Ecological Assessment of the Peterson Dam Reach of the Lamoille River

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Executive Summary

Prior to the construction of Peterson dam in 1948, the Lamoille River provided habitat conditions between the Peterson dam site and Milton dam that are now scarce. Salmon and lake sturgeon are believed to have historically ascended upstream at least to Miners Falls. Walleye, suckers and redhorse ascended at least to Manley Falls. These and other fishes migrate into the river from Lake Champlain to spawn. Only a small area of the gravelly or rocky substrates and faster flowing water they require exists downstream of Peterson dam. Suitable spawning and incubation habitat for these species exists upstream of Peterson dam, although the dam renders it unusable due to the impoundment of water. Removal of Peterson dam would significantly increase the quantity and diversity of available habitat. It would restore the ecological connection between the lake and the river that these species rely on to complete their life cycle. Dam removal would restore habitat for 6 endangered species, 2 that are threatened and 6 that are rare (fish and mussel species). River restoration would increase the habitat for mussels, many of which are threatened or endangered primarily as a result of habitat loss. Riverine habitat upstream of Peterson dam could provide native mussels with a refuge from zebra mussels.

The Lamoille River walleye population is limited by the number of young fish entering the population. The currently available area of spawning and incubation habitat for walleye, sturgeon and other fishes with similar habitat requirements is small. The availability of a greater area and range of habitat conditions makes it more likely that fish can find the spawning habitat they need for whatever the prevailing flow conditions are. It is likely that restoring the riverine habitat above Peterson dam will increase walleye reproductive success and consequently the production of young fish.

Unlike the Winooski River, there is no recent evidence of successful sturgeon reproduction or the existence of juveniles in the Lamoille River. Dam removal would restore historic sturgeon staging, spawning, incubation, and juvenile habitat that is probably very important to the restoration of this endangered species.

While there is some uncertainty about the suitability of the temperature regime for salmon rearing, the physical habitat is good. If salmon go upstream only as far as Miners Falls, the best conservative estimate is that an average annual run of about 200 adult salmon could be sustained from natural reproduction in the downstream sub-reaches. Salmon smolt stocking downstream of Peterson dam has produced a modest run of adult salmon, but no known natural reproduction.

If Peterson dam were removed, the upstream reach would provide abundant sea lamprey spawning habitat and presumably some silty areas that could support larvae. The amount of lamprey production that could result from dam removal is uncertain.

Dam removal would eliminate some fish species that currently reside in the impoundment, replacing them with riverine species.

Peterson dam is unique and in a class by itself in terms of its location and the extent of its impact on the environment. As one of the major tributaries to Lake Champlain, the lower Lamoille River plays a vital role for its fish that need both lake and river habitats. The dam interferes with the propagation of fish. Dam removal will restore 2.9 miles of river and historical habitat of key importance to the biological community of Lake Champlain.

Introduction

The removal of Peterson dam and other alternatives are being discussed as part of the relicensing of the Lamoille hydropower project. The "Peterson Reach" extends from Peterson dam upstream to the vicinity of Milton Falls and the Milton dam. Completed in 1948, Peterson dam currently impounds the large majority of this reach, up to Milton Falls. Removal of the dam would restore the river environment and reconnect it with Lake Champlain. The purpose of this report is to assess the ecological implications of dam removal. The physical characteristics of the river reaches are assessed, since they are important to determining the value of the habitat for various species and how far upstream fish entering the river from Lake Champlain can ascend. The significance of restoring the riverine habitat is then discussed for three important fishes (lake sturgeon, walleye and landlocked Atlantic salmon) and for other aquatic species. The value of the Peterson impoundment as habitat is also addressed.

Population Status of Walleye and Lake Sturgeon

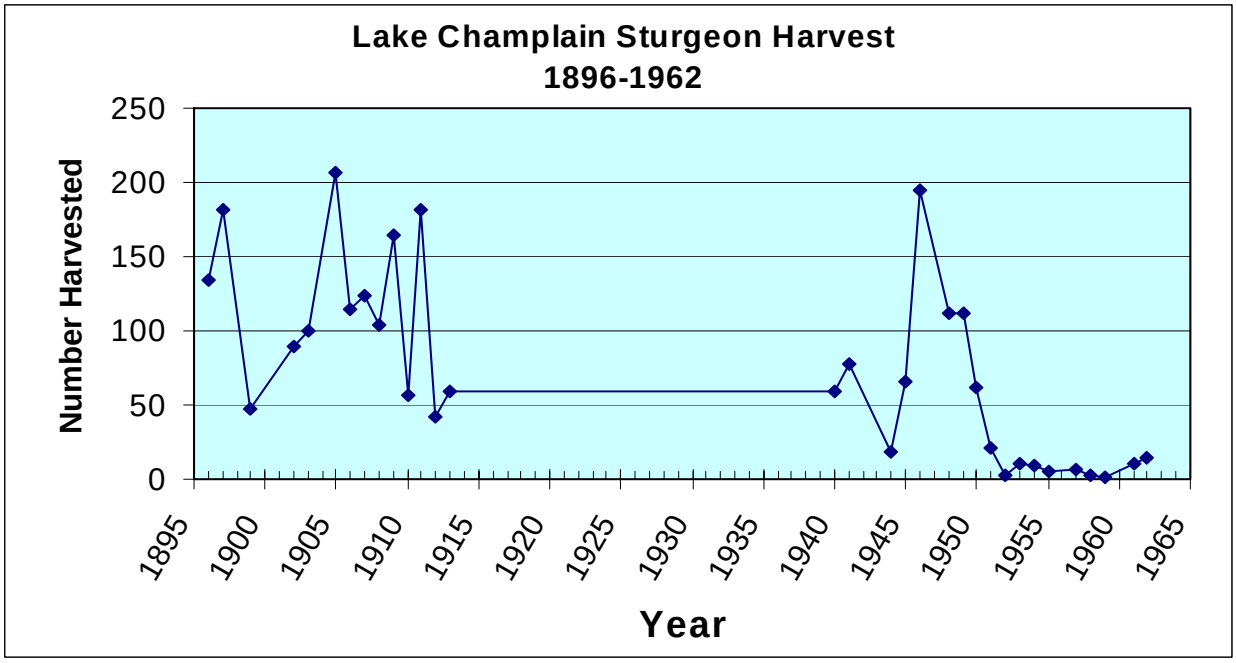
Lake Sturgeon: The lake sturgeon is now scarce in Lake Champlain and is a state-listed endangered species. Historically, spawning runs of lake sturgeon occurred only on the Vermont side of Lake Champlain, primarily in the Missisquoi and Lamoille Rivers and to a lesser extent, in the Winooski River and Otter Creek. Recent surveys and incidental catches by anglers indicate that only a few fish now run these rivers. Males mature around 15 years of age and females, 25 years.

In 1998, the Vermont Department of Fish and Wildlife (VDFW) and U.S. Fish and Wildlife Service began a cooperative assessment program that included sampling for adult sturgeon during spring spawning runs in the Winooski and Lamoille Rivers. One purpose of the program is to build a sufficient information base so that a management plan for lake sturgeon can be developed. During spring gill net sampling in 1998-2002, a total of nine individual sturgeon were captured and tagged in the Lamoille River and 15 in the Winooski River. Some tagged fish have also been recaptured in subsequent years. All fish were males except for two that were too small (38 and 42 inches) for the sex to be determined. Females are probably less vulnerable to capture since they do not spawn every year and do not spend as much time in spawning areas as do males. Efforts have yet to be undertaken to sample juveniles, although one young sturgeon (6.7 inches total length) was caught in August, 2001 in the Winooski River during sampling work for other species. This fish is the only recent evidence of the existence of juveniles.

In 2003, Vermont Fish & Wildlife Department biologists began sampling for sturgeon eggs in the Winooski and Lamoille Rivers. Special egg traps were built using mats of filter fabric wrapped around concrete blocks. The egg traps were placed on river bottoms in suspected spawning areas where they capture eggs as they are released by adult fish. Sturgeon eggs were collected in both rivers, providing documentation that sturgeon are still spawning at both sites. In 2004, biologists expanded their search for sturgeon eggs to all four rivers where sturgeon spawning was historically documented. Sturgeon eggs were collected in both the Winooski and Missisquoi Rivers, and a larval sturgeon was captured in Otter Creek near the dam at Vergennes. Two weeks after eggs were collected in the Winooski River, biologists set drift nets in an

attempt to capture free-floating larval sturgeon drifting from the spawning areas. In four nights of netting, a total of 80 sturgeon larvae were collected. These results show that sturgeon, although few in number, continue to reproduce.

At one time, Lake Champlain supported a licensed, commercial fishery for sturgeon. Harvest records show that a precipitous decline began in the late 1940s, with the catch dropping to just a few fish by 1952.[1] The harvest never recovered, and the fishery was closed in 1967.



