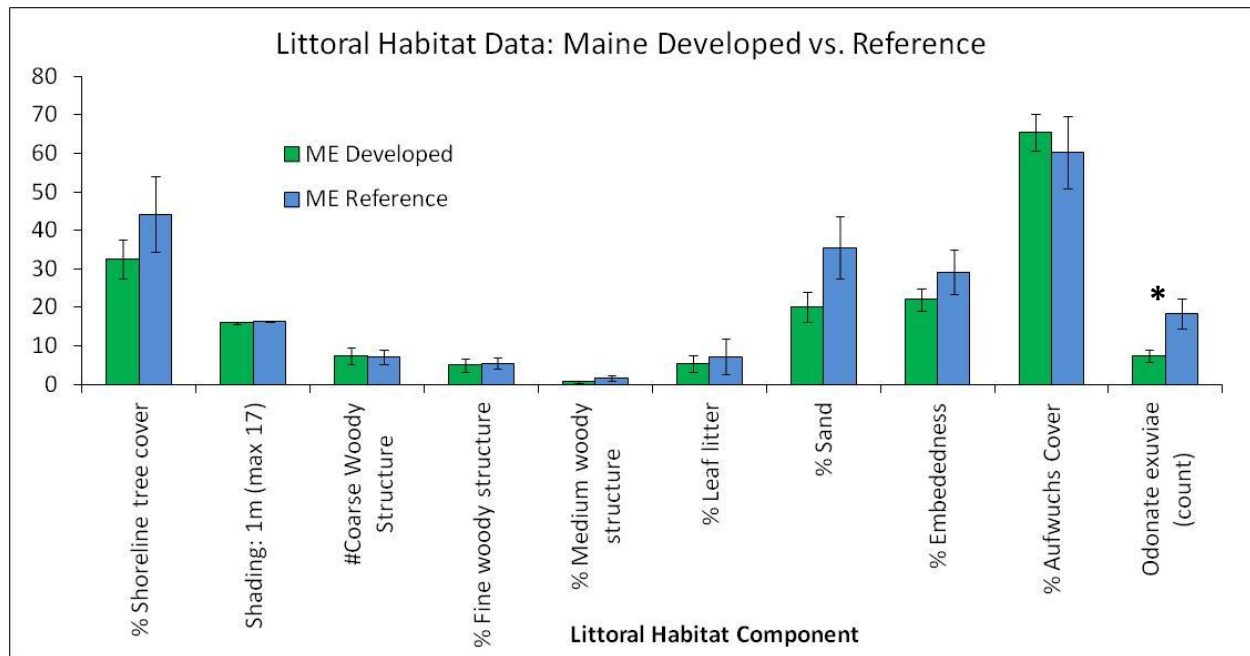
Of the 36 Maine buffered developed sites measured, 23 met all the minimum requirements of Maine's MSZA (Table 1). Of the non-compliant Maine buffered developed sites, two failed the DBH minimum of 12 points within the 25' x 25' shoreline terrestrial plot by one and two points. Two sites did not meet the no vegetation under three feet cut standard. Four failed the intact canopy standard and all but three sites had at least three saplings for recruitment. One site was missing setback of structure data, but of the 35 sites with setback data all but five met the minimum requirement of 100'. The five sites that did not were set back 98, 86, 79, 76 and 56 feet. All but one of the five met the pre-1990s standard of 75' setback.

**Table 1. Conformance of 49 Maine study sites to 5 of the main minimum mandatory zoning standards**

Maine MSZA Standard	# of non-compliant sties for each standard
12 DBH points	2
Greater than three saplings	3
Intact Canopy	3
Vegetation under three feet non cut	4
Building set back 100' from shoreline	5 (1 unknown)

All developed sites were included in the analyses despite not every site meeting all five of the minimum mandatory zoning standards. All 13 of the Maine reference sites met all five of the minimum mandatory zoning standards. The same is not true for the 44 reference sites sampled on Vermont's Large Oligotrophic study lakes. In Vermont, only 66% of reference sites met Maine's standards since reference sites were difficult to find and sometimes had to be squeezed between heavily developed sites in the 'privacy' buffer between camps.





**Figure 5. Comparison of mean and standard error for aquatic habitat and biological parameters in the nearshore littoral zone off developed and reference lakeshore sites in 5 lakes in Maine, (\*) denotes significance at  $\alpha=0.05$ . Developed sites  $n=36$ , Reference sites  $n=13$ . Each habitat component's units - whether % cover, count or densiometer reading - are displayed with the biotope component name on the X axis. Hence, the Y axis is unitless.**

Vermont unbuffered developed lakeshore sites had significantly less shading than reference sites (Figure 3), whereas, Maine developed lakeshore sites showed no significant difference in shading from the reference sites (Figure 5).

Vermont unbuffered developed lakeshore sites had significantly less coarse woody structure than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in coarse woody structure from the reference sites (Figure 5).

