The Vermont Management Plan for Brook, Brown, and Rainbow Trout

The Vermont Fish and Wildlife Department

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Table of Contents

I. Introduction

The management of Vermont's fisheries resources is a multi-faceted program consisting of habitat protection, restoration and enhancement; regulation of angler harvest; and species introductions or restorations, which may include the use of artificially reared (i.e. “cultured”) fish. In addition to its many intrinsic values, fishing in Vermont is also important economically. In 2011, an estimated 131.3 million dollars were spent by anglers in Vermont (U.S. Department of Interior 2014).

Brook, brown and rainbow trout are among Vermont's most sought after species, comprising three of the top five fish species preferred by Vermont resident open-water anglers (Connelly and Knuth, 2010). These anglers spent over one million days of their open-water angling effort in 2009 pursuing these three trout species in small brooks, larger streams and rivers, and in lakes and ponds throughout Vermont (Connelly and Knuth, 2010).

In 1993, the first formal management plan for brook, brown and rainbow trout was adopted in Vermont. The Vermont Management Plan for Brook, Brown and Rainbow Trout provided a comprehensive approach to the management of these important species by integrating public opinion and desires with scientific studies of trout biology and management conducted both in and outside Vermont. The 1993 document served as guidance for fisheries biologists to use in managing Vermont's trout resources and as a public education resource which formally outlined the biological and social justifications of various trout management strategies.

This plan serves to update and document the many advances in our understanding of the threats to and management of brook, brown and rainbow trout, as well as changes in public opinion and desires which have occurred since the development of the 1993 “Trout Plan”. The general approach to trout management is described below:

It is the goal of the Vermont Fish and Wildlife Department to manage the state's trout resources to support wild trout populations and a diversity of quality recreational opportunities.

To meet this goal, it is the policy of the Department to:

1) Place priority on implementing effective habitat protection, restoration, and enhancement measures and harvest regulation in conserving and managing the state's wild trout resources.

2) Utilize cultured trout where management of a recreational trout fishery is justified, but cannot be sustained solely through wild trout management.

This plan should be considered a working document, subject to adjustment as warranted by changes in environmental or social pressures on Vermont's trout resources, or advances in fisheries management techniques.

II. Life History and Ecology

Brook Trout *(Salvelinus fontinalis)*

Habitat

The brook trout is adapted to the widest variety of habitats of the trout species (Flick 1991). It inhabits tiny infertile, high-gradient mountain streams, larger rivers with constant cool water supplies, low-gradient bog streams, beaver ponds and coldwater lakes.

Warm water temperatures are the most important factor limiting brook trout distribution. While temperatures exceeding 68° F are widely considered to initiate physiological stress, temperatures exceeding 64° F can be detrimental to growth and survival of fry and juveniles (Raleigh 1982, Argent and Kimmel 2014). Optimum growth occurs between 55 and 65° F and it can tolerate brief periods of up to 72° F (Raleigh 1982). Exposure to temperatures of 75° F for only a few hours is usually lethal (Flick 1991). Dissolved oxygen requirements vary with water temperature. Optimum dissolved oxygen concentrations are near saturation levels (Raleigh 1982).

Brook trout tolerate a wider range of pH levels than brown trout or rainbow trout. In laboratory studies brook trout have been shown to withstand extremes of 3.5 to 9.8 (Raleigh 1982). In natural conditions a more realistic low pH is around 4.8 (Flick 1991) with an optimum range between 6.5 and 8.0 (Raleigh 1982).

Optimal brook trout habitat in streams is characterized by a 1:1 pool to riffle ratio, silt-free rocky substrate, clear, cold spring-fed water with stable flow and temperature, and well vegetated, stable banks, with abundant instream cover (Raleigh 1982). Brook trout tend to prefer areas out of the main flow with relatively low velocities (about 0.5 ft/sec) and overhead cover such as boulders, vegetation and undercut banks (Scarola 1987, Flick 1991).

In lakes and ponds brook trout tend to inhabit shallow, spring-fed areas less than 15 to 20 feet in depth. During hot weather periods they are more likely to seek shallow coldwater seeps rather than retreat to colder depths (Flick 1991).

Brook trout occupy various habitats during different life stages and times of the year. Brook trout are known to make movements at the local and watershed scale (Davis et al. 2015) for feeding, spawning, and rearing.

Age and Growth

In Vermont, brook trout are often slow growing and short lived, rarely exceeding 3 to 4 years of age. Many headwater mountain streams rarely produce brook trout larger than 6 or 7 inches. In more productive waters, especially lakes and ponds, they may live longer and achieve maximum lengths of over 20 inches and weigh several pounds.

Age at sexual maturity varies among populations. Males may mature as early as their first year of life but usually mature in their second year. Females mature one year later.

Spawning Behavior

Spawning generally occurs in late September and early October at water temperatures of between 40 and 50° F (Raleigh 1982). Brook trout generally migrate to areas of spring-fed upwellings in streams or in lake and pond substrates (Webster and Eiriksdottir 1976, Witzel and MacCrimmon 1983, Flick 1991).The female excavates a pit or redd over a ground water upwelling or the tail of a pool in gravel of 0.1 to 2 inches in diameter which is well aerated (Flick 1991). The male fertilizes the eggs as they are deposited, followed by the female covering the eggs with gravel. Eggs may be deposited by one pair over a series of small redds (Scarola 1987). In Vermont, eggs incubate in the gravel over winter. Incubation takes from about 45 days at 50° F to 165 days at 37° F (Raleigh 1982). Newly hatched fry remain in the gravel until their yolk sac is absorbed, then emerge and inhabit shallow, low velocity areas with rock of 4 to 8 inches in diameter, sufficient in size to resist shifting. At the juvenile stage, they move into swifter riffle areas (Raleigh 1982).

Food Habits

Brook trout appear to be opportunistic sight feeders preferring drifting aquatic macroinvertebrates over benthic (bottom dwelling) organisms when available. Larger individuals may feed on small fish at times, especially in lakes (Raleigh 1982). The brook trout tends to feed more during the day than either the brown or rainbow trout (Scarola 1987).

Brown Trout *(Salmo Trutta)*

Habitat

Brown trout typically inhabit the lower reaches of cold water streams, characterized by deep, slow-moving pools and runs. They also thrive in larger lakes of sufficient depths to maintain cool water temperatures year-round.

As with other trout species, water temperature is a major limiting factor for brown trout. Optimum temperatures range from 53 to 66° F and they can tolerate temperatures near 80° F for short periods. Dissolved oxygen requirements are near saturation levels; greater than 9 mg/l at water temperatures less than 50° F (Raleigh et al. 1986). Brown trout tolerate pH from 5.0 to 9.5 but have an optimal range between 6.8 and 7.8 (Raleigh et al. 1986).

Physical habitat favored by brown trout is characterized by low-gradient stream reaches with slow, deep pools and relatively silt-free rocky substrates in riffles. Preferred pool to riffle ratios are high, favoring 50 to 70% pools and 30 to 50% riffle-run habitat. Well vegetated, stable banks and relatively constant stream flows are also important; overhead canopy cover is increasingly important as stream widths and depths decrease (Raleigh et al. 1986).

Age and Growth

Brown trout usually attain a maximum age of 5 or 6 years, although ages of eight and nine years are not uncommon in waters with low harvest pressure (Bachman 1991). They generally grow at faster rates and achieve larger sizes than brook trout or rainbow trout. In Vermont streams, brown trout tend to reach 5 to 9 inches after two years, 8 to 11 inches by their third year, and 9 to 14 inches by their fourth year of age. Brown trout stocked at 8 inches as yearlings in in coldwater lakes can reach 10-12 inches in their first fall/winter following stocking, 13-17 inches in their second fall and up to 20 inches in their third fall (Kirn 1993, Claussen 1999).

Spawning Behavior

Stream-dwelling male brown trout mature at two to three years of age; females typically mature one year later. Some lake-dwelling strains may not mature until the fourth or fifth year (Bachman 1991). Spawning typically occurs from late October through December, when water temperatures reach an optimum range of 44 to 48° F (Raleigh et al. 1986). Lake or large riverine populations must have access to suitable tributary streams to reproduce. Adult brown trout sometimes migrate considerable distances to reach tributaries or headwaters with well oxygenated gravel at the tail of pools (Cox 2016). Unlike brook trout which appear to exclusively select groundwater upwellings for spawning sites, these areas may or may not be used by brown trout (Witzel and MacCrimmon 1983, Beard and Carline 1991). The female digs a well-defined redd, a process which takes several days. In the latter stages, she is joined by one or more males to complete deposition of eggs and milt (Bachman 1991).

Optimal incubation temperatures range between 36 and 55° F but tolerable levels range from 32 to 59° F. Like brook trout, brown trout eggs overwinter in the gravel. Incubation times vary from 148 days at 35° F (typical of Vermont streams) to 30 days at 57° F (Raleigh et al. 1986). Fry emerge from the gravel after absorbing their yolk sacs and disperse quickly, immediately establishing territories in shallow low velocity pools with rocky substrates. This habitat is also preferred by larger juvenile brown trout, who may force the fry more to the edges of pools and riffles on smoother substrates (Bachman 1991).

Food Habits

Brown trout are opportunistic feeders, but are perhaps more selective than other trout species. Aquatic and terrestrial insects make up the primary food source of browns less than 10 inches in length. As they become larger, they shift more to fish and crustaceans. Mature brown trout in streams feed primarily at night, while those in lakes are more likely to feed during daylight hours (Raleigh et al. 1986).

Rainbow Trout *(Oncorhynchus mykiss)*

Habitat

The rainbow trout inhabits moderate to high gradient cold water streams with swift riffles and deep clear pools, often overlapping with brook trout habitat in their upstream limits and with brown trout in their downstream limits. They are also well adapted to deep cold water lakes within temperature limits. While "steelhead" is a term technically used for the sea-going or anadromous form of rainbow trout (Behnke 2002), lake-run rainbow trout strains managed within Lake Memphremagog and Lake Champlain have been commonly referred to as steelhead.

Rainbow trout in streams have optimum preferred water temperatures similar to those favored by brown trout, from 54 to 66° F, while lake-dwellers select waters between 45 and 64° F (Raleigh et al. 1984). The maximum tolerable water temperature is 77° F, but some populations may be able to withstand temperatures in the low 80s F for short periods (Scarola 1987; Smith 1991). Dissolved oxygen requirements vary with water temperature and are similar to those of brook trout and brown trout (Raleigh et al. 1984). Rainbow trout are more sensitive to pH extremes than other salmonids, especially acidic conditions. A pH range of 6.5 to 8.0 is considered optimal and adults can tolerate levels from 5.5 to 9.0 (Raleigh et al. 1984). Natural reproduction is not successful in waters with pH less than 6.0 (Smith 1991).

Optimal physical stream habitat for rainbow trout has some characteristics of both brook trout and brown trout habitat. A relatively stable flow of clear, cold water; a silt-free rock substrate in riffle-run areas; an approximately even occurrence of pools and riffles, with areas of slow deep water and abundant in-stream cover, along with well-vegetated, stable banks are all important (Raleigh et al. 1984).

Age and Growth

Life expectancy of rainbow trout is highly variable over its range but is generally 3 to 5 years, sometimes longer in lake populations (Raleigh et al. 1984). Rainbow trout growth rates in Vermont streams are similar to those of brook trout, but they tend to grow larger due to their greater longevity. They generally reach 4 to 6 inches after 2 years of age, 6 to 9 inches by their third year and 8 to 12 inches by their fourth year. As with other salmonids, lake dwelling rainbow populations grow faster; 4 year old fish attain lengths of 13 to 17 inches or greater. Stocked trout may exceed these lengths as they are stocked at larger sizes.