Note: No data for 1914-1939

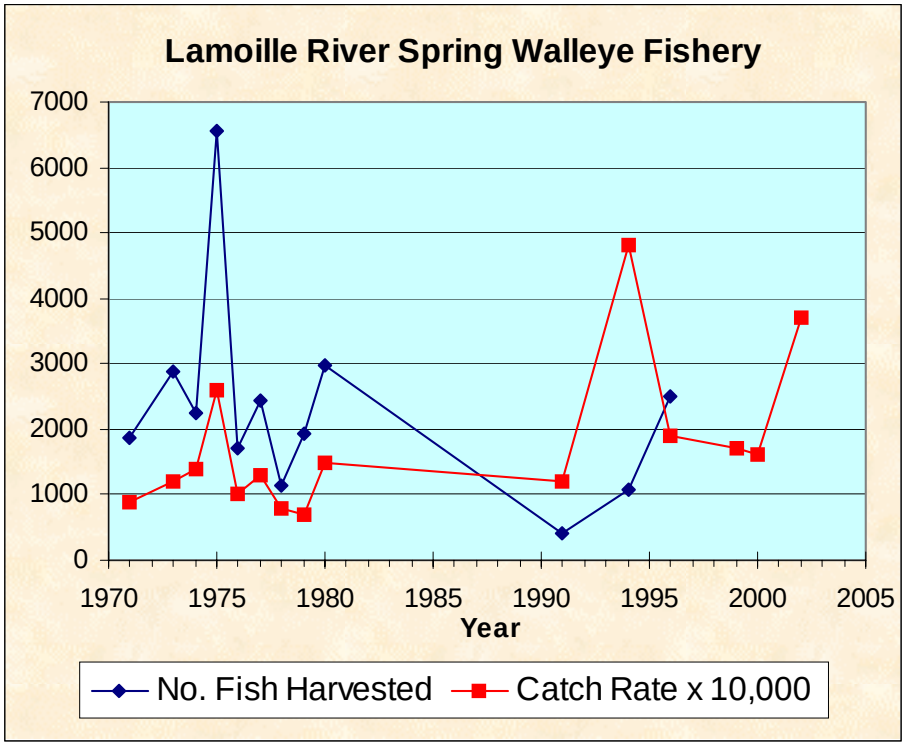
Construction of the Swanton dam in the early 1900s and Peterson dam in 1946-48 significantly reduced the available spawning habitat on the Missisquoi and Lamoille Rivers, respectively. The decline in the commercial harvest is probably due in part to the fact that Peterson dam was built in the immediate vicinity of the sturgeon hole. The dam most likely rendered this hole unsuitable as both a sturgeon holding area and a fishing spot.

Walleye: Lake Champlain walleye spawn in the following rivers: Missisquoi, Lamoille, Winooski, Poultney, and Great Chazy (NY). Fish tagged in the Lamoille River seldom show up outside of Mallets Bay. Mixing between the Lamoille and Missisquoi populations appears to be very limited. Therefore, the Mallets Bay population is reliant upon the Lamoille River spawning habitat.

Walleye numbers have declined significantly in parts of Lake Champlain over the years. While anecdotal reports from anglers indicate that walleye were at one time extremely abundant in the

[1]Halnon, L.C. 1963. Historical survey of Lake Champlain's fishery. Job Completion Report F-1-R-10, Job 6. Vermont Department of Fish and Game. Montpelier, Vermont.

Lamoille River, biological data to describe long term population trends prior to 1970 are lacking. Data are not available for comparing walleye populations in the Lamoille River before and after construction of Peterson dam.



VDFW Data for the spring walleye harvest in the Lamoille River are shown in the following graph. The catch rate is shown as the number of fish caught per 10,000 hours of effort in order to fit on the same scale as harvest. Walleye populations tend to fluctuate widely under natural conditions, as reflected in the graph, so that it is difficult to draw conclusions about population trends. In addition, fishing conditions influence harvest and catch rates. Walleye fingerlings were stocked in the Lamoille River from 1986 to 1991, and recovery of fish with fin clips indicates that these fish have contributed to the fishery. The high catch rate in 1994 is indicative of a large catch of walleye too small to legally harvest. Lamoille walleye typically reach legal size (18 inches) at age 4. The Lake Champlain walleye management plan[2] established a goal for the spring walleye fishery in the Lamoille River of 2,000 fish annually. This goal was selected based on the post-1970 data as a level that could reasonably be achieved within five years. However, the Department is trying to increase walleye populations and believes this harvest can be increased in the future. Higher numbers are certainly possible, such as the 1975 harvest of 6,559 fish.

The Lamoille walleye population is recruitment limited, meaning that the size of the population is limited by the number of young fish. This conclusion is supported by the fact that there are good numbers of older fish in the population, indicating that adult mortality is low. Low recruitment could result from reproductive failure or poor survival during the first year of life. Reproductive failure could be caused by a lack of suitable spawning sites, flow manipulation, or water quality problems such as sediment, low dissolved oxygen or pollutants. VDFW biologists have observed that walleye egg deposition in the Lamoille is very dense, suggesting that

[2]Vermont Department of Fish and Wildlife. 1998. A plan for management of walleye fisheries in Lake Champlain, Vermont waters, 1998-2002. Waterbury, Vermont.

spawning habitat is in short supply. Additional spawning habitat would probably be of immediate benefit to the population.

The CVPS report *Lower Lamoille River Habitat Values*[3] states that in 1990 the company began operating the hydropower stations as run-of-river during the spring, and that the "stabilized flows downstream of Peterson during walleye spawning may have resulted in greater walleye returns." While the increased walleye harvest between 1991 and 1996 may be due to a number of factors, such a population response to flow would confirm that spawning success is limiting the population.

Salmon: The Lamoille River has been stocked with salmon every year since 1983 and intermittently during the 1970s. Most of the fish were stocked downstream of Peterson dam, as smolts[4] that should immediately emigrate to Lake Champlain. These fish were stocked in the river so that they would imprint on it and hopefully return again as adults. The target stocking goal for most of this time has been 15,000 salmon, although the actual number stocked varied somewhat from year to year. Currently the stocking goal below Peterson dam is 20,000 smolts. Annual numbers of adult salmon collected by VDFW electrofishing in the Lamoille River during the fall run varied from a high of 320 in 1993 to a low of 2 in 1996.[5] The average catch during 1987-1997 was 77. Variation in the catch was affected by sampling effort and river flows. VDFW personnel have observed salmon excavating redds (nests) in gravel areas downstream of Peterson dam. However, no natural reproduction indicated by the presence of juvenile salmon has been documented. Flow regulation in the past has probably not provided year-round juvenile rearing habitat.

Physical Characteristics of the Peterson Reach of the Lamoille River

The habitat needs of fish differ by species, life stage and time of year, and a major determinant of habitat value is the physical nature of the environment. Therefore an effort to assess the habitat benefits associated with dam removal requires an examination of the physical characteristics of the reach. For rivers, these characteristics include water depth, water velocity, the nature of the river bottom or substrate material and the occurrence of barriers to movement. The existence of riffles[6], runs[7] and pools are also important, related considerations. Water

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[3]Central Vermont Public Service Company. 2000. Lower Lamoille River Habitat Values. Lamoille River Hydroelectric Project, FERC No. 2205. Prepared by Gomez and Sullivan Engineers, P.C.

[4]A smolt is a juvenile salmon that has undergone morphological, physiological and behavioral changes that prepare it to then migrate downstream from the river it grew up in.

[5]Fisheries Technical Committee. 1999. A comprehensive evaluation of an eight year program of sea lamprey control in Lake Champlain. Lake Champlain Fish and Wildlife Management Cooperative.

[6]Riffle: A relatively shallow, swift-flowing reach of stream where the water surface is broken into waves by obstructions wholly or partly submerged.

[7]Run: A portion of a stream with low surface turbulence which approximates uniform flow, and in which the slope of the water surface is roughly parallel to the overall gradient of a stream reach.

temperature, dissolved oxygen and other water quality attributes are also important but will be addressed separately.

Since the reach is now underwater and not visible, information about it must be derived from historic records. Recent surveys with the impoundment drawn down provide some information about the upper portion of the reach. The dam was constructed in 1946-1948. Several sources of information are available and form the basis of this assessment:

1) 1941 and 1942 aerial photographs of the reach,
2) 1896 survey showing the river and some elevations (scale 1"=300'),
3) 1927 and 1948 USGS topographic maps,
4) various photographs reproduced in the report, *Lower Lamoille River History*[8],
5) accounts of local residents familiar with the reach prior to dam construction,
6) CVPS consultant's observations of the upper reach during a 4-5 foot impoundment drawdown, 2000,
7) VNRC's observations of the upper reach during an abnormally large impoundment drawdown, 1999,
8) personal observations of the reach upstream of Miners Falls during a 7-foot impoundment drawdown on August 16, 2001, and
9) bathymetric map of Miners Falls prepared by CVPS, 2003.

A copy of the 1896 map is attached to illustrate the configuration of the reach.
The Vermont Natural Resources Council and Central Vermont Public Service have both produced reports about the Peterson Reach, based on all or some of the above sources. The VNRC report *Habitat Suitability of the Peterson Reach and Description of the Peterson Reach Mesohabitat*[9] included a reproduction of the 1942 aerial photo. However, stereo pair photos taken on September 22, 1941 were used in this analysis in order to take advantage of the three-dimensional quality.