Vermont unbuffered developed lakeshore sites had significantly less fine and medium woody structure than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in fine or medium woody structure from the reference sites (Figure 5).

Vermont unbuffered developed lakeshore sites had significantly less deciduous leaf litter than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in deciduous leaf litter from the reference sites (Figure 5).

Vermont unbuffered developed lakeshore sites had significantly more sand than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in sand from the reference sites (Figure 5).

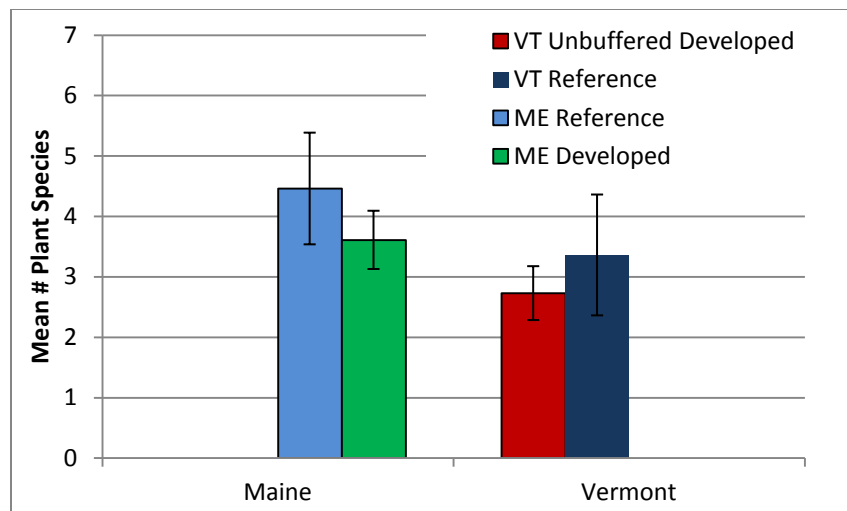
Vermont unbuffered developed lakeshore sites had significantly more embedded sediments than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in embeddedness from the reference sites (Figure 5).

Aufwuchs cover in Vermont unbuffered developed lakeshore sites was considerably less than cover in Vermont reference lakeshore sites, the difference being statistically significant (Figure 3). In contrast, Maine developed lakeshore sites showed no significant difference in aufwuchs cover from the reference sites (Figure 5).

In both Vermont and Maine, significantly less odonate exuviae were found in nearshore littoral habitat along developed shores than reference sites (Figure 3 and Figure 5).

### Aquatic Macrophyte Data

Since this study focused on large oligotrophic lakes, both plant cover and the mean number of species found at sites were low. Looking at plant species data, no significant differences were found in the species richness data between states or development classes (Figure 6). There is slight evidence that reference sites have higher numbers of plant species than developed sites.



**Figure 6. Mean and standard error for aquatic plant species richness at unbuffered developed sites in Vermont, and buffered developed and reference undeveloped sites in Vermont and Maine, (\*) denotes significance at  $\alpha=0.05$ . Data are from large (>200 ac) oligotrophic lakes only.**

The change in aquatic plant cover as a result of lakeshore development was the same for large oligotrophic lakes in both Vermont and Maine (Figure 7), with less aquatic plant cover found at developed sites than at reference sites. VTDEC found that aquatic plant cover was the one parameter measured that did not respond to unbuffered lakeshore development the same way across all lake classes (Figure 7).