Spawning Behavior

Rainbow trout in streams generally become sexually mature during their second or third year; some lake fish may mature later in life (Raleigh et al. 1984, Smith 1991). They spawn almost exclusively in streams and like brown trout, may undergo extensive movements to reach spawning habitats. Unlike brook and brown trout, most rainbow trout spawn in the spring in Vermont (usually March through May), triggered by rising spring flows and water temperatures. Selective breeding in hatcheries has produced strains that spawn in the fall months or other times of year, however (Smith 1991).

Like other salmonid species, the female digs the redd, usually in fine gravel at the tail of a pool. Optimal egg incubation occurs in water temperatures between 45 and 54° F. Eggs hatch within 28 to 49 days (Raleigh et al. 1984). Fry emerge from the gravel about 2 weeks after hatching and congregate in schools in calm areas near the edges of the stream channel. After several weeks, schools disperse as the fry become more territorial. By the end of their first year, juvenile rainbow trout move into the more swift-flowing riffle areas (Smith 1991).

Food Habits

Rainbow trout consume a wide variety of foods, depending on availability. Stream populations tend to prefer drifting aquatic and terrestrial insects while lake populations may feed more on zooplankton and benthic invertebrates and shift more to fish as they reach about 12 inches in length (Raleigh et al. 1984).

Species Interactions

Trout populations are always affected to some degree by the presence of other trout species, as well as by warmwater fish. Where the three trout species' stream ranges overlap, they segregate into more distinct habitat types than if only one species was present. Brook trout will tend to occupy the deeper pools, rainbow trout will be found in the higher-velocity riffle areas and brown trout will inhabit shallower, low-velocity areas along the banks (Bachman 1991).

Brook trout are best able to withstand competition in areas of colder water temperatures. Under marginal temperature conditions they are often displaced out of more productive habitats to colder headwaters (Fausch 1991). This often creates a longitudinal stratification in high-gradient streams with most brook trout relegated to the less fertile upper watershed, rainbow trout in the middle, intermediate habitat, and brown trout to the warmer, more fertile lower reaches (Gard and Seegrist 1972, Larson and Moore 1985, Raleigh et al. 1986). In Vermont, the co-occurrence of two or three trout species is common in wild stream populations.

Many warmwater species are detrimental to trout, particularly in small ponds. Introductions of northern pike, bass or yellow perch have decimated small pond brook trout populations (Flick 1991). Brown trout and rainbow trout can successfully co-exist with warm water species in larger, deeper lakes, primarily due to the availability of cold, deep water habitat which segregates the species much of the year.

III. Management History

Historically brook trout, lake trout (*Salvelinus namaycush*), Atlantic salmon (*Salmo salar*), and possibly arctic char (*Salvelinus alpinus,* also called saibling or golden trout and reported from a few isolated lakes in the Northeast Kingdom but not definitively identified) were the only salmonines inhabiting Vermont's waters. Dams constructed on the Connecticut River and the Lake Champlain drainage virtually eliminated Atlantic salmon in Vermont by the early 1800s, and the golden trout was alleged to have been seen no later than the early 1920s (MacMartin 1962).

The following chronology highlights many notable developments in Vermont's trout management history. Historic information, except where noted, was gathered from the Reports of the Fish Commissioners of the State of Vermont from 1866 through 1892, Biennial Reports of the Department of Fish and Game from 1918 through 1934, Biennial Reports of the State of Vermont Fish and Game Service from 1936 through 1960, and Biennial Reports of the Vermont Fish and Game Department from 1962 through 1970.

1857 - The first official action related to fish occurred when the Governor of Vermont appointed George P. Marsh to investigate artificial propagation of fish (Perry 1964). Marsh (1857) also referred to pollution, particularly from sawmills and factories, and fishermen taking fish during the spawning season, as serious issues that should be corrected.

1866 - A law was passed by the legislature prohibiting the taking of trout except during June, July and August. Atlantic salmon spawn were obtained from New Brunswick with hopes of putting the young salmon in the Connecticut River and some of its tributaries.

There were several private trout hatcheries in operation in Vermont.

1873 - California salmon were stocked into several tributaries to Lake Champlain. The California salmon were listed in the 1874 Report of the Fish Commissioners as "*Salmo Quinnant*?" The so-called Quinnant salmon is now called the king or Chinook salmon (*Oncorhynchus tshawytscha*). The ova were procured by Rev. Livingston Stone under the auspices of the U.S. Fish Commissioners from the McLeod River in California in 1873. Chinook salmon were again stocked in Crystal and Harvey's Lake in 1916 and in Nelson pond and un-named waters in the Lamoille River drainage in 1937 (MacMartin 1962). There are no records of Chinook salmon being caught.

1880 - The legislature revised many existing laws and enacted new ones, particularly those relating to fishing in closed seasons and the use of nets (Perry 1964).

1886 - Rainbow trout were introduced in the town of Lunenburg. They were subsequently stocked throughout the state which resulted in the establishment of self-sustaining naturalized populations. Wild rainbow trout as well as fisheries sustained by cultured fish are now very popular with anglers. Since both steelhead and rainbow trout were widely distributed, the true origins of our wild population are suspect and may be a blend of both forms.

1888 - A six-inch minimum size limit was enacted for brook, brown and rainbow trout. There was no creel limit at this time but anglers were restricted to six pounds of trout/day.

1891 - The first state fish hatchery was constructed in Roxbury, and is still actively rearing trout. Prior to this time, trout were brought into Vermont for stocking by the U.S. Fish Commission. In addition, many early sources of fish eggs were "stripping stations" operated on ponds and lakes such as Caspian Lake for brook trout and Dream Lake (Fairfield Pond) for landlocked salmon. Early fish culture efforts were primarily directed to raising fry or spring fingerlings whereas current culture efforts are for spring yearlings.

1892 - Brown trout were introduced into a small stream in Bennington County. Brown trout were brought into this country from several different sources such as the VonBayr from Germany and the Loch Leven from Scotland. Like the rainbow trout it has become naturalized in numerous streams and a few lakes throughout the state. Wild brown trout continue to sustain many popular fisheries in Vermont, including the Batten Kill.

1900 - Arctic grayling (*Thymallus arcticus*) were stocked in Caspian Lake and later (1932) in the Gonyeau River and other streams in Addison and Rutland Counties. Although a few were caught, they failed to become established (L. Halnon, former Vermont Fish and Wildlife Department biologist, personal communication).

1910 - The legislature revised many fish and game laws. Although the Commissioner requested uniformity of laws throughout the state, they varied considerably.

From 1910 through the 1920s over 300 miles of so-called feeder streams were closed to all fishing based on the premise that brook trout would propagate in these small streams and sustain trout populations downstream in the larger "fishable" sections.

1913 - The first recorded pond reclamation was attempted in Silver Lake in Barnard. The Vermont Fish Commissioners, having realized that widespread introductions of fish often resulted in the loss or demise of the more desirable species, treated Silver Lake with nearly 5,000 pounds of copper sulfate in an attempt to eradicate the existing fish community. Although this effort failed, it was the first use of a toxicant as a reclamation measure recorded in the United States (Lennon et al. 1970).

1932 - Cutthroat trout (*Oncorhynchus clarkii*) were stocked in the Poultney and Middlebury River drainages. As with the Chinook salmon and Arctic grayling this exotic also failed to become established.

1935-1941 - The U.S. Bureau of Commerce undertook stream and lake surveys on waters in the Green Mountain National Forest and from 1937 through about 1941 the Vermont Fish and Game Service conducted biological surveys on lakes and ponds throughout the state. These surveys in addition to the Test Water regulation enacted in 1935, which required mandatory reporting of the catch on selected waters, formed the foundation for fisheries management on a scientific basis.

1946 - The first successful reclamation in Vermont was done using rotenone on Black Pond in Sudbury. Subsequently nearly 40 ponds have been reclaimed. Although this has been a highly successful program, it is expensive and illegal re-introductions of undesirable species, restrictive regulations, and the public's concern about the use of pesticides have severely curtailed this management program.

1952 - Kokanee (*Oncorhynchus nerka*) or dwarf landlocked sockeye salmon were stocked in Bald Hill Pond and Lake Willoughby in 1952 and 1953. They spawned in Lake Willoughby in 1955 and 1956 and progeny from these runs survived and spawned (MacMartin 1962). They have since "died out" and have not been re-introduced.

A comprehensive statewide survey of Vermont's major watersheds was initiated by MacMartin (1962) which spanned 8 years and gathered distribution and biological information on trout from over 1,000 stream sections.

1957 - The daily creel limit of 20 trout was reduced to 12.

In the 1950s and early 1960s numerous small impoundments were created for trout fishing. Unfortunately most of these small ponds are too shallow and warm for trout. As a result many have become overrun with undesirable species and therefore provide only early season, short-term, put-and-take trout fisheries.

1961 - With the passage of the "omnibus" bill, regulations were streamlined and the majority of numerous exceptions to general regulations were eliminated. This bill also expanded angling to 24 hours/day and extended the May through August trout season to run from the last Saturday in April through the last Sunday in September.

1968 - Trout fishing opportunity was broadened to include a special ice fishing season on selected waters over 100 acres in size.

1974 - The open-water season was again expanded to encompass the period from the second Saturday in April through the last Sunday in October. Also in 1974 the six-inch minimum size limit for brook, brown and rainbow trout was eliminated under the general regulation requirement.

1978 - The Vermont Legislature reinstated the 6-inch minimum length limit for trout in Lamoille and Caledonia counties. In addition to this action, the Fish and Game Department was required to conduct studies on the effect of this regulation and report the results to the General Assembly in 1981.

1981 - The 6-inch minimum size limit for trout was eliminated in Lamoille and Caledonia counties based upon the results of a study of trout populations in 35 streams (Claussen 1980).

1984 - The Wallop-Breaux Amendments to the Federal Aid in Sportfish Restoration Act expanded federal monies available to state fisheries agencies for sportfish restoration and boating access programs through taxes on motorboat fuels and import duties on pleasure boats.

1989 - The New England Salmonid Health Guidelines were adopted by member states. These guidelines set forth requirements for the prevention and control of serious fish diseases.

1990 - An experimental program of sea lamprey (*Petromyzon marinus*) control was initiated in Lake Champlain and its tributaries as part of an overall salmonid restoration program.

1991 - The first comprehensive statewide angler survey was mailed to 7,250 Vermont anglers, gathering information on angler use, opinions and desires. The results of the Vermont Angler Survey provided important social information and have been invaluable for the management of Vermont's fisheries. Similar surveys have been conducted in 2000 and 2010, providing long-term trends in angler activity and opinions.

The most recent salmonid culture facility began operation in Grand Isle, in addition to existing facilities in Roxbury, Bennington, Salisbury and Newark. The Ed Weed Fish Culture Station would become one of the state's largest producers of cultured trout and provide trout for all counties in the state.

1993 - The general regulation creel limit of 12 trout/day was changed to an aggregate limit of 12 trout/day of which 6 can be brown trout and/or rainbow trout.

The Vermont Management Plan for Brook, Brown and Rainbow Trout was adopted, providing the first comprehensive approach to trout management in Vermont. This document integrated public opinion and desires with scientific studies of trout biology and management conducted both within and outside Vermont. The plan provided guidance for fisheries biologists to use in managing Vermont's trout resources and served as a public education resource which formally outlined the biological and social justifications of various trout management strategies.

1994 - A "Quality Trout Management" initiative created special fishing regulations for wild trout fisheries on reaches of the White River and Batten Kill.

In addition, reaches of the Black River, Lamoille River, Otter Creek and Winooski River were stocked with large 2-year old trout and managed with a 2-fish daily creel limit. This program has since been expanded to include reaches of East Creek, Passumpsic River, Missisquoi River and Walloomsac River.

1997 - Year-round trout fishing regulations were implemented on nine river reaches across the state. Fishing outside of the traditional open water trout season was limited to artificial flies and lures and required all trout to be immediately released. Year round trout regulations were implemented on an additional eleven river reaches in 2014.