Peterson dam was constructed at Woods Falls. The reach includes the following falls, listed from downstream to upstream:

Woods Falls
Manley Falls
Hulgate Falls
Miners Falls; also known as Poor Farm Falls
Little Falls
Milton Falls; also known as Great Falls

Old maps identify "falls" and "rapids" within the Peterson Reach. It is important to recognize that in common usage, these terms have been applied to a variety of conditions. The term "falls" implies some kind of distinct change in water elevation, and can vary from a chute of water to a

[8]Fellinger, J. 2000. Lower Lamoille River History. Produced for the Vermont Natural Resources Council.

[9]Gustafson, S. and K. Kendall. 2000.

vertical drop. The term “rapids” implies a broken water surface, which can range from steep, rapidly flowing whitewater to a fairly slow flowing stretch punctuated with a number of exposed boulders.

The falls can be used as points for dividing up the reach into sub-reaches for further analysis and discussion. The following reach descriptions are based on the listed original sources. It should be noted that it is difficult to determine substrate conditions from the aerial photographs. Boulders, ledge outcrops, gravel bars, whitewater and shallows are visible, but other underwater features are not. In these photos, pools and runs both generally appear as dark grey, as will a riffle that is more than a foot or so deep and that lacks large rocks protruding above the water surface. For example, an examination of the area downstream of Peterson dam on the aerial photos reveals only a few boulders, ledge outcrops and the shallowest part of the channel near the downstream end of Stoney Island. The deeper riffles, runs and pools cannot be distinguished.

It is possible to interpret what the predominant substrate type will be in a section of the river based on its width and slope. Agency technical staff specializing in stream morphology and channel processes provided such input to VNRC. That information appears in the report by Gustafson and Kendall and in this report .

The following table summarizes the sub-reach physical conditions. Sub-reach lengths were determined from the 1896 survey, using a map wheel plan measure. The lengths of river occupied by Miners Falls (450 feet) and its plunge pool (190 feet) were not included in the table. They were omitted because the sub-reach lengths are used to estimate spawning habitat for walleye and sturgeon and rearing habitat for salmon, and these areas are not expected to provide such habitat. The table also lists the average channel widths, which were based on a series of measurements from the 1896 survey. Width measurements were taken at increments of 300 feet or less along each sub-reach.

Characteristics of the Sub-Reaches of the Peterson Reach

Sub-Reach	Length (ft)	Width (ft)	Area (ft^2)	Substrate*
Below Peterson	The effective area differs for walleye/sturgeon spawning versus salmon rearing. Details appear later in the report.			Cobble/Boulder and Gravel
Woods to Manley	1,950	75	146,250	Cobble
Manley to Hulgate	3,950	184	726,800	Cobble/Gravel
Hulgate to Miners	2,610	203	529,830	Gravel
Miners to Milton	6,180	249	1,538,820	Cobble/Gravel

*Substrate size categories: gravel (0.08"-4"); cobble (4"-10"); boulder (>10").

The following discussion includes references to an interview that VNRC conducted with Richard

"Meester" Morgan in 1995.[10] Mr. Morgan is a life-long resident of West Milton who spent a great deal of time fishing and otherwise enjoying the Lamoille River. The account of Mr. Morgan's observations are consistent with other available information, including the 1986 survey, 1941 aerial photographs and other photographs of the river.

Woods to Manley Sub-reach: This is the narrowest and steepest of the sub-reaches. Ledge, boulders and whitewater are visible in places through the sub-reach. The river banks are predominantly high and steep. The abundance of rocks that are visible on the aerial photos suggests that the substrate over much of this sub-reach is rock. Given the steep and narrow nature of the sub-reach, flowing water processes would be expected to wash away most small material, such as silt, sand and small gravel. The Fellinger report includes a photo (page 10) that clearly shows the rocky nature of the sub-reach. The predominat substrate appears to be cobble (4"-10"). This photo shows a low flow condition, during which much of the sub-reach appears to consist of riffle habitat except for a pool immediately downstream of Manley Falls. Mr. Morgan also describes this pool and indicates that the rest of the reach consisted of rapids. The 1948 USGS topographic map has this section marked as rapids. Under high flows such as those that would often occur during the spring, the sub-reach is probably a fast-flowing run.

Manley to Hulgate Sub-reach: On the aerial photos, this sub-reach includes small areas of whitewater, some shallow areas and some boulders. The gradient is not as steep as the Woods-Manley sub-reach, but is steeper than the upstream sub-reaches. Like the Woods-Manley sub-reach, the river banks are steep. This sub-reach contains two near-right-angle bends (one is immediately upstream of Manley Falls) that probably include deep water to the outside. Mr. Morgan described the area between the two bends as moderately deep, fast water with several short broken water sections. Above the bend, Mr. Morgan described the section as a rapids that flowed over boulders and stones. The 1896 map also labels this section as "rapids." It appears on the aerial photos to contain some boulders, gravel bars, shallow areas and possibly ledge. Most of the sub-reach appears to contain riffle or run habitat. Agency geomorphologists infer that the predominant substrate is cobble and gravel.

Hulgate to Miners Sub-reach: The sub-reach boundary at Hulgate Falls was chosen as the downstream end of the falls, directly downstream of the "finger" of ledge that extends into the channel from the south bank, opposite Streeter Brook. This sub-reach includes some sandbars, shallow areas, scattered boulders in some sections and ledge outcrops. It is a very irregular reach: channel width is highly variable, there are large ledge extensions into the channel, and the channel includes some sharp bends. Parts of the sub-reach are probably riffle habitat. There is probably a pool at the base of Miners Falls. Wide areas near the downstream end of the sub-reach may include pools. In the VNRC interview, Mr. Morgan indicated that a section downstream of Miners Falls about 0.5 miles in length was known as "the pond." Robert Lamphere, another local resident and angler, characterized this reach as "quite flat with some

[10]The content of the interview is included in a written affidavit of C. Mead McCoy, dated 16 November 1995. Mr. McCoy was at the time an employee of VNRC.

rapids."[11] Agency geomorphologists infer that the predominant substrate is gravel.

Miners to Milton Falls Sub-reach: This sub-reach is very uniform in channel width, and no boulders or whitewater are evident on the aerial photos. The nature of the substrate cannot be determined from the aerial photos. For the most part, the river banks along this reach are much less steep than those in the other sub-reaches. Mr. Morgan indicated that the river upstream of Miners Falls was slower with some short, faster moving sections, and he describes the area known as Little Falls as a small rapids formed by ledge. Agency geomorphologists infer that the predominant substrate is gravel. Steve Shepard (a consultant for CVPS) visited this sub-reach last summer when the impoundment was drawn down 4-5 feet and characterized the substrates as sandy. I canoed this reach in August during a 7-foot drawdown. Water depth was variable; some areas were too deep for the substrate to be visible. However, the substrate could be seen in a number of areas where the depth was less than four feet. The dominant substrate was cobble (mostly 3-6") with some larger boulders (6-12") and some large gravel. The following photograph was taken a short distance upstream of Little Falls, and is fairly typical of the reach.

VNRC photographs from similar observations in 1999 also show this substrate, plus some sand and gravel bars. Agency geomorphologists believe that this reach would certainly be gravelly under riverine conditions and that the presence of sand is the result of deposition associated with the impoundment influence. This reach appears in the 1941 aerial photograph to be predominantly a deep, slow run. The cobble substrate suggests that fast water occurs in the sub-

[11] Affidavit dated 15 November 1995.

reach at times of high flow, scouring away some of the finer material.

Physical Characteristics of the Falls of the Peterson Reach and Anticipated Fish Passage

In assessing habitat values of discrete segments of the Peterson Reach, consideration must be given to whether individual "falls" formed barriers to one or more of the fish species of interest. The 1896 survey includes point water surface elevations upstream and downstream of each set of falls other than Milton Falls. The falls are irregular so that determining where each begins and ends is somewhat subjective. Using the survey data, the height of each falls can be estimated. These heights appear below. It is important to keep in mind that none of these heights are vertical drops, but they do provide a general idea of the size of the feature.

Location and Height of the Falls in the Peterson Reach

Falls	Height (ft)	Distance from Dam	
		Miles	Feet
Woods Falls	4.8*	0	0
Manley Falls	7.3	0.37	1,950
Hulgate Falls	3.2	1.12	5,900
Miners Falls	24.0	1.65	8,700
Little Falls	1.3	2.82	14,880
Milton Bypass	---	2.90	15,330

*Lake elevation = 96.8 feet

The following descriptions of the falls are based on interpretation of the aerial photographs. In addition, the Fellinger report includes photos of Woods and Manley falls. While the rock features that comprise the falls are relatively permanent, the nature of the falls will change with the amount of flow in the river. The aerial photographs were taken at a time when flow was low.

Woods Falls: Middle Rock divides the flow at this falls into two channels. Photos in the Fellinger report show no steep drop or falls exists to the north side of Middle Rock. The difference between upstream and downstream water surface elevations probably decreases in the spring when the lake level is higher. It is probable that most fishes were able to ascend past Woods Falls.