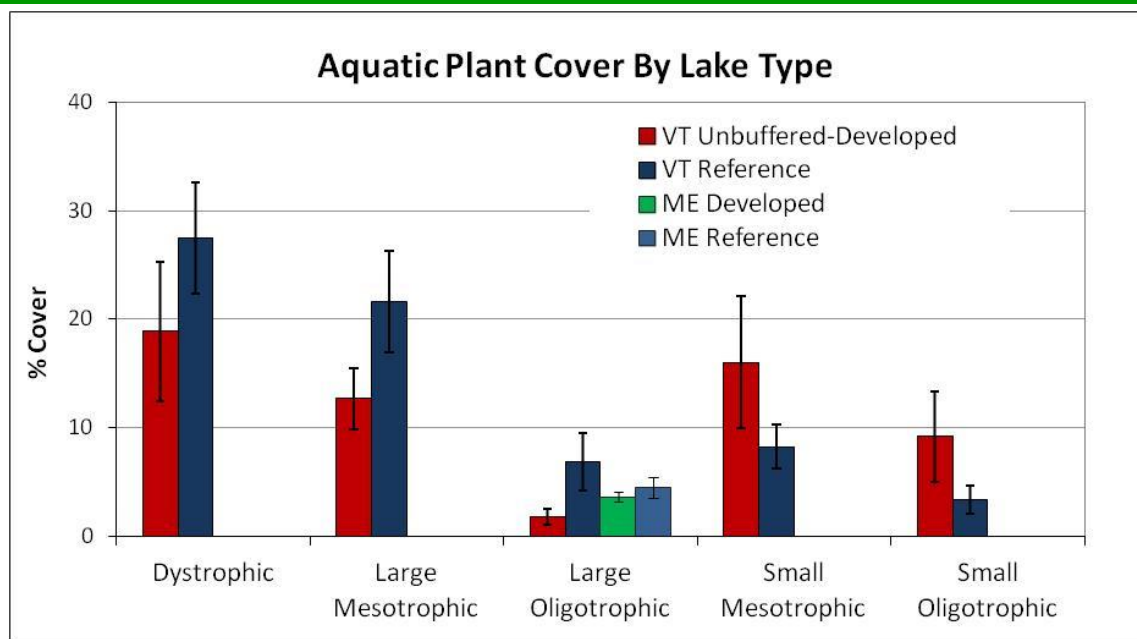


Figure 7. Aquatic plant cover in Vermont and Maine study lakes, (\*) denotes significance at  $\alpha=0.05$ . Response to development varied with lake class.

### Extent of Lakeshore Converted to Lawn

Vermont's eight large oligotrophic lakes had significantly more randomly selected sites with lawn present in the immediate 25' x 25' riparian plot than the five large oligotrophic lakes studied in Maine. At the whole lake level, on average, 20% of Maine's lakeshore had been converted to lawn, whereas on Vermont lakes 45% of the lakeshore had been converted to lawn (Figure 8).

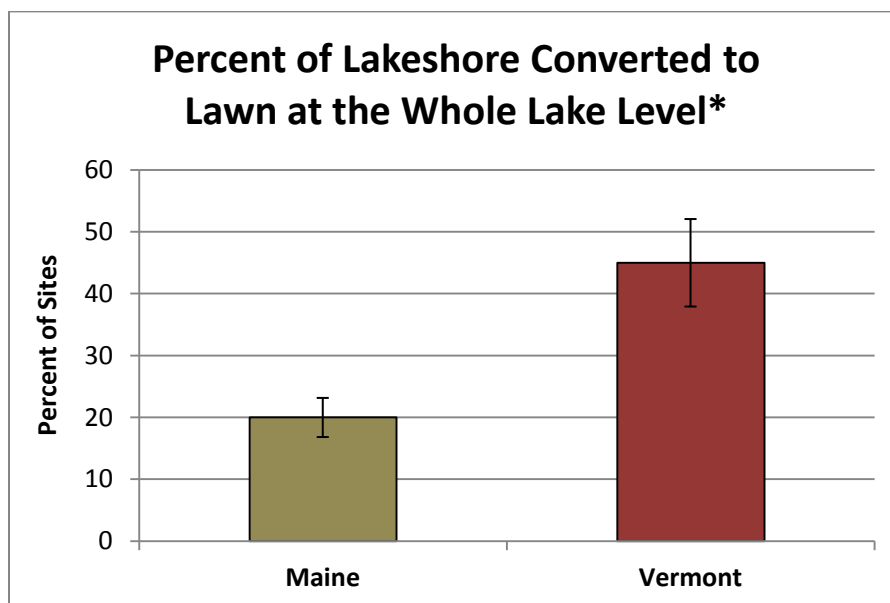


Figure 8. Percent of 10 randomly selected shoreline locations with lawn present on each of the Littoral Habitat Assessment study lakes in Maine (n=5) and Vermont (n=8). Sites were generated as equidistant points along lake perimeters and evaluated for presence of lawn using 2012 high-resolution aerial imagery. \*Vermont showed a significantly higher proportion of sites with lawn present (t-test;  $p = 0.009$ ). Data are from large (>200 ac) oligotrophic lakes only.



## DISCUSSION

Vermont and Maine have adopted different strategies for protecting their lakes from the negative impacts of lakeshore development. Both leave responsibility to the towns to adopt a specific ordinance appropriate to the town's preferences. Maine requires that towns adopt a shoreland zoning ordinance at least as restrictive as the model ordinance developed by MEDEP lake scientists. Although the VTWQS set forth management objectives and criteria for the protection of aquatic habitat, biota and wildlife, Vermont has no minimum required standards. The responsibility to craft an ordinance protecting aquatic habitat has been left to town volunteers.

The VTDEC is tasked with ensuring that Vermont's lakes are managed and protected in compliance with the Vermont Water Quality Standards (VWQS). The VWQS serve as the foundation for protecting all of Vermont's surface waters, and classify each waterbody, establish uses (e.g. swimming, fishing, aquatic biota, wildlife and aquatic habitat) that must be protected, and set minimum chemical, physical and biological criteria that must be met in all of Vermont's waters. The VWQS are intended to achieve the goals set out in Vermont's water quality policy (10 V.S.A. Section 1250), which include the prevention of degradation of high quality waters; the prevention, abatement and control of all activities harmful to water quality; the maintenance of water quality necessary to sustain existing aquatic communities; and to seek over the long term to upgrade the quality of waters and to reduce existing risks to water quality. These goals are supported through the surface water management objectives and criteria set forth in the VWQS. Until the studies described in this report, VTDEC had not systematically measured the impacts of lakeshore development on aquatic habitat, biota and wildlife to determine if these impacts were in conflict with the Vermont Water Quality Standards and Vermont's water quality policy. In addition, VTDEC did not know if lakeshore development standards existed that could protect aquatic habitat, biota and wildlife consistent with the goals of the the VWQS and Vermont's water quality policy.