2001 - A suite of special fishing regulations for wild trout fisheries were implemented on reaches of the Dog River, Winooski River, Lamoille River, New Haven River and Mettawee River.

2003 - An experimental program to develop sterile "triploid" trout was initiated to reduce the risk of genetic interactions between hatchery-reared and wild trout (Kirn 2011). Currently triploid trout are recommended for all stream stockings and select lake and pond stockings of brook trout and rainbow trout where potential interactions with wild stocks exist. Although widely used in the western and southeastern U.S., Vermont is the first northeastern state to incorporate triploid trout as part of normal fish culture production.

2007 - An expansion of 2-year old trout stocking was implemented in over two dozen ponds. Two-year old trout comprise a portion of the annual stocking allotment for these put & take ponds and are managed under general trout regulations.

The Vermont Fish and Wildlife Board enacted an Emergency Rule to restrict the harvest and transport of wild caught baitfish in response to a deadly fish disease known as Viral Hemorrhagic Septicemia (VHS) that was rapidly spreading through the St. Lawrence River and Great Lakes (Good 2007). The emergency rule was followed by a permanent baitfish use regulation in 2008.

2009 - Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont (Bates and Kirn 2009) was adopted and provided a new approach to culvert design which insures the free passage of trout and other aquatic species. Concepts and considerations from this design approach were later incorporated into state stream alteration standards which require new culverts, culvert replacements and culvert repairs to achieve and maintain trout and aquatic organism passage.

The allocation of trout reared at the Ed Weed Fish Culture Station (EWFCS) was shifted in response to a threat of Viral Hemorrhagic Septicemia (VHS), a serious fish disease that spread through the Great Lakes system including many New York waters. Because EWFCS draws its water from Lake Champlain, which is directly connected to the Great Lakes through a canal system, fish stocking from EWFCS was reallocated to Lake Champlain and its tributaries (downstream of barriers) to minimize the risk of inadvertently spreading VHS or other harmful pathogens and species. This shift in production required the retooling of other state fish culture facilities and a cooperative agreement with the USFWS hatchery system to adjust to the lost production at EWFCS.

2011 - Tropical Storm Irene deposited over six inches of rain in several Vermont watersheds in the central and southeastern portions of Vermont and resulted in significant damage to Vermont's oldest fish culture station in Roxbury. A near complete loss of outdoor rearing ponds created significant shortages of trout for stocking in public waters for years to come.

Post-flood alterations in Vermont streams resulted in the degradation of over 77 miles of trout stream habitat (Kirn 2012). Concerns regarding the post-flood responses prompted increased communication and coordination between Vermont Fish and Wildlife Department (VFWD), Vermont Department of Environmental Conservation (VDEC) and the Vermont Transportation Agency (VTrans). Over the next several years, this collaboration has resulted in the development of procedures, policies, trainings and regulations which greatly reduce impacts to river processes and aquatic habitat while improving flood resilience of transportation infrastructure in the future.

2017 – A statewide evaluation of 150 sites in 138 streams within 17 watersheds indicated wild brook trout populations in Vermont streams were relatively stable over a period of five decades (Kirn 2017a). Present-day brook trout populations were characterized by abundant natural reproduction and multiple age-classes, including the contribution of older, larger fish. While most population measures were consistent between the two time periods, significantly higher densities of young-of-year brook trout were observed in current populations which may reflect improved environmental protections initiated since the 1950s.

IV. Status of Existing Fisheries

Brook, brown and rainbow trout may be considered the mainstay of Vermont's coldwater fishery resource. All three species have a wide distribution in the state with populations occurring in a range of riverine and lacustrine (pond and lake) habitats. Several thousand miles of streams and rivers support trout and over 100 lakes and ponds are managed for one or more of these species. Many populations are fully or partially sustained by natural spawning while others are primarily or entirely the result of stocking programs. These populations, wild or stocked, provide anglers with a wide range of fishing opportunities and environments in which to fish.

Virtually every watershed in Vermont contains suitable habitat for supporting one or more trout species. Trout populations occur from steep mountain headwater streams down into many of the large low lying rivers; in small beaver ponds, mid-size lakes and ponds as well as in many of Vermont's largest lakes.

Figure 1 illustrates the current distribution of brook, brown and rainbow trout in Vermont watersheds. Many of these waters sustain wild populations, some are entirely dependent on the stocking of cultured trout, and other waters include both wild and cultured fish. The maps are subject to change as management objectives, particularly involving cultured trout, are modified in response to further evaluation.

Brook Trout

The brook trout is the most widely distributed trout species in the state and is the only one of the three trout species covered in this plan that is native to Vermont. Provided that habitat conditions are suitable and competition with other species is minimal, wild brook trout populations are found in most coldwater streams and in several ponds in Vermont. It is the trout species most likely to be encountered in small headwater streams and beaver ponds. A statewide evaluation of wild brook trout streams characterized present day populations as supporting abundant natural reproduction and multiple age-classes, including the contribution of older, larger fish (Kirn 2017a). In moderate sized streams, wild brook trout are often found with wild brown and/or rainbow trout populations. While in some cases the nonnative trout species have reduced or displaced brook trout, in other situations brook trout persist as the dominant trout species. With a few notable exceptions such as the Batten Kill and Castleton River, brook trout are generally not found in Vermont’s larger rivers where higher water temperatures limit these populations.

Many of Vermont's lakes and ponds have suitable habitat for brook trout but may have inadequate spawning areas or the presence of competing fish species (Bonney 2006). Consequently these waters have very limited potential for wild brook trout management. Wild brook trout ponds in Vermont tend to be mostly confined to the Northeast Kingdom (Gerardi and Kratzer 2011) and a few remote waters in the Green Mountains (MacKenzie 2017). Small beaver ponds supporting wild brook trout are widely distributed throughout the state and provide unique, although transient fishing opportunities until pond conditions degrade.

Stocking has expanded fishing opportunities in many waters that otherwise are not capable of supporting wild brook trout populations due to inadequate habitat or competing species. Several Vermont waters sustain habitat conditions capable of providing multiple year survival of stocked trout, however, the majority of brook trout stocking provides an immediate, but often short-term put-and-take recreational fishery.

Brown Trout

Following the introduction of brown trout into Vermont during the late 1800s, the species soon established a firm foothold in all major watersheds (Figure 1). While this species often frequents streams and rivers also occupied by brook and/or rainbow trout, brown trout have a preference for the deeper, lower velocity and more fertile downstream riverine reaches (Raleigh et al. 1986).

The establishment of self-sustaining brown trout populations has greatly diversified fishing opportunities in Vermont by providing a trout species well adapted to many lowland river reaches where brook trout are not well suited. Although difficult to catch, large wild brown trout are successfully targeted in many river systems around the state, including the Batten Kill, Otter Creek and Winooski watersheds. Stream and river stocking of brown trout is generally discouraged due to poor angler catches (Kirn 1999) unless direct evaluations indicate a reasonable fishery can be provided. Although limited, brown trout have the best chance of surviving more than one season when stocked in streams and rivers (Engstrom-Heg 1990).

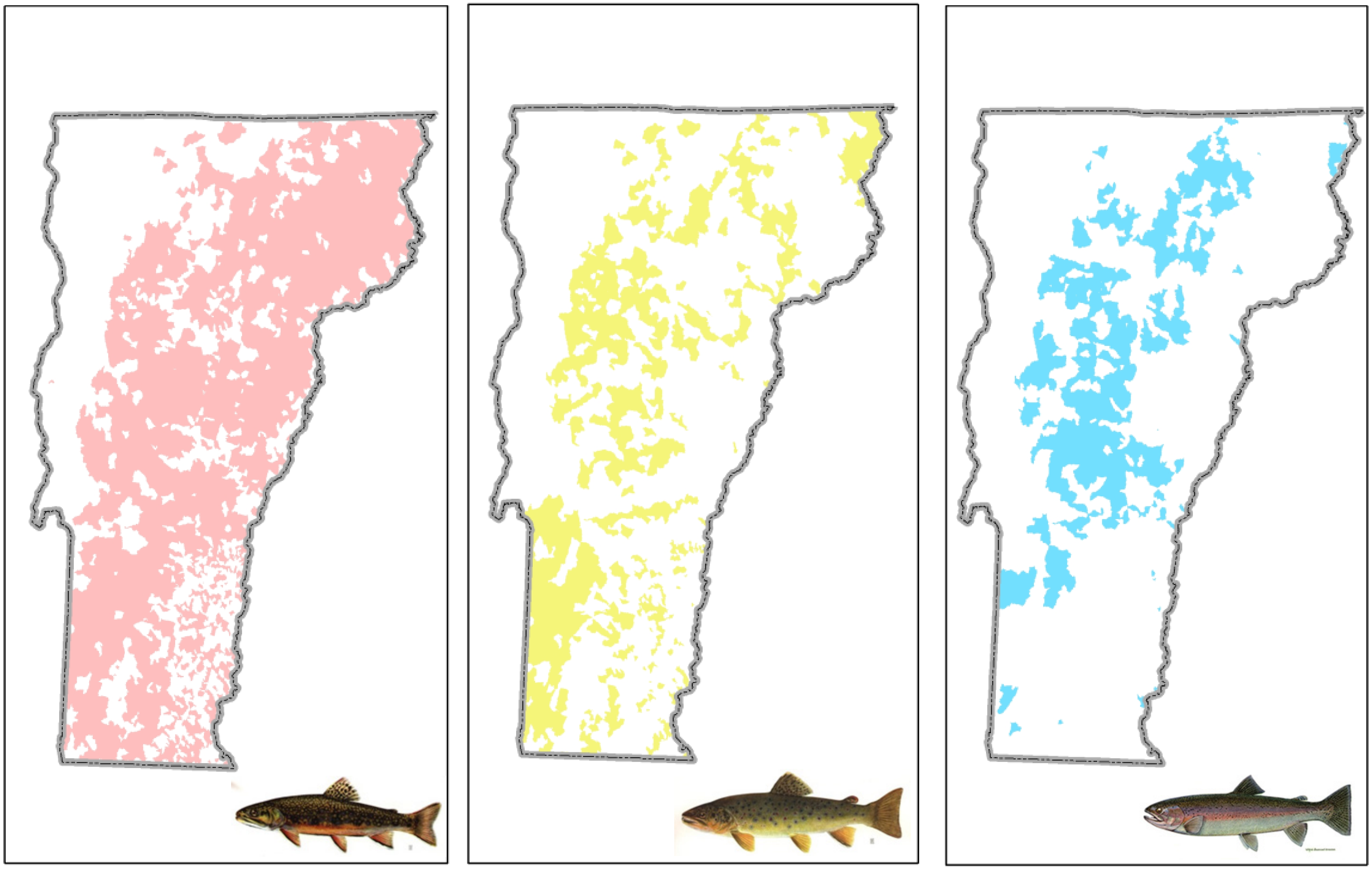
Staley (1966) notes brown trout compete well with other trout species, withstand angling pressure well and, as a result, can do well in many lake and pond situations. Although limited in flowing waters, stocked brown trout often survive multiple years in coldwater lakes and ponds. Brown trout are predatory and often attain large sizes in these waters, generating great interest among anglers. Stocked brown trout in lakes can often provide excellent winter fisheries, but are less vulnerable in open-water fisheries (Kirn 1999).

Rainbow Trout

Since its introduction in the late 1800s rainbow trout have become an important component of the state's fisheries in both river and lake habitats (Figure 1). These fisheries exist today as a result of natural reproduction, stocking or a combination of the two. However, while brown trout eventually established wild populations throughout much of the state, wild rainbow trout populations are noticeably absent from the large drainages of southeastern Vermont, including the Williams, Saxtons, West and Deerfield Rivers (MacMartin 1962). Waters in this region have characteristically low alkalinities, a condition which impacts rainbow trout reproduction (Peterson et al. 1982). Consequently, rainbow trout fisheries in the southeast region are dependent on stocking. Notable exceptions include the numerous small lowland watersheds draining into the Connecticut River. As reaches of the Connecticut River also support wild rainbow trout populations, it is believed that these small watersheds provide spawning habitat for the Connecticut River population.