Manley Falls: This falls exists at a ledge constriction of the river. It is partly obscured by shade in the aerial photo. While no significant barrier to upstream fish passage is evident, the site may under high flow conditions be a narrow chute with high velocities. It is not possible to determine from the aerial photo whether this falls may have impeded the upstream passage of fishes such as walleye, suckers, redhorse and minnows. It is unlikely to have prevented salmon

and lake sturgeon from ascending.

Hulgate Falls: This falls exists on a bend in the river. Some ledge and whitewater are visible on the aerial photo, but the falls just looks like a steep area. It was probably not an impediment to upstream fish passage.

Miners Falls: These falls are by far the largest in the Peterson Reach, but are not vertical. The ledges that make up the falls extend along about 450 feet of river length. The left side (looking downstream) of the falls is made up of stepped ledge that may have provided for upstream fish passage at higher flow levels. The bathymetric map prepared by CVPS suggests that there may be several possible routes that fish could use to move up the falls. However, it is unclear whether the ledges include adequate resting areas to allow fish to ascend. At low flow conditions, the water flows down a chute on the right side of the falls. This falls was probably an impediment to upstream passage by all fishes except possibly lake sturgeon and salmon. The swimming performance of sturgeon, relative to body length, is inferior to that of salmonids.[12] It seems unlikely that sturgeon would be able to ascend this falls.

Little Falls: This falls, located about 450 feet below the Milton project and bypass, is insignificant as a barrier to fish movement. An island divides the river at the falls, with the right channel (looking downstream) showing some boulders or ledge outcrops plus some whitewater. A small falls appears exist in the left channel. This area was viewed in its unimpounded state in August. It is not an impediment to upstream fish passage.

Historical Use of the Peterson Reach by Lake Sturgeon, Walleye and Salmon Before Construction of Peterson Dam

Lake Sturgeon and Walleye: The Lamoille River historically supported abundant runs of both sturgeon and walleye. Accounts of local residents familiar with the reach prior to dam construction provide information about the areas used by sturgeon, walleye and other fishes. Some accounts are second hand. While only a certain amount of weight was given to the local accounts, their consistency with the physical evidence suggests they are credible. These accounts are summarized below.

Sturgeon ascended upstream to Miners Falls.[13]

Walleye, sucker, redhorse and bullhead were observed immediately below Manley Falls. Sturgeon went upstream at least to Manley Falls.[14]

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[12]Peake, S., F.W.H. Beamish, R.S. McKinley, D.A. Scruton and C. Katapodis. 1997. Relating swimming performance of lake sturgeon, *Acipenser fulvescens*, to fishway design. Can. J. Fisheries and Aquatic Sciences 54:1361-1366.

[13]Anderson, J.K. 1995. Memorandum to Rod Wentworth, describing accounts from Mr. Lamphere (reported as deceased) and another unidentified person, formerly a sturgeon netter.

[14]Lamphere, R. Affidavit dated 15 November 1995 and personal communication on 16 November 2000.

> Sturgeon were observed attempting to ascend Miners Falls. Completion of Peterson dam trapped sturgeon upstream in the impoundment. Quite a number of sturgeon were caught there for years, until sturgeon fishing was prohibited [1967].[15]
>
> Spawning fish coming from Lake Champlain went up the Lamoille River at least to Miners Falls. Walleye and sturgeon were observed in the sub-reach below Miners Falls. Walleye, redhorse and suckers were caught in the Peterson Reach all the way up to Milton Falls.[16] Mr. Morgan recalls that his father caught a sturgeon at Miners Falls.

As discussed previously, all the falls downstream of Miners Falls appear passable by sturgeon. The observations of sturgeon upstream to Miners Falls corroborate this conclusion. It is very unlikely that walleye were able to ascend Miner Falls. The observance of these fish in the upstream sub-reach suggests that they dropped down from Arrowhead Mountain Reservoir or established residence in the sub-reach. The accounts of local residents provide strong evidence that walleye, suckers and redhorse historically ascended to Manley Falls; further upstream passage is less clear. The evidence on the physical nature of Woods Falls also indicates it is not a barrier.

Salmon: Salmon were once abundant in Lake Champlain and its tributaries but were extirpated in the first half of the 1800s. The construction of dams that prevented salmon from reaching spawning and rearing habitat has been cited as the chief cause.[17] Webster[18] researched the history of salmon in Lake Champlain and stated that "the Winooski, Lamoille and Missisquoi Rivers were all considered exceptionally fine salmon streams." Edmunds[19] assessed the Lamoille River and other Lake Champlain tributaries for purposes of salmon restoration, with an emphasis on obstructions to fish passage. His findings are quoted below:

> "You are next introduced into the Lamoille River, which I regard as the most favored

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[15]Baker, F. Affidavit dated 17 November 1995.

[16]Morgan, R. Interview included in a written affidavit of C. Mead McCoy, dated 16 November 1995.

[17]Thompson, Z. 1853. History of Vermont, natural, civil and statistical. Stacy and Jameson, Printers. Burlington, VT.

Van Oosten, J. 1933. Resumé of the history of Atlantic salmon in the United States with special reference to its re-establishment in Lake Champlain. Bureau of Fisheries. Washington, D.C.

Watson, W.C. 1876. The salmon of Lake Champlain and its tributaries. Report of U.S. Commissioner of Fish and Fisheries (1873-4 and 1874-5):531-540.

[18]Webster, D.A. 1982. Early history of the Atlantic salmon in New York. New York Fish and Game Journal 29(1):27-44.

[19]Edmunds, M.C. 1874. Obstructions in the tributaries of Lake Champlain. Report of U.S. Commissioner of Fish and Fisheries (1872-1873):622-629.

> region in Vermont in which to begin the experiment of restocking with salmon. It is a more rapid stream than the Winooski; has more dams situated on it, yet no high perpendicular fall. Although it has many cataracts and cascades, yet not being abrupt, and the dams and falls being low, they could be easily surmounted by the salmon without the aid of fish-ways. The bed of the river being gravelly and the water clear and cold, I think it affords unsurpassed advantage for the introduction of salmon. It will doubtless be the stream upon which operations will first be commenced."
>
> "I am of the opinion that in former years the salmon never got up the large rivers into the interior of the country to any great extent, but that they found their fields for propagation around the mouths of the large rivers and in the coves and inlets of the lake. I reason thus from the fact that nearly or quite all of the large rivers have high natural falls upon them from five to fifteen miles inland, over which it would be impossible for salmon to ascend; and that their abundant increase in the lake was solely due to the nice gravelly coves and inlets so abundant along the shore of the lake and up the mouths of the large rivers."

Historical use of the Lamoille River by salmon seems extremely likely, although specific references of salmon observations in the Lamoille River have not been found. Salmon are strong swimmers and leapers and capable of ascending substantial falls. Other investigators have observed salmon jumping up to about 10 feet.[20] It is very likely that salmon would be able to ascend Milton Falls under flows that would occur at times during the spawning run. Of the downstream falls, only the ability of salmon to ascend Miners Falls seems uncertain.

Probable Historical Upstream Ascent of Salmon, Walleye and Lake Sturgeon in the Lamoille River

Sub-Reach	Salmon	Walleye	Sturgeon
Woods to Manley	Yes	Yes	Yes
Manley to Hulgate	Yes	Unclear	Yes
Hulgate to Miners	Yes	Unclear	Yes
Miners to Milton	Unclear	Unlikely	Unlikely
Milton to Fairfax	Unclear	Unlikely	Unlikely

Currently Available Habitat Downstream of Peterson Dam

Physical Characteristics: Peterson dam is located 5.6 miles upstream from Lake Champlain. The vast majority of this reach is slow flowing, with a low gradient, fine substrates

[20]Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. Part 1 of Influence of forest and rangeland management on anadromous fish habitat in the western United States and Canada. W.R. Meehan, technical editor. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. USDA Forest Service General Technical Report PNW-96.

(sand, silt, mud) and lake backwater influence. In contrast, only a relatively short reach immediately below the dam has a rocky bottom, comprised of gravel or larger material. The CVPS report[21] characterizes this reach:

> "Just downstream of the Peterson Dam, there is a short reach with several different aquatic habitats. At the base of the dam is a large pool which grades out to a run several hundred feet downstream. This pool includes a very deep spot known as the "sturgeon hole" which was historically used by sturgeon as a pre-spawning holding location. Substrates throughout this area are ledge, boulder and rubble. This area leads into a riffle with primarily cobble substrates. The riffle area is divided by an island. Downstream of the island, the water deepens, the substrates become finer (sand is the dominant substrate), and the run habitat described above begins. These pool, run, and riffle habitats have a combined total length of about 600 feet.
>
> In the 600 feet downstream of the dam, the seasonal changes in Lake Champlain water levels alternately inundate and expose portions of the riffle and run. In the spring, most of this area is inundated and flow releases from Peterson station go directly into deeper water. At other times of the year, varying flows from Peterson station affect more of this habitat, depending on the elevation of Lake Champlain."