By studying 234 reference lakeshore sites and 151 unbuffered developed lakeshore sites on 40 lakes in Vermont, VTDEC determined that the level of development allowed on Vermont lakes is degrading aquatic habitat and biota in conflict with the Vermont Water Quality Standards (Merrell, Howe, & Warren, 2009) and Vermont's water quality policy. In comparison, by studying 13 reference lakeshore sites and 36 developed sites following Maine's minimum mandatory standards on 5 lakes in Maine, VTDEC and MEDEP determined that at the site level the kind of development allowed on Maine lakes was not degrading aquatic habitat and biota and would protect Vermont's waters consistent with the VWQS and Vermont's water quality policy.

The effectiveness of Maine's Mandatory Shoreland Zoning Act (MSZA) in Maine, and the effect of an absence of such a law in Vermont, was reflected in each littoral habitat variable measured. All variables, except for one, showed that Maine's MSZA is successful in mitigating the effects of shoreland development. These habitat variables are discussed in categories below.

### *Shoreline Tree Cover and Shading*

Trees along immediate lakeshores may be the most important part of a riparian buffer, as these trees provide the greatest amount of shading, dampening of erosive rain energy, habitat structure and food items for the littoral area. Vermont unbuffered-developed lakeshores sites had significantly less tree cover, and resulting littoral shading, than reference sites (Figure 3). In contrast, Maine developed lakeshore sites showed no significant difference in shading from the reference sites (Figure 5).

Trees provide fish with important habitat structure, shade to keep water cool and protective cover to hide them from avian predators. Fish species richness is lower along developed shores compared to undeveloped lakeshores (Engel & Pederson Jr., 1998) and (Brazner, 1997) the number of sensitive native species decline, while more disturbance tolerant species endure (Brazner, 1997), (Brown, Josephson, & Krueger, 2000) and (Taillon & Fox, 2004).



*Example of how visible fish can be to avian predators when littoral areas are not shaded (VTDEC)*

Dragonflies and damselflies, important predators of mosquitoes, use trees along the lakeshore for refuge from predation while transforming from their aquatic phase into their adult phase. This

transformation requires that they allow their newly unraveled wings time to dry in a place safe from predators. Trees provide that safety (Taylor, 2006).



*Skin or 'exuviae' left behind by a dragonfly on a cedar along the shore of Fosters Pond, Vermont (VTDEC)*

Wildlife is also impacted by the removal of trees along a lakeshore. A study in Ontario found the winter browse supply for deer was four times lower on developed lakeshore lots than undeveloped lots (Armstrong, Euler, & Racey, 1983). Voigt and Broadfoot (1995) found that the winter carrying capacity of deer in Ontario was 30 deer per mile for undeveloped lakes versus 5 per mile for developed lakes.



*Deer browse line along lakeshore in Vermont (VTDEC)*

Another study in central Ontario found that mink activity decreased as a function of the level of lakeshore development. The clearing of vegetation from developed lots was responsible for the decline in mink activity along developed shores (Racey & Euler, 1983).



### *Woody Habitat Structure and Leaf Litter*

Vermont unbuffered developed lakeshore sites had significantly less coarse, medium and fine woody structure than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in coarse, medium or fine woody structure from the reference sites (Figure 5). Coarse woody structure provides habitat for many life stages of fish and basking sites for turtles (Engel & Pederson Jr., 1998). Turtles are cold-blooded so the temperature of their surroundings directly influences their body temperature. Basking in the sun on coarse woody structure helps turtles increase their rate of food digestion. It also helps rid them of ectoparasites and reduce the amounts of algae growing on their shells, which makes them more maneuverable underwater (Franklin, 2007).



*When coarse woody structure as basking sites is limiting, turtles stack themselves on top of one another in an attempt to receive the sunlight (VTDEC)*

An experiment in Little Rock Lake, Wisconsin found that when coarse woody structure was reduced from 475 logs/km to 128 logs/km, yellow perch went from the most abundant fish in the lake to very low densities (Helmus & Sass, 2008).

Fine and medium woody structure provide habitat and cover to fish from both avian and aquatic predators. It also provides structure above the sediments which frogs and other amphibians may use to attach their eggs. This is important because eggs that are not suspended in the water column can be buried by siltation that can smother the eggs. A study by Woodford and Meyer (2002) found that green frog abundance declines with more homes per mile of lakeshore.