Rainbow trout are often preferred for put-and-take stream and pond fisheries as they provide good angler returns and can tolerate competition and warmer water temperatures than brook trout. While rainbow trout can survive, grow to large sizes and provide quality open-water fisheries in many lakes and ponds, they generally are not very vulnerable during the ice fishing season (Kirn 1999). While most rainbow trout fisheries in Vermont lakes are maintained through stocking, a few waters in the Northeast Kingdom region are totally supported by natural reproduction. Low alkalinity and a lack of adequate spawning habitat are the primary factors limiting wild rainbow trout fisheries in other lakes and ponds.

Figure 1. Distribution of wild brook trout (left), brown trout (center) and rainbow trout (right), in Vermont by USGS HUC-14 watershed. Colored polygons denote a confirmed presence based on VFWD sampling information in at least one water body within a given HUC-14 watershed. Maps are subject to change with future trout population assessments.



V. Management of Trout Habitat

Habitat may be described as the sum of environmental conditions in a specific area occupied by an organism, population or community (Hanson 1962). Therefore, the habitat of a population (e.g. brook trout) includes other organisms as well as the physical environment (Odum 1953). Major components of trout habitat include:

- ***Water Quality*** – Temperature, pH, dissolved oxygen, sediment and alkalinity play a large role in the distribution and abundance of trout populations.
- ***Hydrology*** – Trout are dependent on a variety of flows to fulfill their life cycle needs. Alterations of natural hydrology can affect the physical, chemical and biological character of a waterbody to the detriment of trout and other aquatic populations.
- ***Physical Habitat*** – Includes the water's bed, banks, substrate, vegetation, natural and artificial features and adjacent riparian zone and floodplain. High quality physical habitat (as pictured below in Figure 2) is:
    - *Diverse* – Trout require specific habitats including riffles, pools and various depths, velocities and substrates for different life stages.
    - *Complex* – Trout habitat is formed and maintained by the interaction of water with surrounding lands. Organic material, from leaves to large trees, as well as boulders, cobbles, gravels and fine sediment originate from the banks and surrounding land and strongly influence aquatic habitat quality.
    - *Messy* – Boulders, fallen trees and large wood accumulations provide important complex habitats for trout and other aquatic life. Uniform channels or shorelines of neatly manicured lawns may be attractive to some, but provide poor trout habitat.
    - *Connected* - Just as we use the road network to meet our life needs, trout and other aquatic organisms move through stream networks to feed, rest, reproduce and escape unfavorable conditions.

Figure 2. An example of high quality stream habitat.

The quality and quantity of aquatic habitat will largely influence how well a waterbody can support trout. Therefore, the greatest opportunity to maintain or improve Vermont's trout fisheries is though the protection and enhancement of aquatic habitat. To be successful this will require a diverse approach which includes participation in environmental regulatory processes at the project and policy level; engagement with land and water developers; coordination with and support of state, federal and private natural resource agencies and organizations; outreach to private landowners; riparian and instream habitat enhancement projects; and land acquisition.

Major Threats to Trout Habitat

Among the most serious influences that continue to degrade water quality and threaten trout habitat in Vermont are increased water temperature, sedimentation, physical habitat alteration, flow alteration and habitat fragmentation (VFWD 2016, VTANR 2016). The introduction and spread of undesirable pathogens and aquatic species is also a major concern for the future of Vermont's trout fisheries.

Increased Water Temperature - Water temperature has a profound effect on the distribution and abundance of aquatic populations (Poole and Berman 2001, DeWeber and Wagner 2014). Coldwater species, like trout, are particularly susceptible to changes in water temperatures (Argent and Kimmel 2013). Global climate change predictions suggest further losses of brook trout populations throughout their range due to increases in temperature and flood frequency (Wenger et al. 2011). In Vermont, Kratzer and Warren (2013) found brook trout abundance to be negatively correlated with the duration of temperatures exceeding 68°F. Maximizing cold water in smaller tributary streams is also extremely important for moderating temperatures and providing thermal refuges for trout in the larger streams, rivers, lakes and ponds into which they feed (Baird and Kruger 2003).

The loss of riparian vegetation and its associated shading of surface and ground water resources is a major cause of increased water temperatures (Beschta et al. 1986, Poole and Berman 2001, DeWeber and Wagner 2014). The damming of streams also promotes increased temperatures as the wider, slower impoundment is exposed to increased solar radiation and heating. Maxted et al. (2005) and Lessard and Hayes (2003) reported that increased temperatures and reduced dissolved oxygen associated with small impoundments were detrimental to macroinvertebrate communities and coldwater fish populations. Hydroelectric operations can also result in substantial and abrupt changes in stream temperatures when the temperature of generation flows substantially differs from ambient stream temperatures (Kirn 2016b).

Excess Sediment – The natural process of erosion, through the scouring of a stream's bed and banks, and the transport and deposition of this material, helps to create and maintain important aquatic habitat features. This process forms pools and undercut banks, recruits trees into the stream channel and provides fresh, well sorted gravels for prime trout spawning habitat. When excess sediment enters the stream system from poor land use practices, these physical and ecological processes can suffer. Sediment discharges can come from a variety of sources including town roads, poor farming or logging practices, construction sites and development adjacent to streambanks and shorelines (VTANR 2016). Waters (1995) provides a comprehensive review of the biological impacts of sediment in streams which is summarized below:

Suspended sediments & turbidity:

- May result in respiratory impairment and gill abrasion and lead to direct mortality or increased susceptibility to disease.
- May degrade water quality conditions which result in avoidance of stream reaches with important habitats.
- May reduce photosynthesis and associated primary productivity.
- May increase invertebrate drift.
- May result in reduced feeding and growth.
- Carries nutrients (phosphorous, nitrogen) which can lead to degradation of water quality in downstream receiving waters, particularly lakes and ponds.

Deposited sediments:

- May degrade spawning habitat conditions by creating embedded substrates which cannot be excavated by trout for egg deposition.
- May reduce interstitial flow which provides oxygen and waste removal for developing trout eggs and fry.
- May entrap trout fry and make them unable to emerge from gravels.
- May degrade available habitat for fish, aquatic invertebrates and amphibians.
- May degrade or eliminate pool habitats.

Physical Habitat Alteration –Trout require diverse and complex habitats for spawning and incubation, feeding, resting and refuge from extreme conditions and predators. The loss of aquatic habitat diversity and complexity has been well studied and is directly linked to decreased diversity and abundance of macroinvertebrate and fish populations (Groen and Schmulbach 1978, Chapman and Knudsen 1980, Edwards, et. al 1984, Carline and Klosiewski 1985, Lau et. al 2006). These conditions are often the result of instream impoundments, loss of functioning riparian and floodplain habitats, channelization and the removal of instream substrate and natural wood. In the Northeast Kingdom of Vermont and elsewhere, historic logging practices have resulted in reduced instream habitat diversity, including the loss of large wood complexes which provide important brook trout habitat (Kratzer and Warren 2013, Kratzer 2014.) Stream gravel mining, which proliferated in Vermont during the 1970s and 1980s, has been associated with increased channel instability causing streambed degradation, loss of bank vegetation, increased lateral migration and damage to private and public infrastructure (VDEC 2017). VDEC (2011) estimated that nearly 74% of Vermont streams are actively adjusting from changes in hydrology, sediment loads and past stream management activities including channelization, gravel mining and berming. While detrimental instream activities are currently less common due to more stringent environmental regulation, post flood alterations recently resulted in significant degradation of over 75 miles of stream following Tropical Storm Irene in 2011 (Kirn 2012).

Flow Alteration – In Vermont, streamflows are altered by impoundments, through hydroelectric generation, flood control operations and recreational boating releases; water withdrawals for snowmaking, irrigation, cooling and public water supplies; and diversions for off-stream ponds. The alteration of natural flow regimes through damming and diversion can greatly affect aquatic populations by modifying physical and chemical processes, reducing abundance and diversity, shifting species composition, reducing habitat diversity and disrupting natural behavioral cues

(Novak et. al. 2016). Hydrologic alteration may occur on both long (e.g., seasonal cycles of reservoir drawdown/refill) and short (e.g., daily cycles) time scales, presenting flow regimes that differ dramatically from those in which trout evolved (e.g., Lytle and Poff 2004). Extreme flow fluctuations can cause stranding and displacement of fish, as well as behavioral changes in spawning activity, nest dewatering, nest scouring, and reduced survival and growth of juvenile fishes (Young et al. 2011, Nuhfer et al. 2017). Hydroelectric generation and recreational boating releases are examples where extreme flow alteration, inadequate or interrupted base flows and unregulated ramping rates can have negative consequences to aquatic resources by degrading the quality and quantity of aquatic habitats.

Hydroelectric project operations can have a profound impact on downstream temperature and water quality. Releases from deep, hypolimnetic intakes are often oxygen deficient, and may result in extreme water temperature fluctuations in receiving waters (Kirn 2016b). Surface releases, on the other hand, may further elevate downstream temperatures by diminishing the effects of diurnal cooling (Kirn 2017b). Hydroelectric and flood control dams can also result in severe water level fluctuation of impounded reservoirs which may significantly reduce the biological productivity of these waters (Ploskey 1986). The timing of drawdown and refill cycles can also affect the ability of trout to access spawning tributaries by exposing physical obstructions or degrading water quality.

Flow alterations during the winter months from activities such as snowmaking or hydroelectric production, occur when trout are less mobile, physiologically vulnerable and have eggs (brook trout and brown trout) within stream gravels (Brown et al. 2011). Cunjak (1996) suggests water withdrawals probably impact stream fishes more than any other type of winter stream alteration due to direct loss of available instream habitat, physiological stress related to reduced water temperatures, and increased ice formation with its associated impacts. However, winter ecology of trout in general, and the impacts of snowmaking water withdrawals on fish populations are poorly understood (Krimmer et al. 2011) and may be difficult to discern due to natural population variability and the influence of other environmental factors (Kirn 1997).

Habitat Fragmentation - Trout move daily, seasonally, and during different life stages to feed, rest, reproduce, seek refuge from extreme conditions and repopulate vacated habitats. Studies in Michigan and Vermont have documented daily movement of adult brown trout, which leave daytime resting areas and travel upstream or downstream overnight, sometimes over a mile or more, presumably to forage, and then return to daytime home sites (Diana, 2004; Cox 2016). Cox (2016) also documented an adult brown trout moving over nine miles from the mainstem to a small tributary during its spawning period. Rainbow trout from large lakes and rivers also move into tributary streams in the spring to spawn throughout Vermont. While brown trout and rainbow trout are well known for their migratory tendencies, brook trout also rely on regular seasonal movements to maintain viable populations. Gowan and Fausch (1996) documented brook trout summer seasonal movements of over a mile and shorter distances traveled regularly by resident brook trout. Movement occurs even in high gradient streams, as evidenced by Adams et al. (2000) who observed upstream movement of brook trout in slopes as high as 22%.

In addition to moving during higher flows to access suitable spawning habitat in spring and fall, trout and salmon also move during summer low flows and in anticipation of winter low flows.