Based on the scale maps in the CVPS instream flow reports from 1987[22] and 2000[23], the plunge pool is about 250 feet long. If the plunge pool is excluded, about 350 feet of river remain that provide riffle or run habitat with coarse bottom substrates suitable for walleye and sturgeon spawning.

Walleye and Sturgeon Spawning Habitat: Walleye and sturgeon have similar spawning habitat requirements. They prefer cobble-size (4"-10") material for spawning, although coarse gravel may also be used to some extent. Department observations of walleye indicate that the spawning habitat is fairly limited in area. Currently walleye, suckers, redhorse, and other fish spawn primarily in the channel on the north side of Stoney Island — an area about 150 feet wide by 350 feet long. Sturgeon are presumed to also utilize this area. Under high water conditions, areas on the south side of the island are used. CVPS conducted an instream flow study in 1986.[24] That study also showed that the large majority of habitat occurred within the same 350-foot section of river in the vicinity of Stoney Island. Not all areas within this section provide suitable

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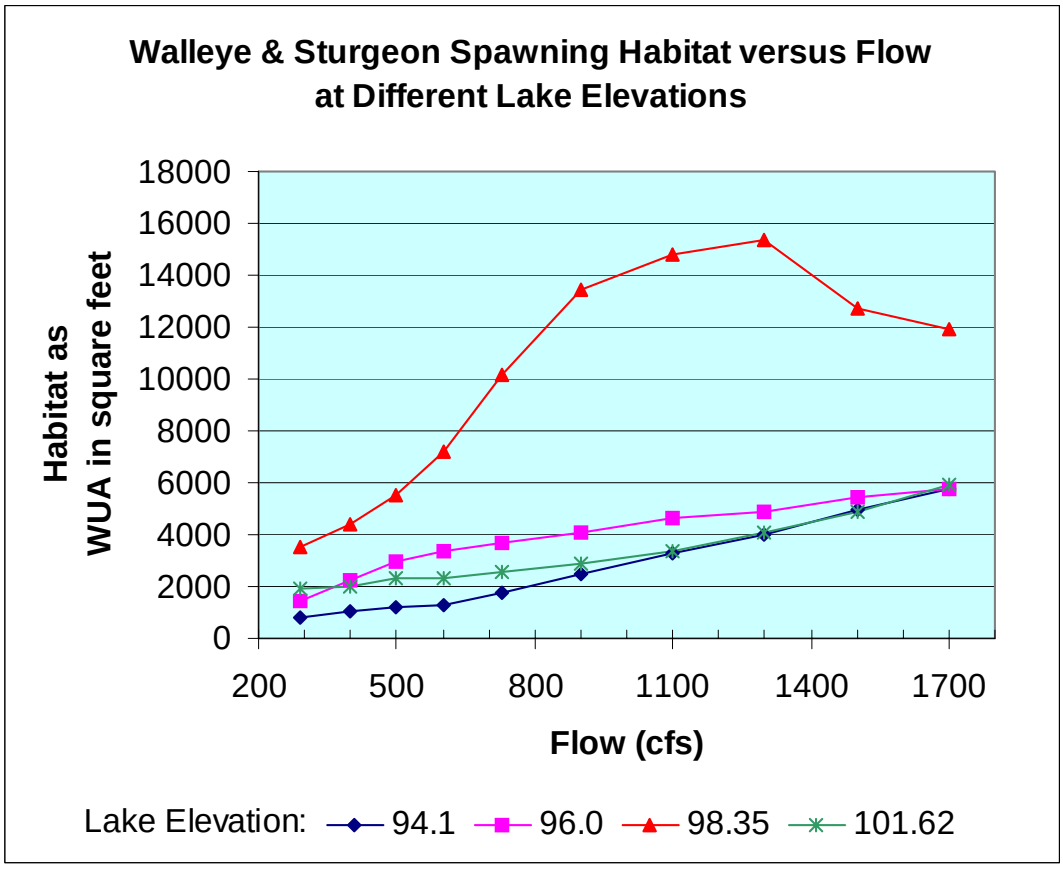
[21]Central Vermont Public Service Company. 2000. Lower Lamoille River Habitat Values. Lamoille River Hydroelectric Project, FERC No. 2205. Prepared by Gomez and Sullivan Engineers, P.C.

[22]Central Vermont Public Service Company. 1987. Lamoille River instream flow study, November 1986. Prepared by Stetson-Harza, Utica, New York. Revised Application for New License Lamoille Project No. 2205, before the Federal Energy Regulatory Commission. Volume II, Appendix A.

[23]Central Vermont Public Service Company. 2000. Instream flow and habitat study report. Prepared by Gomez and Sullivan, Dunbarton, New Hampshire. Lamoille River Hydroelectric Project, FERC No. 2205.

[24]Central Vermont Public Service Company, 1987, Op. cit.

spawning habitat since some are too shallow or lack adequate velocities. In addition, available habitat varies significantly with the spring water level of Lake Champlain. Spring lake levels typically cause a backwater effect all the way up to Peterson dam, which in turn influences habitat conditions. The greatest amount of habitat exists at the median lake level for April and May (98.35 feet). The following graph compares the amount of habitat[25] available over a range of river flows at four different lake levels. Data were collected at transects in the vicinity of Stoney Island (#9-11) as part of the CVPS 1986 instream flow study.



Much less habitat is available at lake levels other than 98.35 feet. And, lake levels outside of the range 98.35 ± 1 foot occur 50% of the time during April and May. The amount of available spawning habitat for walleye and sturgeon downstream of Peterson dam is relatively small, and its suitability can decrease significantly depending on the prevailing lake level. At a flow of 1,300 cfs, only 26-31% of the habitat available at 98.35 feet occurs at the other lake levels.

The 350-foot section of river that includes good rocky substrate for walleye and sturgeon spawning habitat is about 100,375 square feet in area. This estimate includes the entire width of the river except for Stoney Island. While not all parts of this reach have the water depths and

[25]Measured as weighted usable area (WUA), which combines elements of both habitat quantity and quality. A decrease in WUA can result from a decrease in the square footage of suitable habitat, a decrease in the quality of suitable habitat, or both.

velocities necessary to constitute suitable spawning habitat, it can be used for comparative purposes with habitat in the upstream reach. Since potentially suitable habitat upstream of the dam can only be broadly assessed, it is appropriate to similarly identify habitat downstream of the dam. This reach is shown on the attached 1896 map as the shaded area downstream of Woods Falls.

Salmon Spawning and Juvenile Rearing Habitat: Salmon spawn during the fall, in areas of gravel with good intragravel water movement, water depths of about one to four feet and velocities of about one to three feet per second. The female excavates a redd in which eggs are deposited. Following spawning, the female covers the eggs with gravel to protect them. Juvenile salmon typically occupy riffles and runs with rocky substrate.

Habitat for both spawning and juvenile rearing exists in a short section of river downstream of Peterson dam and was assessed in the recent CVPS habitat-flow study.[26] The study results indicate that the potential salmon spawning and rearing habitat downstream of the dam is represented predominantly by transects P-1 through P-4. This habitat includes about 1,100 feet of river. Salmon production estimates for this sub-reach and those upstream of the dam are discussed in detail later in this report. In estimating production for all the sub-reaches, the same level of smolt production was assumed throughout. However, the river also provides habitat for bass, pike and other warmwater fishes, plus open access from the lake for fish that use the area seasonally, such as walleye. Predation on juvenile salmon downstream of the dam is likely to be considerable, and it probably will not produce many salmon..

Projected Habitat Use with Removal of Peterson Dam

Walleye and Sturgeon Spawning Habitat: Removal of Peterson dam would provide additional spawning habitat for walleye and sturgeon; the following analysis evaluates the habitat gains. Detailed habitat information is available only for the sub-reach downstream of Peterson dam. To provide an “apples-to-apples” comparison, the potential spawning habitat for walleye and sturgeon has been estimated from the total area (length x average width) of each sub-reach, adjusted by an estimate of the percentage of each reach believed to provide suitable habitat. While these predictions are approximate, they are useful for comparing habitat availability between the sub-reaches. A sub-reach was considered 100% usable if it appeared to consist entirely of suitable spawning substrate with a gradient sufficient to provide rapidly flowing water at spring-time flow levels. Sub-reaches that did not entirely meet this criterion were assigned a lower usable habitat percentage. This approach probably over-estimates the true amount of suitable habitat but it does so consistently for all sub-reaches. A more precise estimate is not possible since the impoundment hides our view of the river.

[26]Central Vermont Public Service Company. 2000. Instream flow and habitat study report. Prepared by Gomez and Sullivan, Dunbarton, New Hampshire. Lamoille River Hydroelectric Project, FERC No. 2205.

The following table lists the area of potential spawning habitat in the sub-reaches upstream of Peterson dam, compared to that downstream of the dam.