*Fine and medium woody structure (VTDEC)*

Vermont unbuffered developed lakeshore sites had significantly less deciduous leaf litter than reference sites (Figure 3), whereas, Maine buffered-developed lakeshore sites showed no significant difference in deciduous leaf litter from the reference sites (Figure 5). Leaf litter provides food and habitat for aquatic macroinvertebrates (France, 1998). VTDEC has begun to collect aquatic macroinvertebrates and preliminary findings suggest that macroinvertebrate communities in rocky littoral areas in unbuffered developed sites are significantly altered from those found at reference sites. Ontario researchers found that, depending on the substrate, macroinvertebrate biomass or species composition was altered by lakeshore development (De Sousa, Pinel-Alloul, & Cattaneo, 2008).

### ***Stormwater Runoff and Deposition of Fine Sediments***

Vermont unbuffered developed lakeshore sites showed significantly more sand and embeddedness than reference sites (Figure 3), whereas, Maine developed lakeshore sites had no significant difference in sand or embeddedness from the reference sites (Figure 5). Modeling work from Wisconsin has shown that an unbuffered developed lakeshore site contributes seven times the phosphorus and 18 times the sediment that a naturally forested site contributes (Panuska, 1995). While it is illegal to put sand into a lake in Vermont, it is not illegal for residents to put sand along their lakeshore. Sand added to the lakeshore is washed into the lake by rain and wave activity.

As sediment and sand runs off the lakeshore and into the nearshore littoral habitat the interstitial spaces between cobble, gravel, and woody structure become embedded. These spaces, which provide

habitat for fish and macroinvertebrates, are degraded or lost as a result. Many macroinvertebrates live in the spaces created between rocks; when these spaces are filled in with fine sediment, their habitat is lost. The increased runoff of sediment and sand reduces the nesting success of fish, because the eggs are under a film of sediment or sand and no longer oxygenated. The probability that a fish nest will produce swim up fry is higher on lakes with fewer dwellings (Wagner, Jubar, & Bremigan, 2006). A study by Reed (2001) found that largemouth bass nests were found mainly along undisturbed lakeshores.



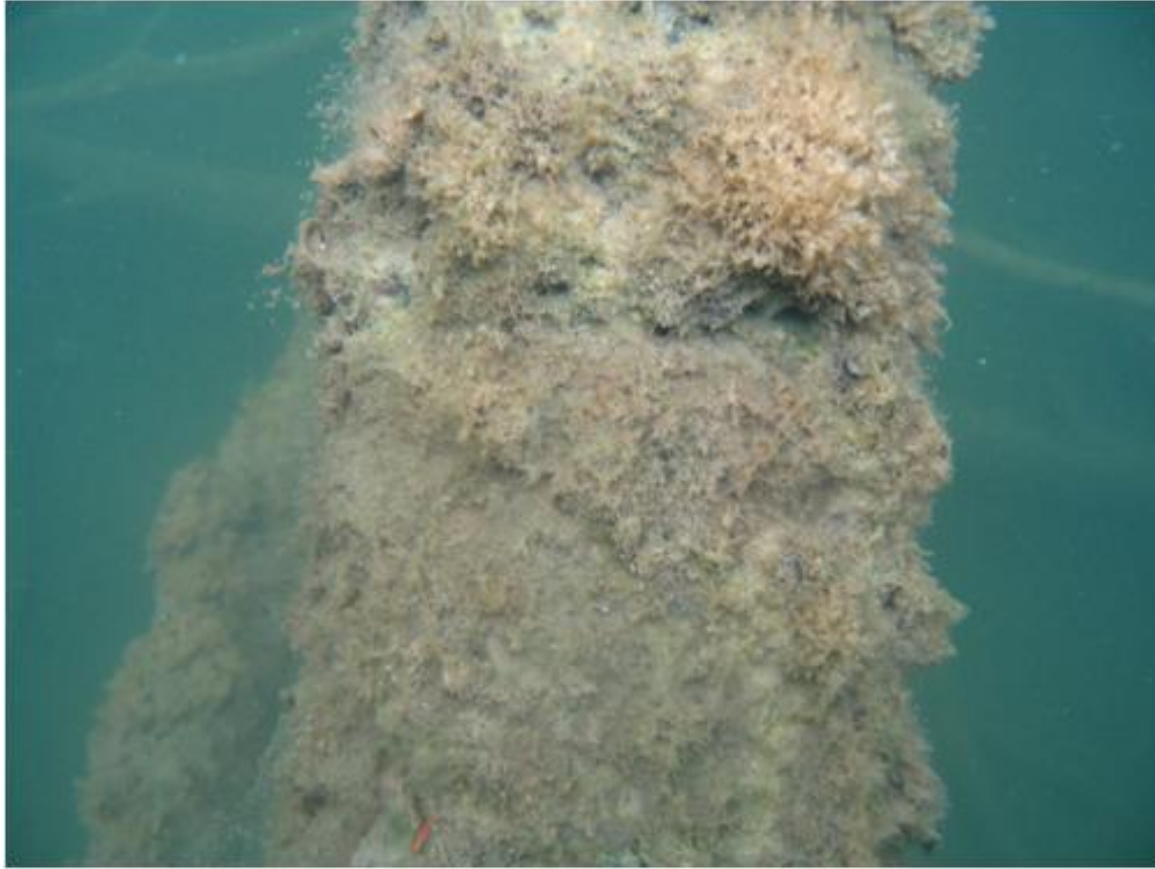
*The clean area of this rock shows how embedded it had become in the sediments; the embedded portion of the rock indicates potential lost habitat for fish and macroinvertebrates (VTDEC)*