Peterson and Fausch (2003) observed peak movement of brook trout in the summer and fall, with nearly 80% of recaptured fish moving upstream and over a mile away within a summer. Likewise, Kanno et al. (2013) observed distinct peak movements in June and September-October of wild brook trout in a Massachusetts stream. The moderating effect of groundwater on extreme water temperatures can also provide motivation for fish movement. Brook trout often spawn in areas of groundwater inflow (Webster and Eiriksdottir 1976, Witzel and MacCrimmon 1983, Curry and Noakes 1995, Waters 1995), and have been observed to overwinter in pools in proximity to groundwater discharges (Cunjak and Power 1986). Access to groundwater upwellings and tributary confluences is also important for thermal refuge for trout and other species during summer months (Baird and Kruger 2003). These observations highlight the importance of well-connected stream networks to trout and other aquatic populations.

Hundreds of dams and thousands of culverts in Vermont create partial or complete barriers for trout and other aquatic populations. An assessment of culverts in Vermont indicates that only six percent provide full aquatic organism passage (AOP) (Figure 3; VFWD 2016). Similarly, most dams preclude upstream aquatic passage. Few of Vermont's hydroelectric dams offer passage routes other than spillways or powerhouses, and those that do typically are limited to one direction and for a limited group of species and sizes of fish. These barriers to the movement and migration of trout populations may lead to a variety of impacts including:

- Loss or reduction of migratory populations due to obstructed access to critical spawning, rearing, feeding or refuge habitats;
- Loss or reduction of resident populations by preventing recolonization of upstream habitats after catastrophic events, such as floods or toxic discharges;
- Altered species composition and distribution;
- Isolated populations with reduced genetic diversity and increased risk of extirpation (Letcher et al. 2007, Whiteley et al. 2013).

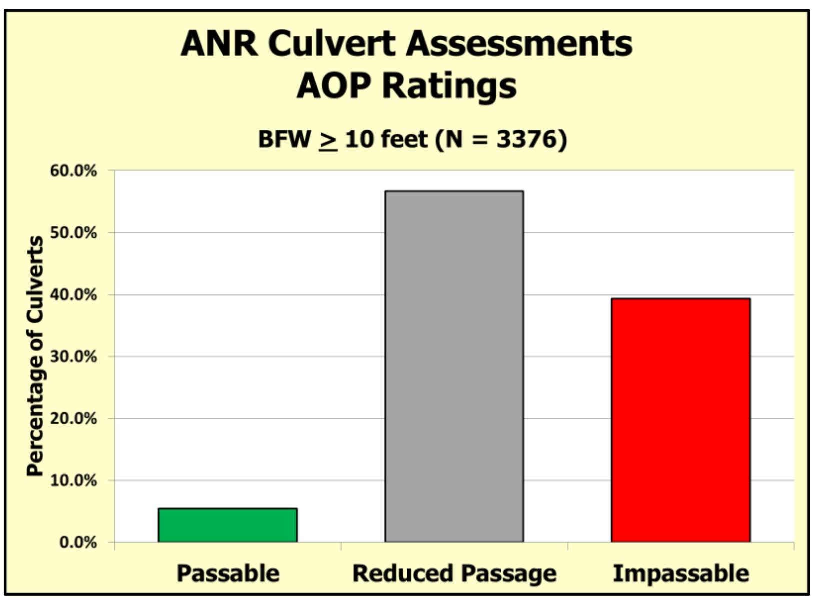


Figure 3. Aquatic organism passage (AOP) ratings for culverts in Vermont streams with a bankfull width ≥ 10 feet.

Undesirable Aquatic Species – The introduction and establishment of fish pathogens or undesirable aquatic species can have a profound impact on trout populations. The establishment of smallmouth bass, northern pike, chain pickerel and other warmwater fish species has been implicated in declines of wild brook trout in Maine (Bonney 2009) and Vermont (Gerardi and Kratzer 2011). The movement of fish, including baitfish, not only increases the potential for introducing new populations but may introduce and spread serious fish pathogens such as whirling disease and viral hemorrhagic septicemia (VHS) (Good 2007), parasites and other harmful organisms.

Habitat Protection

Vermont is fortunate to have many waters with excellent habitat conditions for brook, brown and rainbow trout. From an ecological and economic standpoint, it is far more effective to protect these habitats rather than allow them to be degraded and attempt to restore them at a later time (Feld et. al 2011). The primary tools available for fisheries managers to protect trout habitat include:

- ***Environmental Regulation*** –
    - Land and water development project review;
    - Development and influence of municipal, state and federal aquatic habitat related regulations, policies and procedures;
- ***Collaboration and Coordination*** with state and federal agencies, municipalities and other organizations and programs which directly impact or regulate aquatic habitat;
- ***Partnerships with Non-governmental Organizations*** such as angler, watershed and conservation organizations;
- ***Public Outreach and Technical Assistance*** to influence land use activities on private lands;
- ***Land Acquisition*** to protect critical aquatic habitats.

Habitat Protection - Focal Areas:

<u>Riparian Zones</u> - Maintaining and enhancing a naturally vegetated riparian zone along the shores of streams/rivers and lakes/ponds is a simple yet extremely effective means of protecting the trout habitat (VTANR 2005). The importance of these zones has been well known for many years as reflected in this excerpt from the 1899-1900 report of the Vermont Fish and Game Commissioners:

> *"It is a well known fact that the best fishing is where a forest is near the shore, and best of all where the limbs overhang the water. Not only do the trees afford shelter, furnish food and prevent evaporation, but at the same time they keep the water clear and cool in the summer. In the winter the forests afford protection by lessening the severity of the winter frosts, and in all forest regions the changes of temperature are not so severe as in treeless countries and on the open plain: and the effect upon the water is even greater….But the forests not only regulate the flow of water, as above stated, but they purify the water."*
>
> ***- Frank H. Carleton, from the Fifteenth Biennial Report of the Commissioners of Fish and Game of the State of Vermont, 1899-1900.***

The 2016 Riparian Management guidelines for Agency of Natural Resources Lands (VTANR 2015) further details the variety of important functions which riparian zones provide to address many of the threats to trout habitat described earlier:

> ***"Temperature Moderation***
> *Riparian vegetation has a profound effect on moderating temperatures in both surface and ground waters. Forest canopies limit the input of solar radiation and insulate waterbodies from extreme temperature changes during the summer and winter months. Aquatic species such as brook trout, slimy sculpin, spring salamander and many invertebrates are dependent upon cold, well oxygenated waters for their long term viability. Maximizing cold water in tributary streams is also extremely important for moderating temperatures and providing thermal refuges in the larger streams, rivers and lakes which they feed.*
>
> ***Sediment and Nutrient Retention and Control***
> *The impact of sediment discharges to aquatic habitats and the populations they support has been well documented. Sediment can have direct detrimental effects on populations or result in degraded habitats which impact reproduction and abundance. As nutrients are attached to soil particles, processes that control sediment transport to surface waters also affect nutrient inputs. Riparian vegetation influences the discharge of suspended sediments by reducing soil erosion; filtering and trapping sediment transports from upland sources prior to entering surface waters; binding and fortifying streambanks and shorelands; creating pools and debris jams which store sediments; and moderating stream flows and bed scour during high water events. The effectiveness of riparian areas for controlling sediment and associated nutrients will be influenced by slope, vegetative cover, ground complexity and roughness, soil type, permeability and stability, and adjacent land uses.*
>
> ***Large Wood Recruitment and Retention***
> *Large wood features, such as individual logs, rootwads and more complex log jams are recruited from riparian areas into nearby waterbodies by means of natural aging and falling, wind throw, flood, and landslide. Large wood plays an important role in the development and maintenance of aquatic habitat structure and complexity. Larger wood provides more stable habitat features and sources of organic material as they are less prone to movement than smaller individual pieces. The interaction of stream flow with large wood causes scour, captures and retains smaller wood and creates complex pool and near-bank habitats with hiding and isolation cover, thereby increasing the number of fish that can occupy a given area. Large wood features also moderate sediment transport rates thereby reducing sedimentation of spawning habitats and rapid filling of pools.*
>
> ***Energy & Food Supply***
> *Allochthonous (produced outside of the aquatic system) organic material, in the form of leaves, needles and woody debris from riparian vegetation, represent the dominant energy source supporting biological processes in small streams. Once recruited to the stream, this material is conditioned by microbes before becoming available to aquatic invertebrates which, in turn, can be consumed by fish. Large wood is very important in*

capturing and retaining leaves, organic litter and smaller wood, both within the stream channel and its floodplain, allowing for this energy source to be utilized within the stream reach before being transported downstream.

Shoreland Stability and Stream Channel Equilibrium
Trees and their root systems, individual stems or complexes of wood act as hard borders and protect shorelands, streambanks and beds from erosion. The presence of large wood, including log jams, influences flow velocity, channel shape and sediment storage and is important in dissipating energy of high flow events. Standing and downed wood in floodplains also serve to trap sediment and organic material and reduce velocities during flood flows."

Many studies have focused on determining an effective width for various riparian functions. While study results may vary due to differences in waterbody characteristics, topography, climate, vegetation and adjacent land uses, there is general support that the influence of many important riparian functions extends 100 feet or more from waterbodies. These conclusions are supported by comprehensive works including a recent review by Sweeny and Newbold (2014) who conclude *"Overall, buffers > 30m wide are needed to protect the physical, chemical, and biological integrity of small streams."* In *Riparian Management in Forests of the Continental Eastern United States*, Verry et al. (2000) also indicate that many riparian functions approach 60 to 80% of their maximum within 100 feet. In some cases, such as small, stable streams, a narrower riparian zone may be adequate to protect trout habitat (VTANR 2015).

Lakes and ponds require similar riparian protections to support functioning aquatic habitats. A study of 40 Vermont lakes showed significant differences in biological measures between sites with undeveloped, naturally vegetated shorelines vs. developed shorelines (Merrell et al. 2009). Decreases in tree cover, shading, woody structure, leaf litter and biological production were noted adjacent to developed shorelines whereas sediment and the percentage of sand substrate generally increased. This study further confirmed the importance of protecting riparian functions along Vermont's lakes and ponds and lead to the passage of the Shoreland Protection Act in 2014.

Aquatic Organism Passage (AOP) – Past stream crossings were simply designed to pass a certain amount of water (e.g. a 25-year, 50-year or 100-year flood event) but did not recognize the stream substrate (gravels, cobbles, boulders) and debris (trees and limbs, ice, man-made items) also transported during high flow events (VFWD 2010). As a result, these structures were substantially undersized and create problems for stream channel stability, threaten roadways and other infrastructure, and degrade and fragment aquatic habitat. From a trout's view, undersized culverts create difficulties for passage by creating excessive velocities at higher flows, shallow depths at low flows, and drop at the culvert outlet which is often too high for trout and other aquatic species to navigate.

Vermont has made considerable progress improving AOP at road stream crossings with a comprehensive approach which includes technical assistance and training, regulation revision, assessment, coordination and partnerships. Highlights of this effort are found at http://www.vtfishandwildlife.com/cms/One.aspx?portalId=73163&pageId=1763294 and include:

- *Technical Guidelines for the Design of Road-Stream Crossings for Passage of Aquatic Organisms in Vermont (Bates and Kirn 2009)*: Through the State Wildlife Grant program (SWG), the VFWD funded the development of technical design guidelines for aquatic organism passage (AOP) at road-stream crossings in collaboration with VTDEC and VTrans.

- *AOP Workshops:* Due to the complexities of stream crossing designs which include hydrological, biological, geomorphic and engineering considerations, a series of stream crossing design workshops was conducted to build this understanding and expertise by state, federal, municipal and consulting engineers, road crews, transportation planners and others involved in stream crossing design and construction in Vermont.

- *The Vermont Stream Crossing Handbook (VFWD 2010):* provides a user-friendly compendium to the technical guidelines in the form of a "handbook" for private landowners, municipal road crews, town planning and conservation commissions and other individuals and organizations involved in road/stream crossing planning, design and construction.