Potential Spawning Habitat for Walleye and Lake Sturgeon				
Sub-Reach	Total Area (ft^2)	Percent Usable Habitat	Cumulative Usable Habitat (ft^2)	Amount of Usable Habitat Compared to that Currently Available
Below Peterson	100,375	100%	100,375	1 x
Woods to Manley	146,250	100%	246,625	2.5 x
Manley to Hulgate	726,800	85%	864,405	8.6 x
Hulgate to Miners	529,830	65%	1,208,795	12.0 x

The 350-foot section of river downstream of Peterson dam consists entirely of suitable rocky substrate and was assumed to be 100% usable.

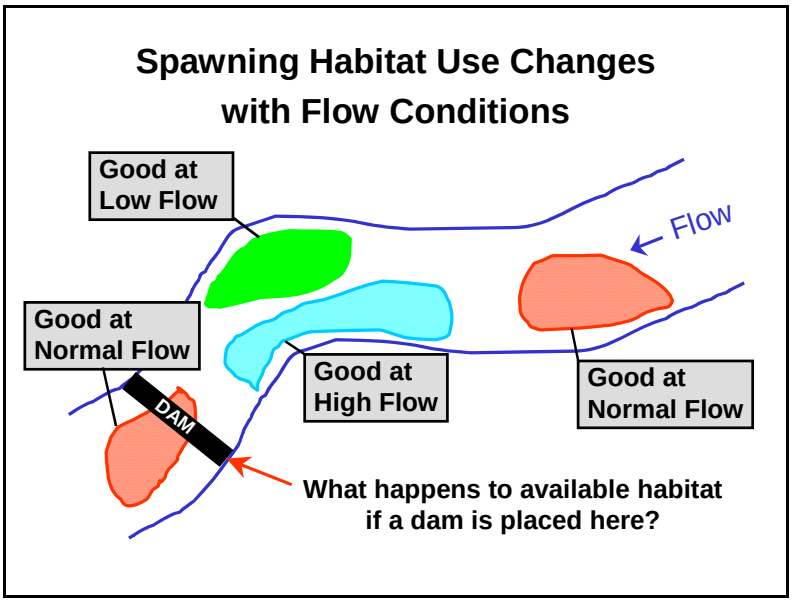
The photograph in the Fellinger report of the river upstream of Woods Falls suggests that the Woods to Manley sub-reach may provide suitable walleye and sturgeon habitat throughout. The substrates look very good. A similar situation exists on the Poultney River, where walleye spawning occurs from bank to bank over a reach of that river. If Peterson dam were removed to make this sub-reach accessible, the potential walleye and sturgeon spawning habitat would increase by 146%, to about 2.5 times what is now available.

The Manley to Hulgate sub-reach also appears to be broadly suitable as walleye and sturgeon spawning habitat, but was assumed to be 85% usable since it includes some areas of gravel that are probably not suitable.

The Hulgate to Miners sub-reach appears to provide a diversity of habitat conditions. The gradient in this sub-reach is less than in downstream reaches, and the dominant substrate is believed to be gravel and therefore not as favorable as further downstream. This sub-reach was assumed to be 65% usable, but there is considerable uncertainty about the amount and quality of walleye and sturgeon spawning habitat. These fish spawn in relatively high velocities. Since this sub-reach is less steep and wider than the sub-reaches downstream of Hulgate Falls, it may provide suitable velocity conditions at higher flow levels, when the amount of suitable habitat in downstream areas is less.

It is likely that sturgeon went upstream as far as Miners Falls, in which case dam removal would result in an 12-fold increase in their potential spawning habitat. There is some question as to whether walleye historically ascended beyond Manley Falls. If they passed this impediment, it is

very likely that they would then be able to ascend the smaller Hulgate Falls and move upstream as far as the base of Miners Falls. If walleye go no further upstream than Manley Falls, dam removal would change the amount of available usable habitat from about 100,000 square feet to nearly 250,000 square feet — 2.5 times as much as is now available. If they move upstream as far as Miners Falls, the amount of available usable habitat rises to over 1.2 million square feet — 12 times as much as is now available.



Removal of Peterson dam would provide more habitat area and more diversity of habitat for spawning and incubation. The availability of additional habitat offers several advantages. A larger area of usable habitat insures an adequate supply of habitat of the highest quality, enabling fish to use areas that offer the highest promise for successful reproduction. Runoff and river flow patterns differ each spring. Some areas provide suitable habitat under high water conditions while others are suitable only at lesser flows. The availability of a greater range of habitat conditions makes it more likely that fish can find the spawning habitat they need for whatever the prevailing flow conditions are. In the figure to the right, some habitat exists downstream of the dam that is suitable under normal spring flow conditions. However, the diversity of habitat that is suitable across a range of conditions is only available upstream of the dam. This appears to be the situation for the Peterson Reach.

A greater amount of space makes it easier for the different species of spawning fish to find suitable areas that are not overlapping. If walleye can spread out more, the amount of predation on their eggs by other fishes may decline. If the currently available spawning and incubation habitat is in fact limiting, providing additional habitat should result in an increase in the walleye population.

Young sturgeon typically remain in their natal rivers until at least the fall of their first year of life, before migrating to the lake.[27] The habitat utilized by young-of-year sturgeon includes sand and gravel areas.[28] Dam removal would restore riverine habitat for juvenile sturgeon.

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[27]Kempinger, J.J. 1985. Early life history of lake sturgeon. Progress Report, Study No. 502, Bureau of Research. Wisconsin Department of Natural Resources, Madison.

[28]Threader, R.W., R.J. Pope and P.R.H. Schaap. 1998. Development of a habitat suitability index model for lake sturgeon. Ontario Hydro Report No. H-07015.01--0012.

It is very likely that the Mallets Bay/Lamoille River walleye population will benefit from increased spawning success in response to restoration of the historic spawning habitat upstream of Peterson dam. Restoration would be consistent with the Lake Champlain Walleye Restoration Plan,[29] which identifies habitat protection and restoration as its top priority.

Salmon Spawning and Juvenile Rearing Habitat: There appears to be a substantial amount of suitable salmon spawning habitat within the Peterson Reach. If it were restored to a riverine condition, it is difficult to determine if the Woods to Manley sub-reach would include suitable habitat for salmon spawning. The substrate may be too coarse. However, the Manley to Hulgate and Hulgate to Miners sub-reaches appear to include adequate spawning habitat, and downstream dispersal of fry is likely. Good spawning habitat in Miners to Milton sub-reach may be limited to areas at the upper end. As stated previously, salmon would likely ascend to Miners Falls; further upstream movement is uncertain. After hatching, most juvenile salmon spend two years in the stream before migrating to the lake during the spring as smolts. And, most of these salmon will return to the river in the fall, after almost 1.5 years (two growing seasons) in the lake. Mortality during this first year of lake life is typically higher than in subsequent years.

The suitability of the Peterson Reach as juvenile salmon rearing habitat is uncertain because of its temperature regime. This reach exhibits less diurnal fluctuation than the reach upstream of Arrowhead Mountain Reservoir, since the Clarks Falls station withdraws water from deeper in the water column. Compared to the river upstream of Arrowhead Mountain Reservoir, daily temperature maxima are lower but minima are higher. The daily high temperatures are less of an concern than the fact that temperatures do not cool down as much at night. Temperatures measured last summer stayed well below the upper limit for survival but were at times too high for normal feeding. The data for the Peterson Reach raise a concern about the amount of time temperatures may be too high for juvenile salmon to feed, at least during the hotter summers. The only way to definitively determine the suitability of the reach as salmon rearing habitat is to try it for a number of years. Mr. Morgan reported that he caught trout throughout the year in the lower Lamoille River. Since salmon can tolerate higher temperatures than trout, Mr. Morgan's comment suggests that the reach could support salmon. More night-time cooling (1-2° C) would occur in the reach under riverine conditions. Streeter Brook (and possibly other small tributaries and groundwater seeps) is likely to provide cooler water during the summer.

Overall, the nature of the physical habitat for salmon rearing is good. Since some salmon reproduction in the Peterson Reach is likely, it is desirable to estimate the size of run of adult fish that would be supported by wild production in this reach.

The number of adult salmon that return to the Lamoille is driven by the number of smolts that leave the river and their subsequent survival in the lake. These factors are in turn influenced by many other variables. Smolt production can be influenced by the extent of wild spawning and the subsequent survival of the eggs, fry and parr. This survival is influenced by the quality and

[29]Vermont Department of Fish and Wildlife. 1998. Lake Champlain walleye fishery restoration plan, supplement to: a plan for management of walleye fisheries in Lake Champlain Vermont waters, 1999-2003. Waterbury, Vermont.

quantity of the habitat and by the weather, such as the summer temperature and flow regime. Favorable conditions can lead to a greater proportion of fish smoltifying at age 1 than at age 2, which tends to increase overall production. Lake survival is determined by both natural and fishing mortality. Since environmental factors vary from year to year, so does the size of the adult salmon run.

Despite this variation, it is possible to estimate the average run size through a simple mathematical model based on 1) the area of rearing habitat, 2) the smolt production per unit area, 3) survival in the lake, and 4) the number of repeat spawners. A "Unit" of habitat is 100 m^2 in size. The model assumes that the available habitat is fully utilized.