### ***Effects on Lake Biology: Aufwuchs, Odonates and Aquatic Plants***

Aufwuchs is the biofilm of small animals and plants that grows on rocks, woody structure, aquatic plants, and benthic substrates. Fish, snails, and other aquatic animals feed on it. Only when looked at under a microscope can one see the diversity and complexity of life that makes up aufwuchs. Bryan and Scarnecchia (1992) found that the number and abundance of juvenile fish species declines with increased lakeshore development and this may be in part due to less cover of aufwuchs.

Aufwuchs cover in Vermont unbuffered developed lakeshore sites was considerably less than cover in Vermont reference lakeshore sites, the difference being statistically significant (Figure 3). In contrast, Maine developed lakeshore sites showed no significant difference in aufwuchs cover from the reference sites (Figure 5).





*Aufwuchs growing on coarse woody structure in a Vermont lake (VTDEC)*

Dragonflies and damselflies, which are insects from the order Odonata, rely on both healthy littoral areas and intact riparian habitats. They live the first part of their lives, which may last several years, in the lake and the adult part in the terrestrial world. In order to make the transformation from the aquatic phase into their adult phase, they need to find a safe place to crawl out of the lake and emerge from their larval exoskeleton, or *exuviae*. The emergence spot must provide cover from predators as well as a surface where they can unravel their wings to let them dry and harden until they are ready to take flight. As part of these Littoral Habitat Surveys, VTDEC searched for the *exuviae* that were left behind on trees, shrubs or leaf litter. In both Vermont and Maine, significantly less odonate *exuviae* were found in nearshore littoral habitat along developed shores than reference sites (Figure 3 and Figure 5). This result suggests that odonates may require larger expanses of undeveloped shoreland than is found at sites meeting Maine's minimum shoreland protection standards to show no change from reference. Although, the number of odonate *exuviae* found along Vermont's reference sites was the same as that found along Maine's developed sites. This finding could be due to regional differences in odonates or due to the different years each state was sampled. It also may be a sign that odonates are sensitive to whole lake impacts of lakeshore buffer degradation, since Vermont's lakes were fringed by more lawn (45%) than Maine's (20%) were.



VTDEC found that aquatic plant cover was the one parameter measured that did not respond to unbuffered lakeshore development the same way across all lake classes (Figure 7). Lake size and trophic condition are important drivers of how aquatic plants respond to unbuffered development. Vermont dystrophic lakes are the dark colored tannic lakes with poor acid neutralizing capacity and that are more impacted by acid rain. These lakes often have wetlands for lakeshore. To sample an adequate number of reference sites in this class of lakes, VTDEC used sections of lakeshore with wetlands present for reference sites, something successfully avoided on all the other lake classes. Hence, many of the dystrophic reference sites were adjacent to wetlands where an elevated number of aquatic plants grow. In contrast, the developed sites were adjacent to upland sites with less aquatic macrophyte cover. The pattern of aquatic plant growth found at unbuffered developed sites in the dystrophic lakes is due to the lack of forested undeveloped sites on these lakes.

On small lakes, both oligotrophic and mesotrophic, aquatic plant cover was greater at the developed sites. On these lakes, unbuffered lakeshore owners' activities on land actually enhance habitat conditions for aquatic plant growth. The removal of the trees results in less shading of the littoral zone, so light is more available. In addition, the increased runoff provides local sources of nutrient enrichment. Elevated light and nutrients result in increased plant growth on large mesotrophic and large oligotrophic lakes as well, yet the opposite effect was observed in these lake classes. Less vegetation was found at the unbuffered developed sites than at the reference sites. This response can be interpreted to be due to active removal of the plants by the lakeshore residents. The larger lakes support a much wider variety of lake uses than the smaller lakes, and many of these uses are not always compatible with aquatic plants making them active targets for removal or collateral damage from heavier use of the littoral zone.

The change in aquatic plant cover in relation to lakeshore development was the same for large oligotrophic lakes in both Vermont and Maine (Figure 7). The lowest aquatic plant cover was found at the developed sites, although the magnitude of difference from reference was less in the sites meeting Maine's MSZA standards compared to the Vermont unbuffered developed sites. Difference between reference and developed sites in both Vermont and Maine were not statistically significant, primarily because there was variability in plant abundance. Some of the variability at the developed sites is attributed to the level of effort the lakeshore owner is putting into removal of aquatic plants.