- *Stream Crossing Regulations:* The implementation and evaluation of the AOP technical design guideline criteria and concepts has provided important information to develop new regulatory standards within the VT Stream Alteration General Permit which regulates activities in perennial streams. Specific criteria for culvert sizing, embedment, profile, and substrate infill have been developed which will provide greater consistency in project design and improved effectiveness for AOP. Similar efforts have been applied to the US Army Corps of Engineers Vermont General Permit.

- *Culvert Assessments:* VFWD has conducted and provided SWG funding to a variety of partners to complete thousands of stream crossing surveys to provide information on AOP and geomorphic compatibility. Once completed, these assessments provide necessary information to more effectively identify and begin the process of prioritizing structures for AOP improvements. To enhance the availability and use of this data, the assessments were added to the Vermont Agency of Natural Resources *Natural Resource Atlas*, a publicly available web-based GIS tool.

- *AOP Partnerships:* VFWD has partnered with USFS, USFWS and many angler, watershed and natural resource organizations to assess, design, fund and implement many on-the-ground AOP improvement projects including culvert retrofits, culvert replacements and dam removals, most of which have benefited brook trout or other trout species.

While benefits to trout and other aquatic populations from Vermont's new culvert design approach are being realized, the economic benefits of these structures are also increasingly recognized

(Levine 2013, Gillespie et al. 2014, MAF&G 2015, O'Shaughnessy et al. 2016). These benefits include increased structure lifespan, reduced maintenance, and reduced risk of catastrophic failure. In essence, stream crossings which are compatible with natural stream processes are good for the structure, the roadway and other private and public infrastructure and for fish.

Although Vermont has established itself as a leader in resolving AOP issues at road-stream crossings, progress in addressing the 1200+ dams in the state has been a tougher challenge. Many Vermont streams contain old abandoned mill dams that have outlived their purpose or are in a state of decay. The Department policy is to support dam removal and oppose reconstruction in most circumstances. While a few dams are removed each year, in part due to the efforts of partner organizations, other dam removals are difficult to implement due to social conflicts (Fox et al. 2016) and regulatory complexities. VFWD will continue to play an important role in discussions surrounding dam removal, repair and construction in our efforts to protect and enhance trout habitat and fisheries.

In some cases, the removal of an obstruction may raise concerns of further expansion of the distribution of naturalized rainbow trout or brown trout into allopatric brook trout waters (Fausch et al. 2009). While displacement of brook trout has been documented in other states, Vermont has many waters where robust populations of wild brook trout have sustained themselves for decades in the presence of one or both of these species. Several studies suggest that habitat variables like water chemistry (e.g., pH, Baldigo and Lawrence 2000), temperature (Butryn et al. 2013), and adjacent land cover (Hudy et al. 2008, Wagner et al. 2013), are better predictors of brook trout abundance than the presence of nonnative trout. In fact, brook trout are better equipped to persist in acidic waters (natural or anthropogenic) and flashy spring/summer hydrology, conditions common to Vermont, than either brown or rainbow trout (e.g., Kocovsky and Carline 2005, Kanno et al. 2017). This is supported by an evaluation of wild brook trout in Vermont streams which observed a decline in co-occurring nonnative trout populations since the 1950s (Kirn 2017a). While the potential risk of nonnative trout expansion should be carefully considered when evaluating proactive AOP projects, the geomorphic, water quality, aquatic habitat quality and other ecological benefits associated with the removal of a physical obstruction will generally outweigh these concerns.

Instream Management Practices – Instream work can be widespread following flood events and can have long lasting impacts to trout habitats and populations (Kirn 2012). Excessive instream alteration practices observed following Tropical Storm Irene in 2011 prompted focus on the development of standard instream practices which meet primary goals of infrastructure protection and public safety while minimizing future flood risks and impacts to water quality and aquatic habitat (Schiff et al. 2014). VFWD participated in the development of the *Vermont Standard River Management Principles and Practices* (Schiff et al. 2014) which considers aquatic habitat during the design process rather than later in the permit review process. To further the understanding of these concepts and considerations, VDEC, VTrans and VFWD have collaborated in a formal training program for state, regional and municipal transportation staff as well as environmental consultants and regulators. These practices, as well as new flood recovery regulations which limit the scope of post flood activities, aim to reduce habitat impacts following future flood recovery efforts and for non-flood projects as transportation and municipal officials become more familiar with these techniques and concepts.

Although not as frequent, there are also opportunities to influence projects involving lake and pond habitats through several VDEC regulatory programs. Consistent and effective participation by VFWD at the project and policy level will be critical to assure that aquatic habitat concerns are addressed during projects affecting both instream and lake/pond habitats.

<u>Hydroelectric Dam Regulation</u> – As of 2017, there were 102 hydroelectric dams operating in Vermont, some with flood control operations, and many causing significant impacts to aquatic habitats and fisheries. Fisheries impacts from hydropower development on rivers and streams are outlined by Tyrus and Winter (1992), and include but are not limited to:

> *"Conversion of rivers and streams to impounded waters with concomitant loss of stream fisheries. Impounded waters are usually managed to completely replace native fauna with a new introduced one;*
>
> *Physical habitat alteration of downstream areas including changes in water temperature, channel morphology, or stream substrates that impact native fishes;*
>
> *Reduction in recruitment of some species due to loss of spawning and rearing habitat caused by upstream flooding, lack of access to spawning areas, inadequate fish passage and others;*
>
> *Stress and direct loss of fish due to project operation; i.e., stranding, nitrogen saturation and reduced dissolved oxygen levels:*
>
> *Loss of stream productivity due to variable releases, scouring of instream habitats, and altered water temperatures;*
>
> *Replacement of native species by introduced fishes whose life histories are more compatible with altered stream environments."*

There are engineering and operational approaches to address some of these problems, although they are far from perfect. For example, elevated water temperatures in the outlet stream may be corrected by changing the outlet structure to draw from deeper, cooler lake water, rather than at the surface. Fish traps and fish ladders can be installed at dams to allow for upstream passage, although their effectiveness is often limited to a small fraction of the fish community (Brown et al. 2013). To avoid mortality from entrainment and impingement on trash racks or from passing through turbines, downstream passage can be attempted via a release of water near the power plant intake, which then carries the fish past the dam by way of a pipe or sluiceway. These facilities are not entirely effective, and retrofitting existing dams with facilities that fish use effectively is particularly difficult and expensive. Brown et al. (2013) describes several failed restoration programs to caution against the reliance of fish passage and other technologies to compensate for ecosystem wide impacts of hydroelectric dams.

In recent years, run-of-river (ROR) hydropower has emerged as a viable option for generating electricity without disrupting a river's natural flow regime. This operating regime, in which producers generate power using incoming flows only, is assumed to be an improvement over store-and-release schemes which respond more to market forces than natural hydrological cycles (Anderson et al. 2014). Although ROR operations are generally preferred for protecting trout populations, attaining a more natural flow regime may be complicated by the need for project infrastructure and operational improvements (Gibeau et al. 2017).

Deep water outlet structures can provide beneficial coldwater releases below hydroelectric projects which create temperature regimes suitable for coldwater species such as trout (Walters et al. 1997, MacDonald et al. 2012, Kelly et al. 2017). Consistent coldwater releases can be particularly important in light of climate change predictions. Peaking operations, however, can result in extreme fluctuations of water temperature, as high generation flows quickly overwhelm the base flow conditions (Kirn 2016b). In some situations, coldwater releases may result in sub-optimal conditions for trout growth immediately below the project. As these releases also extend and enhance coldwater habitats and fisheries further downstream, broader trout fisheries benefits may be realized and outweigh localized impacts. In addition to temperature effects, deep water releases can result in degraded water quality, including low dissolved oxygen and high metal concentrations, which can be harmful to trout and other fish (Grizzle 1981).

Many of Vermont's lakes and reservoirs have outlet structures that allow for control of the water level. Water levels are sometimes drawn down for hydropower generation, to control aquatic plants or to control ice damage to docks and shorelines. Significant water level manipulations are clearly damaging to the overall ecological integrity and productivity of a lake or reservoir (Wildi 2010, Kaczmarek et al 2016, Carmignani and Roy 2017). Winter drawdowns, which are typically a part of these water level management efforts, have a devastating effect on aquatic plants and invertebrates which would normally inhabit the littoral zone (Ploskey 1986, Carmignani and Roy 2017). As a result, other organisms which depend upon these species for food or cover are also impacted. From a trout fisheries management perspective, lake and reservoir water levels should generally not be artificially fluctuated.

Continued participation in hydropower regulatory processes is a high priority of the Department's habitat program. Many existing projects were licensed many years ago when environmental concerns were overlooked or poorly understood. Some projects were built before a license was required. Considering that license terms are for 30-50 years, the opportunity for long-term progress for restoration of impaired fisheries resources is high. The Department will need to effectively participate in hydropower licensing to assure that fisheries and aquatic habitat interests are addressed.

Climate Change Resiliency - Global climate change is influencing precipitation rates, snow pack and soil moisture; temperature; the spread of diseases and invasive species; the frequency of flooding and droughts; movement of species and their habitats, and predator-prey relationships (VFWD 2015). Trout species, particularly brook trout, are expected to be particularly sensitive to climate change due to their stringent temperature requirements (Wenger et al. 2011, Argent and Kimmel 2013). Therefore, it is important to build climate change resiliency strategies into trout management and evaluate its effects through implementing research and monitoring programs. Monitoring species distribution and abundance; stream temperatures, coldwater refugia, early detection of invasive species, pests and pathogens; and the identification of genetically adapted species will help to inform future management of trout and their habitats in light of climate change (VFWD 2015).

<u>Land and Water Development Regulation</u> - Vermont has a number of laws that regulate development and other activities in or next to rivers/streams and lakes/ponds (Section X). However, these laws do not protect fish and their habitat unless the Department actively participates in the permit processes. This participation is the Department's main vehicle for protecting habitat. While these duties are shared among the Department's fisheries staff and varies from year to year, the current effort is equivalent to over two full-time positions. The Department also promotes, initiates and influences the development of regulations, procedures, policies and guidelines that protect trout habitats and populations.

<u>Outreach and Technical Assistance</u> – The majority of land in Vermont is in private ownership and therefore not subject to most environmental regulations which control activities detrimental to aquatic habitat and trout populations. Due to the profound effect these activities have on aquatic habitat and trout populations, it is imperative that the Department develop effective strategies to engage and inform riparian landowners regarding the importance of these habitats for aquatic ecosystems to positively influence their management of these lands. Likewise, engagement with land and water developers, including state and municipal transportation programs, outside of the regulatory arena will foster better understanding of aquatic habitat issues; improve working relationships and the acceptance of aquatic habitat protection strategies.

<u>Land Acquisition and Management</u> - The Department acquires land to protect important aquatic and terrestrial habitats and to provide public access for hunting, fishing and wildlife viewing. In addition to larger landholdings managed as Wildlife Management Areas, the Department owns and manages over 200 riparian land parcels. In addition to providing access to anglers, many of these lands provide protection of important riparian habitats. Appropriate stewardship of existing lands and future acquisition of parcels with important habitat and recreational value will continue to be part of the Department’s habitat protection approach.

Habitat Restoration and Enhancement

While it is far more effective to protect habitat in the first place, existing problems are sometimes significant enough to warrant the expense of corrective action. Habitat restoration and enhancement, often referred to as habitat improvement, focuses on the correction of past habitat abuses. Habitat improvement is best accomplished when restoring the natural processes which will maintain desired habitat conditions over the long term (Roni et al. 2008, Simenstad and Bottom 2010). Habitat enhancement efforts will be most effective if pursued strategically, in a manner that recognizes the value of individual projects within a larger watershed context. Habitat can also be enhanced through the chemical control of unwanted fish species and by reducing or eliminating obstacles to fish movement within streams.