Estimated Size of Adult Salmon Run =

Units of Rearing Habitat
x
Smolt Production per Unit
x
Lake Survival Rate
+
Repeat Spawners

The values used in the model are based on salmon production and survival data from Lake Champlain studies as well as from other Vermont waters and elsewhere. In addition, these values take into account the characteristics of the Lamoille River. Lake Champlain salmon data were compiled as part of the evaluation of the sea lamprey control program.[30] While river returns have been poor, in-progress changes in stocking strategies and genetic strains should greatly improve returns. Open water creel surveys indicate that about 2% of the stocked smolts are later caught as adults, so that it is certainly reasonable to expect lake survival to exceed 2%. A model of survival for landlocked salmon in Lake Winnipesaukee, New Hampshire indicates that for fish stocked as yearlings, survival to age 2+, 3+ and 4+ is about 63%, 43% and 20%, respectively.[31] Annual survival in Maine lakes is often around 50%, although both higher and lower values occur as well.[32]

About 9% of the salmon harvested in the main lake area of Lake Champlain during the open water fishing season had lived in the lake for two or more years. This value should increase if long-term sea lamprey control is implemented. It is reasonable to expect lake survival to increase and the number of repeat spawners to exceed 10%.

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[30]Fisheries Technical Committee, Op. cit.

[31]Seamans, R.G., Jr. and A.E. Newell, Jr. 1973. Management of lake Atlantic salmon (*Salmo salar*) in New Hampshire. NH Fish and Game Department, Concord, NH.

[32]Warner, K. and K.A. Havey. 1985. Life history, ecology and management of Maine landlocked salmon (*Salmo salar*). Maine Department of Inland Fisheries and Wildlife. Augusta, ME.

The *Strategic Plan for the Restoration of Atlantic Salmon to the Connecticut River* used a smolt production value of 2/unit to produce its best conservative projection of adult returns. Values were also included based on smolt production of 1.5/unit and 2.5/unit. Some rivers produce two or three times these values; Vermont examples include parts of the upper Clyde River, upper Saxtons River, lower Williams River, and parts of the West River watershed.

Relatively conservative values were used for the model variables. A similar model used to predict salmon returns to the Clyde River included the following values:
smolt production 3-9/unit; lake survival 16-49%; repeat spawners 20%.

The number of habitat units for each sub-reach upstream of Peterson dam was calculated from 1896 survey, as described previously. Since the recent CVPS flow study includes information about salmon physical habitat in the sub-reach downstream of Peterson dam, data from this report were used to estimate habitat units. These results indicate that the potential salmon spawning and rearing habitat downstream of the dam is represented by transects P-1 through P-4. This habitat includes about 1,100 feet of river and an area of about 338,600 square feet.

Before applying the model, the total area of each sub-reach was adjusted based on the physical habitat characteristics, according to the following formula:

Units of Rearing Habitat = Total # of Units x Percent Usable Habitat

The percent usable habitat value is used to "discount" a sub-reach that is not good rearing physical habitat throughout. For example, large pools are not expected to be used by juvenile salmon except possibly along the margins. So, a sub-reach with pools occupying 25% of its area with otherwise good habitat would be considered 75% usable. The Manley to Hulgate sub-reach was rated at 80% since it appeared to contain some pool area. The Hulgate to Miners sub-reach was rated at 65% since it appeared that about 1/3 of the sub-reach is made up of pool habitat. The large majority of the Miners to Milton sub-reach appears to be a slow run. This sub-reach was rated at 50% to reflect the fact that slow runs are typically less desirable as juvenile salmon rearing habitat than riffles. Uncertainty about the nature of this sub-reach could be addressed by viewing the reach with a partial drawdown of Peterson impoundment. The Woods to Manley sub-reach has very good substrate for salmon rearing. While velocities are likely to be high during high flow events, the coarse substrate should provide numerous velocity refuges for fish. The sub-reach below Peterson was considered 65% usable since much of it is subjected to a significant lake backwater effect during part of the year. CVPS indicates in its flow study report that the higher lake levels which typically occur in spring and early summer make the section of river represented by transect P-4 less suitable for riffle species.[33]

[33]Central Vermont Public Service Company. 2000. Instream flow and habitat study report. Prepared by Gomez and Sullivan, Dunbarton, New Hampshire. Lamoille River Hydroelectric Project, FERC No. 2205.

The following tables show the usable spawning and rearing habitat by sub-reach and then the estimates of the adult run that wold result from natural reproduction within the Peterson Reach.

Potential Salmon Spawning and Rearing Habitat Downstream of Milton Falls				
Sub-Reach	Total No. of 100 m^2 Units	Percent Usable Habitat	No. of Usable 100 m^2 Units	Amount of Usable Habitat Compared to that Below Peterson Dam
Below Peterson	315	65%	204	1 x
Woods to Manley	136	100%	136	1.7 x
Manley to Hulgate	675	80%	540	4.3 x
Hulgate to Miners	492	65%	320	5.9 x
Miners to Milton	1,429	50%	715	9.4 x

Estimates of Adult Salmon Returns from Wild Production in the Lower Lamoille River					
Model Variable/ River Reach	Model Scenario				
	Low	Med-1	Med-2	High	Best Est.*
Smolts per Unit	1.5	3	4.5	6	1.5
Lake Survival	2%	5%	10%	20%	10%
Repeat Spawners	5%	10%	20%	20%	10%
Up to Miners Falls	25	165	576	1,584	198
Miners to Milton	15	98	343	943	118
Total up to Milton	40	263	919	2,528	316

*Best conservative estimate

As can be seen from the range of the numbers, there is a good deal of uncertainty in the run estimates. It is however unlikely that the most pessimistic or most optimistic numbers will simultaneously occur for all three model variables, as in the low and high estimates. If salmon do not utilize the sub-reach upstream of Miners Falls, the best conservative estimate is that an average run of nearly about 200 adult salmon could be sustained from natural reproduction in the downstream sub-reaches.

All these sub-reaches can be expected to also support some warmwater fishes that prey on young

salmon. Similar situations exist on other salmon rivers and while predation does not preclude salmon production, it does "take a bite" out of it. This factor is one reason that a conservative smolt production figure (1.5/unit) is used for the "best conservative estimate." Woods and Manley Falls should prevent some of these predator fish from moving upstream, but fish can be expected to drop down from Arrowhead Mountain Reservoir to access the Peterson Reach. Predation is likely to be the worst in the sub-reach downstream of the dam since many fishes from Lake Champlain can readily access it. If for this reason the smolt production below Woods Falls is assumed to be cut in half, the best estimate of the adult run produced from this sub-reach would be 17 instead of 34.

Sea Lamprey Production in the Lamoille River*:* Lake Champlain sea lampreys migrate into tributary streams during the spring, spawning in June. Adults build nests in gravel and cobble areas, spawn and die soon thereafter. Eggs hatch around the end of June, at which point the larvae leave the nest and burrow into sand or silt, preferably mixed with organic matter. The non-parasitic larvae live in the stream for three or more years before moving to the lake and transforming into their parasitic stage.

There is currently no known lamprey production in the river downstream of Peterson dam. Spawning habitat is limited and flow regulation may inhibit successful reproduction. Also, the downstream substrate may be too sandy to provide suitable larval habitat (Brian Chipman, personal communication).

The amount of lamprey production that could result from dam removal is uncertain. If Peterson dam were removed, the upstream reach would provide abundant spawning habitat and presumably some silty areas that could support larvae. The limited amount of upstream larval habitat is not expected to produce many lamprey. It is also possible that the downstream habitat is in fact suitable for larvae and that lamprey are limited by spawning habitat. Since there is ample spawning habitat in the upstream reach, it could produce young lamprey that could populate the downstream habitat. Some type of lamprey control might be needed if production became significant.

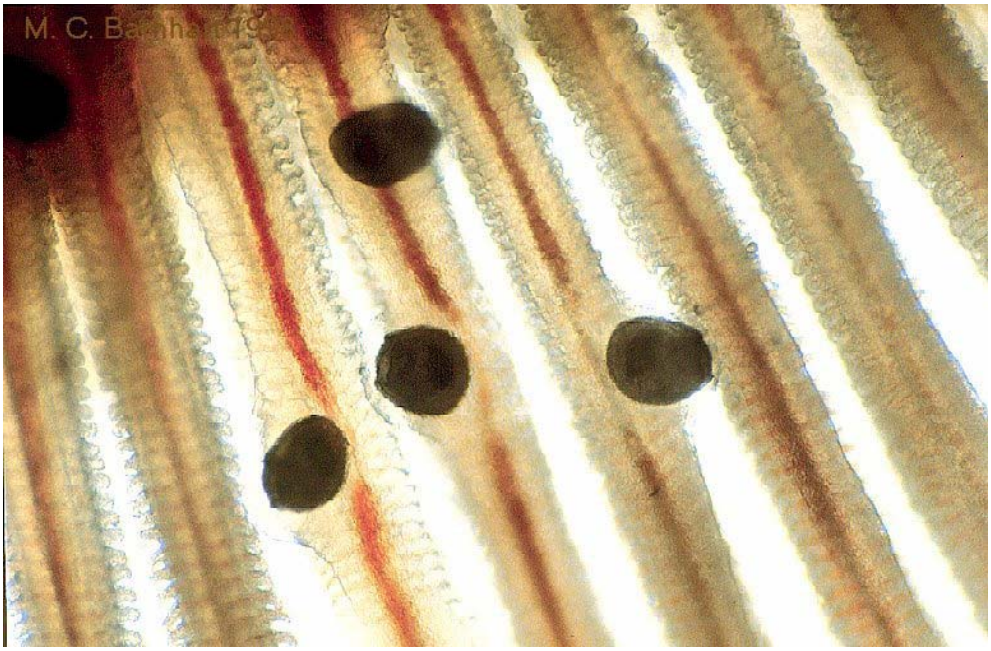
Habitat for Other Species of Fish and Aquatic Life: The Lamoille River downstream of Peterson dam contains a diversity of fish species. Many of these spend all or part of their life cycle in Lake Champlain, entering the river to spawn or feed. The river also provides juvenile rearing habitat for some species. For example, salmon, walleye, lake sturgeon, suckers, redhorses, and some minnow species spawn in the river, over rocky substrates. The connection between the lake and these river habitats is important to their survival and well being.