### ***Water Quality Standards and Maine Waterbodies***

The Vermont Water Quality Standards provide criteria to protect aquatic habitat and biota for each class of waterbody. All habitat parameters measured off the sites following Maine's MSZA standards had no statistically significant change from reference and could be interpreted as meeting Vermont's Water Quality Standards. Two of the three biological parameters, aquatic plant and aufwuchs cover also met Vermont's Water Quality Standards at the Maine developed sites. One biological parameter, odonates, seems to be particularly sensitive to lakeshore development even when it is done following Maine's MSZA standards. Suggesting that in order to achieve compliance with only minor differences from the reference condition for this biota, more stringent standards than Maine's would need to be established.

### *Whole Lake Implications*

While the purpose and design of this study was not to evaluate how effective Maine is at obtaining compliance with the MSZA standards, Figure 8 shows that Maine's law is making a difference at the whole lake level. Grandfathered developed lots and lots not in compliance with the MSZA standards resulted in an average of 20% of the lakeshore still being degraded by conversion of the natural buffer into lawn. Figure 8 also shows that lacking a MSZA, 45% of Vermont's lakeshore has been converted to lawn. It is not known just how much degradation of its lakeshore a lake can endure at the whole lake level. A study of the stressors to Northeastern lakes suggested that breaks for determining whether or not a lake was moderately or highly disturbed could be set at 25 and 50 percent (Whittier, 2003). Using those cutoffs, 80% of Maine's study lakes fell in the low stress category and 20% in the moderate stress category. Whereas, 12.5% of Vermont's lakes of similar size and water quality to those in Maine fell in the low stress category, 37.5% in the moderate stress category and 50% in the high stress category.



*Red spotted newt among fine woody structure, leaf litter and aufwuchs in Vermont (VTDEC)*

## CONCLUSION

When VTDEC went looking for developed lakeshore lots in Vermont to use to test whether Maine's MSZA standards were consistent with Vermont's Water Quality Standards and Vermont's water quality policy for protecting aquatic habitat or biota, not enough sites could be found. In fact, VTDEC looked at over 1,848 developed lakeshore lots in Vermont and found less than 0.5% to have developed their lakeshore lots in compliance with Maine's minimum standards. It was for this reason VTDEC collaborated with MEDEP and sampled developed sites in Maine that met the MSZA standards.

The developed sites surveyed in Maine showed no statistical difference in aquatic habitat from undeveloped reference sites, indicating that the MSZA is an effective tool in mitigating the effects of shoreland development. Only one parameter, number of odonata exuviae, showed statistical differences between developed and undeveloped reference sites in Maine. Although there were still as many odonate exuviae found at the Maine developed sites as there were found at the Vermont reference sites. While this suggests that odonates require larger expanses of undeveloped shoreland than is found at Maine MSZA compliant developed sites to have no change from reference, it also suggests that odonates may be sensitive to whole lake level development

Eighty percent of the Maine study lakes were under low lakeshore disturbance stress. In contrast, 12.5% of Vermont's lakes of similar size and water quality to those in Maine fell in the low stress category, 37.5% in the moderate stress category and 50% in the high stress category. As a result, VTDEC had trouble finding adequate reference sites in Vermont and sometimes had to settle for sites in the 'privacy buffer' between two heavily developed sites. This is why only 66% of Vermont's reference sites on the large oligotrophic lake class met Maine's MSZA.

The Vermont Water Quality Standards provide criteria for the protection of aquatic habitat, biota and wildlife. In this study, all habitat parameters and all but one biological parameter evaluated at lakeshore sites meeting Maine's MSZA standards had no statistical change from reference condition; consequently, these sites could be interpreted as meeting Vermont's Water Quality Standards.

Maine modeled its 1971 Mandatory Shoreland Zoning Act after what had been passed in Vermont in 1970. Vermont passively repealed its law in 1975, while Maine moved ahead. In many cases it is difficult to determine how effective a law is at achieving its intended goal. Even if a study can be designed to do this, there often are not the resources to perform the monitoring. Through a unique collaboration between states, Maine DEP was able to determine that the standards they have enacted through their law work to protect aquatic habitat and biota. Vermont DEC was able to determine that by following Maine's MSZA standards it is possible to develop lakeshore in a manner that does not conflict with the Vermont Water Quality Standards and Vermont's water quality policy. This study has shown that Maine's MSZA standards result in an effective riparian buffer that can ameliorate the harsh effects of shoreland development on habitat and biota in the littoral zone. It also shows that Vermonters as a whole do not voluntarily maintain native woodlands along the shore, such as would comply with Maine's minimum standards.