The Department has partnered with many agencies and organizations to improve trout habitat through instream habitat improvements, culvert retrofits and replacements, dam removals and riparian restoration. These partnerships will continue to be an important component of an overall trout habitat program as, in addition to site specific improvements, these projects provide broader public exposure to aquatic habitat issues and land management practices.

Habitat Improvement

Habitat improvement often focuses on passive or active approaches to create physical changes such as through the addition of complex structures to create cover or pools, fish passage treatments and riparian restoration. Habitat improvement projects should be based upon a clear need or defined problem (e.g. reduced trout population levels) and must consider adjacent land use practices and watershed processes which will influence the long-term effectiveness of the project (Pegg and Chick 2010). It is also important to carefully evaluate all factors which may limit the trout population before considering a habitat improvement project; otherwise improved habitat conditions may not result in increased fish production (Pegg and Chick 2010). For example, if stream temperatures often exceed 80°F, adding instream features to improve brook trout populations will be of little value. Likewise, if robust populations of wild trout currently exist, intrusive habitat alterations will be unnecessary and potentially harmful.

Instream Habitat Structures - Although billions of dollars have been expended in the US since 1990 on river restoration, limited project scope, unclear objectives, inadequate monitoring and variability of results have clouded the benefits of this approach (Bernhardt et al. 2005, Roni et al. 2008, Louhi et al. 2016). While positive improvements from habitat improvement projects have been reported for trout and salmon, projects involving the construction of instream habitat structures can be very complex, expensive, labor intensive and variable in effectiveness (Roni et al. 2008, Bouwes et al. 2016). Unless the natural processes which support and maintain constructed habitat structures are also addressed, these improvements may be ineffective or short lived (Roni et al. 2008, Simenstad and Bottom 2010). Moore and Rutherfurd (2017) also stress the need to develop long-term management and funding mechanisms to conduct ongoing maintenance of stream restoration interventions to avoid project failure. For these reasons, Roni et al. (2008) suggests careful consideration of the project scale, watershed processes (e.g. water quality, hydrology, sediment transport, riparian condition) and effective long-term monitoring before contemplating the use of instream structures. The following excerpts underscore the importance of thinking beyond the banks of the stream to address influences on aquatic ecosystems.

<u>Simentstad and Bottom 2010:</u>
"Protection of existing quality habitat is critical. Habitat improvement in the absence of an overlying conservation program is counterproductive because the ecological integrity of the landscape will continue to erode, jeopardizing the ecological capital upon which the habitat improvement depends…

Ensure no net loss of habitat functions and protect unimpeded natural processes upon which they depend. Habitat improvement actions should achieve proposed benefits without degrading other ecological functions of natural habitats or broader ecosystems…

Habitat improvement measures should re-establish the dynamics of hydrology, sedimentology, geomorphology, and other habitat forming processes that naturally create habitat rather than simply implant structures at inappropriate or unsustainable locations..."

Hunter 1991:
"The future of trout-habitat rehabilitation lies in the development of restoration plans that contain an appropriate mix of land-management changes and in-stream structural work. It's futile and wasteful to place a number of habitat enhancement structures in a stream if the land-use practices that made those structures necessary are not changed…

Structural solutions to in-stream habitat deficiencies by themselves will not provide long term dividends. Only the wise stewardship and management of the lands within the drainage will allow the long-term self-sustaining health of our streams and their trout populations."

Kratzer (2014) provides a current example of an instream habitat improvement project in northeastern Vermont where historic log drives and poor logging practices have severely degraded streams. Streams were straightened and complex habitat features were removed to accommodate log drives on many streams. Repeated cycles of clear-cutting have resulted in young riparian forests that do not provide large woody material at the size and rate of mature forests. Although extreme northeastern Vermont is largely undeveloped, poor instream habitat conditions are still evident today. To remediate these conditions, the Department has partnered with Trout Unlimited, Weyerhaeuser and the US Fish and Wildlife Service to implement strategic wood additions in the Nulhegan River and Paul Stream watersheds to improve habitat complexity and natural stream processes (Figure 4). Enhancement sites were selected where adequate water temperatures and riparian conditions favor long term brook trout persistence. Aquatic passage is also being considered and improved where necessary. Early responses by brook trout are encouraging and further evaluation will determine the long term benefit of these treatments (Kratzer 2016b).

Figure 4. Examples of wood addition treatments in the Paul Stream watershed.

Culvert Replacements and Dam Removals - Culverts and dams create barriers to fish and other aquatic species movement, degrade stream habitat and increase the risk of property damage during high flows. The Department has worked throughout the state in partnership with watershed and angler organizations, the US Fish and Wildlife Service, US Forest Service, The Nature Conservancy, towns and others to identify, design, fund and implement aquatic passage improvements. These projects have included culvert retrofit treatments (baffles and/or tailwater grade controls), full culvert replacements (Figure 5) and the removal of dams (Figure 6). By restoring natural stream processes, these projects improve aquatic passage, habitat quality and flood resiliency.

Figure 5. Pre and post culvert replacement photos from Bradley Brook in Warren, VT. Project partners include the Friends of the Mad River, USFWS, USFS, Town of Warren, Winooski Natural Resource Conservation District and VFWD.

Figure 6. Pre and post photos of the Sargeant Osgood Roundy Dam removal in Randolph, VT. Project partners include American Rivers, TNC, White River Partnership, VDEC and VFWD.

Riparian Restoration –Passive techniques (e.g. livestock exclusions) or active plantings can be effective ways to improve a variety of aquatic habitat conditions over the long term. The active revegetation of riparian areas through plantings can greatly accelerate the natural recovery process and restoration of important riparian functions. Vermont is fortunate to have many watershed and angler organizations as well as supporting state, federal and private natural resource agencies which are knowledgeable and active in the restoration of riparian habitats throughout Vermont. The Department should continue to support and enhance these efforts through technical, financial and direct assistance.

Chemical Control of Undesirable Fish

Chemicals have been used for many years as an effective fishery management tool for the removal of unwanted fish populations, often substantially improving sport fishing (Lennon et al. 1970). "Reclamation" improves conditions for trout by eliminating competing species and predators. The use of chemicals to control sea lamprey within their spawning and nursery streams has been successful in improving survival of lake dwelling trout and salmon in Lake Champlain (Marsden et al. 2003). About 40 ponds have been chemically reclaimed in Vermont, although none since the late 1980's. The re-introduction of unwanted species from the angler's bait bucket or from misguided, illegal stockings can unfortunately undo the benefits of reclamation. As very few lakes and ponds currently support wild brook trout fisheries in Vermont (Gerardi and Kratzer 2011), a carefully developed chemical reclamation program could greatly expand opportunities for wild brook trout management in these waters.

Recommendations

As human population growth increases the pressures on aquatic resources, the importance of habitat protection and restoration will only increase. Habitat protection and restoration is essential to the Department's efforts to sustain and manage the State's wild trout resource. If Vermont is to conserve this important resource, and with it quality angling, then habitat protection and management must be our highest priority and therefore the following actions are recommended:

1. Consistently and effectively participate in the development and implementation of environmental regulatory policies, regulations and procedures to protect, enhance and restore trout habitat.

2. Consistently and effectively advocate for habitat protection, restoration and enhancement with other agencies, developers, private landowners and the public.

3. Continue to engage, inform, support and partner with state, federal and private natural resource organizations and private landowners to protect and restore trout habitat.

4. Develop effective strategies to engage and inform riparian landowners regarding the importance of these habitats for aquatic ecosystems to positively influence their stewardship of these lands.

5. Identify high value wild trout habitat for protection through conservation easements or acquisition.

6. Monitor the effects of habitat protection and enhancement projects on trout populations to ensure the anticipated benefits are achieved, efforts are cost effective and results are used to inform future projects.

VI. Management of Wild Trout

Wild trout, those present through natural spawning, are found in most Vermont streams and rivers. Thousands of miles of upland streams support wild populations of native brook trout, while larger streams and rivers often support a mixture of naturally reproducing brook, brown and/or rainbow trout. In addition to "fishable" populations including adult trout, many miles of tributary streams serve as spawning and nursery habitat for wild trout populations inhabiting larger rivers or lakes. Lakes and ponds which support wild trout, although relatively few in number, also provide important ecological and recreational fishery resources.

Wild trout populations have long been considered indicators of healthy ecosystems. These fish are the result of long-term natural selection pressures and are therefore especially suited for life in the wild. Many anglers consider wild trout superior in their aesthetic, sporting and culinary qualities. From a purely economic standpoint, healthy wild trout populations can sustain important recreational fisheries without the costs associated with hatchery production. The key to managing these populations lies in the maintenance of suitable habitat (i.e., physical habitat, habitat connectivity, water quality and natural hydrology) and the prevention of overharvest, which are covered in Sections V and VIII, respectively.

Respondents of the *2010 Vermont Angler Survey* expressed overall support for the concept of wild trout management (i.e., no stocking) for some waters (Connelly and Knuth 2010). Approximately 50% of both resident and nonresident trout stream anglers felt this program was "very important" while over 25% indicated it was "somewhat important." Only a minor component (< 15%) of the respondents believed wild trout management was "not important."

Vermont's Wild Trout Resources

Streams & Rivers - The greatest potential for managing wild populations of brook, brown or rainbow trout to support recreational fisheries is found in streams and rivers throughout the state. Through the development of electrofishing gear, the direct sampling of trout populations in all but very large rivers has become standard practice. MacMartin's (1962) *Vermont Stream Survey* provided the first comprehensive study of species distribution and relative abundance of wild trout in the major watersheds of Vermont. Since then thousands of stream trout studies, conducted as basic inventory, management evaluations, or environmental impact assessment, have further enhanced our knowledge of Vermont's wild trout stream resources and form the basis of recommended guidelines for wild trout management.

As expected, these surveys provided a wide range of wild trout population densities. Vermont's exceptional wild trout stream fisheries support population densities of at least 30 lbs/acre and/or 400 "catchable" (≥ 6 inches) trout/mile. Very good wild trout levels for spawning tributaries, waters supporting mixed trout species and upland wild brook trout streams are considered to be at least 20 lbs/acre; and/or 200 ≥6-inch trout/mile; and/or 1000 total trout/mile. It should be noted that naturally unproductive waters may support wild trout levels far lower than these thresholds despite maintaining excellent habitat and water quality and natural hydrology regimes.

When interpreting the results of stream electrofishing surveys for developing management strategies, it is important to realize that trout populations within a stream may vary widely from section to section and within a section from year to year (Hall and Knight 1981, Platts and Nelson 1988, Kirn 2017a). Annual fluctuations in trout populations are often related to environmental influences while variation among stream sections tends to be related to differences in habitat.

Lakes & Ponds - Wild trout management opportunities in Vermont's standing waters are very limited. Numerous beaver ponds located on small upland streams throughout the state often provide wild brook trout angling opportunities. However, due to changing impoundment conditions these fisheries are usually temporary in nature (Avery 1983). Several ponds in the Green Mountains (MacKenzie 2017) and the Northeast Kingdom are currently managed as wild brook trout fisheries (Gerardi and Kratzer 2011) and wild rainbow trout and brown trout are a component of the trout fishery in a few other Vermont lakes. Most lakes and ponds support insufficient spawning and nursery habitat as well as contain established populations of non-salmonid competitor and predator species, which generally precludes the recruitment of adequate wild populations to sustain recreational fisheries, even under very restrictive harvest regulation. Where these opportunities do exist, management should emphasize the conservation and enhancement of quality spawning and nursery habitat as well as the recruitment of an adequate spawning population.

Recommendations

Wild Trout Management Guidelines

“Wild trout waters”, as described below, shall be managed in keeping with the Department’s stated policy to *“Place priority on implementing effective habitat protection, restoration, and enhancement measures* (Section V) *and harvest regulation* (Section VIII) *in managing the state's wild trout resources.”* Stocking of cultured trout should be avoided in these waters (Section VII).