The following species occur in this reach of the river: rainbow trout, brown trout, landlocked Atlantic salmon, largemouth bass, smallmouth bass, chain pickerel, northern pike, yellow perch, walleye, pumpkinseed, rock bass, brown bullhead, freshwater drum, American eel, longnose gar, lake sturgeon, mottled sculpin, sea lamprey, burbot, tessellated darter, eastern sand darter, log perch, quillback, white sucker, shorthead redhorse, silvery minnow, banded killifish, spotfin shiner, spottail shiner, mimic shiner, bluntnose minnow, golden shiner, emerald shiner, fallfish, rosyface shiner, and common shiner. Silver redhorse and greater redhorse have been identified in

the Missisquoi River and are likely to also occur in the lower Lamoille River. Those that are rare, threatened or endangered in Vermont follow:

Endangered: lake sturgeon
Threatened: Eastern sand darter
Rare: greater redhorse, silver redhorse, quillback, mottled sculpin, rosyface shiner

The Lamoille, Poultney and Missisquoi Rivers support the greatest species richness for mussels in Vermont. Of the 17 species of freshwater mussels that are native to Vermont, 13 are found in the Lamoille River, 12 occur downstream of Peterson dam, and six of those are threatened or endangered.



As part of their life history, larval mussels attach for up to several weeks to a host fish. The photograph shows larval mussels attached to the gills of a fish. Each species of mussel utilizes only certain fish species as hosts and as a result is reliant on the availability of the correct fish hosts.

Mussel Species of the Lamoille River				
Common Name	Status[a]	Occurrence Relative to Peterson Dam		
		Downstream of Dam[b]	Upstream of AMR[c]	In Impoundment
Pocketbook	E	**X**		**X**
Cylindrical papershell	E	**X**	**X**	
Fragile papershell	E	**X**		
Pink Heelsplitter	E	**X**		
Fluted-shell	E	**X**		**X**
Giant floater	T	**X**[d]	**X**	**X**
Eastern elliptio	common	**X**	**X**	**X**
Eastern lampmussel	common	**X**	**X**	**X**
Squawfoot	common	**X**	**X**	**X**
Eastern floater	common	**X**	**X**	**X**
Triangle floater	common	**X**		**X**
Creek heelsplitter	R	**X**	**X**	
Elktoe	R		**X**	

[a]E=endangered; T=threatened; R=Rare.
[b]Does not include species associated only with the delta at the mouth.
[c]From Arrowhead Mountain Reservoir or the river further upstream.
[d]Probable occurrence; not confirmed.

The substrates preferred by mussels are to some extent species dependent.[34] Some prefer sand and others fairly stony gravel. Overall, use varies from silt to large gravel but most use coarse sand to a sand/gravel complex. The pink heelsplitter, fluted shell, eastern lampmussel and eastern elliptio do use habitats consisting of a matrix of sand, gravel and cobble. These substrates exist downstream of Peterson dam, although gravel and cobble areas are largely restricted to a short reach near the dam.

The Woods to Manley sub-reach may provide some habitat for mussels, but much of the

[34]Fichtel, C. and D.G. Smith. 1995. The freshwater mussels of Vermont. Vermont Fish and Wildlife Department. Technical Report 18.

substrate is probably too coarse. The Manley to Hulgate sub-reach is likely to contain a good deal of mussel habitat, but the predominant substrate type is also rather coarse for mussels. It is not possible to determine the extent to which suitable sand/gravel/cobble complexes occur. The two upstream sub-reaches (Hulgate to Miners; Miners to Milton) are likely to be very suitable for mussels. Eight species of mussel currently reside in the Peterson Impoundment.[35]

Mussel life history includes a period of larval development within a host fish. Each mussel species utilizes specific fish host species. Some mussels can utilize a number of different fishes while others can use only one or two. For example, the only fish host that has been identified for the pink heelsplitter and fragile papershell is the freshwater drum. Because of this association, mussel populations are reliant on the availability of the correct fish hosts. Removal of Peterson dam would lead to upstream movements of host fish, in turn resulting in colonization of these areas by mussels.

The leading cause of mussel population declines is believed to be habitat loss, such as from dam construction, flow regulation, siltation and river channel alterations.[36] An additional, growing threat in the Lake Champlain basin is the invasion of zebra mussels, which attach to, envelope and kill native mussels. The slow water habitat downstream of Peterson dam is likely to become colonized by zebra mussels, as has happened in Otter Creek and Little Otter Creek, putting the native mussel populations at risk. Removal of Peterson dam would restore upstream river habitat that zebra mussels are unlikely to colonize more than sparsely. Zebra mussels do not utilize a fish host as part of their life cycle and would therefore have difficulty populating upstream areas. Colonization could occur by downstream drift if zebra mussels became established in Arrowhead Mountain Reservoir. However, zebra mussels don't do well in flowing waters unless the current is negligible. Currents in most of the Peterson Reach are likely to be unfavorable for zebra mussels, so this reach would serve as a refuge for native mussels.

Native mussels are unlikely to colonize the Miners to Milton sub-reach since very few fish hosts will ascend Miners Falls. Since this sub-reach appears to contain suitable mussel habitat, native mussels could be transplanted to there from downstream areas if threatened by zebra mussels.

Removing Peterson dam would re-establish a river-lake ecological connection that is important to many species of fish and mussels. The amount of gravelly, rocky habitat downstream of Peterson dam is small.

[35]Found by the Department of Environmental Conservation and U.S. Fish and Wildlife Service during a July 31, 2001 survey of the impoundment or during the August 16, 2001 impoundment drawdown.

[36]Fichtel and Smith, Op. Cit.

Fisheries Habitat of the Peterson Impoundment

Peterson dam forms a narrow and steep-sided impoundment 136 acres in size. Low dissolved oxygen levels were measured during the summer by the Department of Fish and Wildlife in the impoundment's deeper waters in 1969[37] and again in 1988 (Brian Chipman, personal communication).

The Department of Fish and Wildlife surveyed fish populations in the impoundment in 1969[38] and 1988[39]. Fishes collected include smallmouth bass, rock bass, walleye, northern pike, yellow perch, pumpkinseed, brown bullhead, white sucker, shorthead redhorse, golden shiner, common shiner, log perch and banded killifish. Population levels of these fish have not been assessed. The sport fishery consists primarily of walleye, northern pike and smallmouth bass. These fish may be sustained either by natural reproduction, by fish that drop down from Arrowhead Mountain Reservoir, or both. Habitat exists in the Milton bypass that many of these species could use for spawning, given an adequate flow regime. Anderson[40] found that age 1+ and age 2+ smallmouth bass were absent during his 1969 survey, which he attributed to water fluctuation.

The impoundment is not under active fishery management. Fishing pressure is low, due in part to the limited public access. There is a public access to the impoundment at the Milton hydropower station, but it is only open during certain daylight hours. Some anglers have expressed concerns that dam removal will eliminate fishing in the impoundment for fish such as northern pike, smallmouth bass and walleye.

By eliminating the impoundment, dam removal would essentially trade still water or pond fish for river fish. Walleye, northern pike, pumpkinseed, bullhead, and golden shiner populations would probably be eliminated. New riverine species, such as salmon, sturgeon, brown trout, tessellated darter and various minnows, would presumably become established. Walleye would seasonally use part of the Peterson Reach for spawning. The lower Lamoille River plays a vital role for Lake Champlain fish that need both lake and river habitats. Stillwater fishes exist in many locations; rivers connected to Lake Champlain are few.

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[37] Anderson, J.K. 1970. Peterson dam. Job Performance Report. Vermont Department of Fish and Game. Montpelier, Vermont.

[38] Ibid.

[39] Chipman, B.D. 1990. Job Performance Report. Vermont Department of Fish and Wildlife. Waterbury, Vermont.

[40] Anderson, Op. cit.

1896 Survey Of Lamoille River
Peterson Reach