## BIBLIOGRAPHY

- Armstrong, E., Euler, D., & Racey, G. (1983). White-tailed deer habitat and cottage development in central Ontario. *Journal of Wildlife Management* , 47, 605-612.
- Brazner, J. (1997). Regional, habitat, and human development influences on coastal wetland and beach fish assemblages in Green Bay, Lake Michigan. *J. Great Lakes Res.* , 23(1), 36-51.
- Brown, P., Josephson, D., & Krueger, C. (2000). Summer habitat use by introduced smallmouth bass in an oligotrophic Adirondack lake. *Journal of Freshwater Ecology* , 15 (2), 135-144.
- Byran, M., & Scarnecchia, D. (1992). Species richness, composition and abundance of fish, larvae and juveniles inhabiting natural and developed shorelines of a glacial Iowa lake. *Environ. Biol. Fishes* , 35, 329-341.
- De Sousa, S., Pinel-Alloul, B., & Cattaneo, A. (2008). Response of littoral macroinvertebrate communities on rocks and sediments to lake residential development. *Can. J. Fish. Aquat. Sci* , 65, 1206-1216.
- Engel, S., & Pederson Jr., J. (1998). *The construction, aesthetics and effects of lakeshore development: a literature review*. Madison: WI DNR, Research Report 177.
- France, R. (1998). Colonization of leaf litter by littoral macroinvertebrates with reference to successional changes in boreal tree composition expected after riparian clear-cutting. *The American Midland Naturalist* , 140 (2).
- Franklin, C. J. (2007). *Turtles: An Extraordinary History 200 Million Years in the Making*. Voyageur Press.
- Graczyk, D., Hunt, R., Greb, S., & Buchwald, C. a. (2003). *Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999–2001*. Retrieved 2 27, 2012, from USGS Web site: <http://pubs.usgs.gov/wri/wrir-03-4144/pdf/wrir-03-4144.pdf>
- Helmus, M., & Sass, G. (2008). The rapid effects of a whole-lake reduction of coarse woody debris on fish and benthic macroinvertebrates. *Freshwater Biology* , 53, 1423–1433.
- MEDEP. (2003). *Issue Profile: Mandatory Shoreland Protection Act*. Retrieved 2 27, 2012, from Maine Department of Environmental Protection: <http://www.maine.gov/dep/land/slz/ip-shore.html>
- MEDEP. (2008). *Maine Shoreland Zoning: A Handbook for Shoreland Owners*. Retrieved 2012, from <http://www.maine.gov/dep/land/slz/citizenguide.pdf>



- Merrell, K., Howe, E., & Warren, S. (2009, Spring). *Examining Shorelines, Littorally: The Effects of Unbuffered Lakeshore Development on Littoral Habitat*. Retrieved 2 27, 2012, from Vermont Department of Environmental Conservation:  
[http://www.anr.state.vt.us/dec/waterq/lakes/docs/lp\\_littorally.pdf](http://www.anr.state.vt.us/dec/waterq/lakes/docs/lp_littorally.pdf)
- Panuska, J. a. (1995). *Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agriculture and Forested Watersheds. Research Management Findings, No. 38*. Madison: Bureau of Research, Wisconsin Department of Natural Resources.
- Racey, G., & Euler, D. (1983). Changes in mink habitat and food selection as influenced by cottage development in central Ontario. *Journal of Applied Ecology* , 20, 387-402.
- Reed, J. (2001). Influence of shoreline development on nest site selection by largemouth bass and black crappie. International North American Lake Management Society Conference.
- Taillon, D., & Fox, M. (2004). The influence of residential and cottage development on littoral zone fish communities in a mesotrophic north temperate lake. *Environmental Biology of Fishes* , 71, 275-285.
- Taylor, P. D. (2006). Movement behaviours of a forest odonate in two heterogeneous landscapes. In A. C. (Ed), *Forests and Dragonflies* (pp. 225-238). Pontevedra, Spain: Pensoft Publishers.
- Voigt, D. R., & Broadfoot, J. D. (1995). Effects of cottage development on white-tailed deer, *Odocoileus virginianus*, winter habitat in Lake Muskoka, Ontario. *Canadian Field-Naturalist* , 109, 201-204.
- VTDEC. (2013, March). Residence Density Near Vermont Lakes. Montpelier, VT: Conservation, Vermont Department of Environmental.
- VTWRP. (2008). *Vermont Water Quality Standards*. Retrieved February 16, 2012, from Vermont Natural Resources Board: <http://www.nrb.state.vt.us/wrp/publications/wqs.pdf>
- Wagner, T., Jubar, A., & Bremigan, M. (2006). Can habitat alteration and spring angling explain largemouth bass nest success? *Transactions of the American Fisheries Society* , 135, 843-852.
- Whittier, T. S. (2003). Indicators of Ecological Stress and their Extent in the Population of Northeastern Lakes: A Regional Scale Assessment. *Bioscience* , 52 (3), 235-247.
- Woodford, J., & Meyer, M. (2002). Impact of lakeshore development on green frog abundance. *Biological Conservation* , 110, 277-284.