Streams & Rivers:

1. Stream or river segments which maintain, or through harvest regulation have the potential to maintain excellent trout population densities of ≥30 lbs/acre and/or ≥400 trout/mile (≥ 6 inches) through natural reproduction, regardless of fishing pressure **[W1]**

2. Stream or river segments which presently maintain, or through harvest regulation have the potential to maintain very good trout densities of 20-29 lbs/acre and/or 200-399 trout/mile (≥ 6 inches) through natural reproduction and which are subject to low or moderate fishing pressure (<400 angler-hours/mile/year). **[W2]**

3. Small upland streams which maintain very good densities (≥20/lbs/acre and/or ≥1000 trout/mile) of brook trout through natural reproduction. Although environmental factors coupled with relatively short life cycles associated with these populations preclude most wild brook trout from attaining a large size, these streams are often sustaining populations near their maximum potential. **[W3]**

4. Spawning and nursery tributaries supporting very good wild trout densities ≥20/lbs/acre and/or ≥1000 trout/mile which are important in sustaining significant wild trout populations in larger rivers or lakes. **[W4]**

Lakes & Ponds:

Due to limited opportunities in Vermont, lakes and ponds with the potential for wild trout management should be evaluated with management strategies which exclude the use of cultured trout. **[W5]**

VII. Management of Cultured Trout

Artificially reared, i.e. "cultured" trout provide an effective management tool for maintaining recreational fisheries where adequate wild populations cannot be sustained due to physical or environmental habitat limitations, particularly when these populations are subject to high fishing pressure. In Vermont, many popular trout fisheries in ponds, lakes and large rivers are dependent on the stocking of cultured trout. While an important component of many state fisheries agencies, the large expense of cultured trout programs has raised questions of their economic, social and ecological cost/benefit (Johnson et al. 1995, White et al. 1995, Loomis and Fix 1997, Ham and Pearsons 2001). As fish culture comprises the majority of the fisheries management budget in Vermont, this program must be managed effectively to meet fisheries management objectives and ensure the greatest benefit to the angling community while avoiding or minimizing impacts to wild trout and other aquatic populations. The use of cultured trout should not be considered an alternative to the protection or restoration of suitable trout habitat. As with wild trout populations, only when optimal habitat conditions are available for cultured trout, will their benefits be fully realized.

Management Objectives

Trout stocking in Vermont can be separated into three general categories, each with distinct objectives:

Introductory Stocking is conducted where the establishment or restoration of a self-sustaining population is the primary objective. Therefore, suitable habitat required for all life stages must be available for this type of stocking to be effective. Introductory stockings may be appropriate following pond reclamation or in situations where wild populations have been lost due to natural or human caused events and physical barriers that prevent recolonization. Historic introductions of nonnative brown and rainbow trout into suitable habitats have resulted in a wide distribution of these species throughout the state.

Maintenance Stocking, often referred to as "put-grow-and-take" stocking, is conducted in waters where suitable habitat and food resources are available to sustain growth and survival of stocked trout over more than one season, but where wild trout populations are limited, often due to inadequate spawning or nursery habitat. Best results for this type of stocking occur where competitor and predator populations are low (Butler and Borgeson 1966). In Vermont, maintenance stocking is primarily conducted in larger, deeper lakes and ponds, where water quality necessary for trout survival is sustained year-round. Substantial overwinter survival of brook, brown and rainbow trout stocked in streams and rivers, however, is generally not observed (Engstrom-Heg 1990, Wiley 1995, Kirn 1999, High and Meyer 2009, Dillon et. al. 2000, Alexiades et al. 2014).

Put-and-Take Stocking, where trout are stocked for immediate catch, provides an instantaneous and often short-term trout fishery. These programs can be described as providing recreation, largely independent of growth and survival considerations (Butler and Borgeson 1966). Although suitable habitat need not be available year round for this stocking program, greater success can be expected where habitat conditions allow fish to be caught over an extended period of time. Both resident and nonresident anglers responding to the *2010 Vermont Angler Survey* (Connelly and Knuth 2010) expressed broad support for this stocking program in both streams and rivers, and lakes and ponds. Over half of these anglers indicated this type of stocking was "very important" while less than 10% felt it was "not important". Due to very limited survival of stocked trout observed in Vermont studies (Kirn 1999), all stream and river stocking is considered put-and-take.

Stocking Considerations

In developing trout stocking recommendations for a body of water, the following factors should be considered:

<u>Wild Trout Population</u> - The potential impact of stocking artificially reared trout on wild, self-sustaining populations has been the focus of many scientific studies and has raised concerns among segments of the professional fisheries and trout angling communities (White et al. 1995, Pearsons 2008, Araki and Schmid 2010, Sass et al. 2017). Specific areas of concern include: potential genetic alteration of wild stocks due to interbreeding or altered selection pressures (Hindar et al. 1991, Krueger and May 1991, Currens et al. 1997, Kirn 2003b, Habera and Moore 2005); displacement of native species by hatchery-reared trout (Waters 1983, Larson and Moore 1985, Hindar et al. 1991, Kanno et. at. 2016); direct mortality of wild trout due to behavioral interactions with stocked trout (Bachman 1984, Vincent 1987); and contamination of wild trout through introduction of disease (Goede 1986, Hindar et al. 1991, Krueger and May 1991, Stewart 1991). Over the past 25 years, Vermont has made great strides in trout culture and stocking practices to minimize these potential risks.

<u>Genetics:</u>

Philipp et al. (1993), Waples (1991), Kreuger and May (1991) and Hindar et al. (1991) each provide thorough reviews of potential genetic impacts from the practice of supplementing wild salmonid populations with hatchery stocks. Waples (1991) describes three primary issues of concern: *"(1) direct genetic effects (caused by hybridization and introgression); (2) indirect genetic effects (principally due to altered selection regimes or reductions in population size caused by competition, predation, disease, or other factors); and (3) genetic changes to hatchery stocks (through selection, drift, or stock transfers), which magnify the consequences of hybridization with wild fish."* Hindar et al. (1991) concludes: *"A wide variety of outcomes, ranging from no detectable effect to complete introgression or displacement, has been observed following the release of cultured fish into natural settings. Where genetic effects on performance traits have been documented, they always appear to be negative in comparison with the unaffected native populations."*

Of the three trout species, brook trout are likely the most at risk from this interaction, as hatchery-reared trout need only survive to the first fall after stocking (about four months) to spawn with wild stocks. While precocial male brown trout may also spawn in their first fall following stocking, later maturing brown trout and rainbow trout would generally need to survive the winter months and high spring flows to spawn with their wild counterparts. This potential should be limited as overwinter survival of stocked trout in streams, which support the majority of Vermont's wild trout resources, is uncommon in Vermont (Kirn 1999) and other states (Wiley 1995, Dillon et. al. 2000, High and Meyer 2009, Alexiades et. al 2014). However, even when reproductive success of hatchery fish is low, the practice of frequent (e.g. annual) stockings can result in altered genetic characteristics of wild stocks (Skaala et al. 1996). While Vermont has relatively few standing waters supporting wild trout, “holdover” trout from maintenance stockings in coldwater lakes and ponds can ascend tributary streams and interact with wild populations (Humston et al. 2012).

Although cases of reproductive isolation have been observed in conjunction with long term stocking programs, introgression and hybridization between wild and hatchery stocks has been well documented for many salmonid species, including brook, brown and rainbow trout (Reinitz 1977, Krueger and Menzel 1979, Campton and Johnston 1985, Carmichael et al. 1993, McCraken et al. 1993, Leary et al. 1996, Williams et al. 1996, Currens et al. 1997, Williams et al. 1997, Henderson et al. 2000, Galbreath et al. 2001, Hansen et al. 2001, Dillman and Koppleman 2006, Bennet and Kirshiner 2009, Harbicht et al. 2014). Suggested approaches to minimize these risks include isolation (no stocking in the presence of wild populations), stocking fish which are genetically similar to the wild population, and sterilization of stocked fish (Hindar et al. 1991).

While the practice of avoiding trout stocking in areas of abundant wild trout can minimize genetic interactions, movement of cultured trout from stocked waters into non-stocked wild trout waters may readily occur if barriers are not present (Cresswell 1981, Baird et al. 2006, High and Meyer 2009). To further address this concern, the Vermont Fish and Wildlife Department has initiated the use of sterile (triploid) trout in applications where interactions with wild trout populations are likely (Kirn 2011). The use of triploid trout is being used as a fisheries management strategy for conserving native populations while meeting the public demand for recreational angling opportunities in several states (Dillon et. al. 2000, Habera and Moore 2005, Kozfkay et. al. 2006). Management applications of triploid trout in Vermont and other states have generally revealed similar or superior performance (catch rate, survival, growth) when compared with their diploid counterparts, (Dillon et. al. 2000, Teuscher et al. 2003, Kozfkay et. al. 2006, Kirn 2011, Budy et al. 2012).

Displacement:

Establishment of rainbow and brown trout in many Vermont streams and rivers has undoubtedly resulted in the partial or complete displacement of native brook trout populations in some waters as has been reported in other states and provinces (Waters 1983, Larson and Moore 1985, EBTJV, Thibault and Dodson 2013, Kanno et. at. 2016). In a Minnesota stream, Waters (1983) reported a change from virtually 100% brook trout to predominantly brown trout over a 15-year period. Larson and Moore (1985) observed similar encroachments on native brook trout populations by rainbow trout in the southern Appalachian Mountains. In a recent study of wild brook trout streams in Vermont, a decline in sympatric brown trout and rainbow trout sites were observed over the past 50 years, suggesting that nonnative trout populations have not appreciably expanded since the 1950s (Kirn 2017a). Despite these findings, the potential displacement of isolated wild brook trout populations must be seriously considered before making new introductions of stocked rainbow trout or brown trout. Stocking avoidance or the use of triploid trout should be practiced where trout stockings have the potential to establish nonnative trout species to the detriment of native brook trout populations.

Direct Mortality:

Some studies have suggested that increased mortality of wild trout may occur following the stocking of hatchery reared trout as the result of increased energy expenditure and stress associated with agonistic encounters with hatchery trout (Bachman 1984, Vincent 1987). Other studies have not supported this finding (Nehring 1987, Engstrom-Heg 1990, Meyer et al. 2017) or have observed it only in cases where very high densities of hatchery trout were stocked relative to the existing wild population (Petrosky and Bjorn 1988, McKenna et al. 2013).

Trout stocking in Vermont streams and rivers is normally conducted in the spring when wild trout biomass is at its lowest (McFadden 1961, Hunt 1966, Engstrom-Heg and Hulbert 1982), stream temperatures and therefore metabolic needs are relatively low, and fishing pressure is at its highest. In addition, maximum trout stocking densities are based upon wild trout levels observed in Vermont. When higher densities are justified, multiple stockings are conducted to reduce trout densities at a given time. These factors should minimize the potential for direct impacts from competitive pressures of stocked fish on wild trout in streams.

Disease:
The role of infectious diseases in fish populations is often poorly understood or underestimated, despite documentation of their contribution to significant mortalities in both cultured and wild populations (Goede 1986, Stewart 1991, Nehring and Walker 1996, Vincent 1996, Moffitt et al. 2004). Goede (1986) categorizes the potential consequences of disease introduction on fish populations into four components: *mortality*, which may be substantial yet unobserved or underestimated; creation of a *reservoir of infection* which may contaminate a system in perpetuity; *reduced performance* (e.g. growth, survival, stamina) which may result in increased vulnerability to predation; and *increased sensitivity to stressors*, where stress induced by the disease organism may exacerbate its own state, reduce the fish's capability to perform with respect to other stressors, and predispose the fish for multiple infections with other organisms.

Vermont Fish and Wildlife Department manages a Fish Health Program to prevent and control the introduction of harmful fish pathogens within Vermont through monitoring and regulation of fish culture facilities and fish transportation activities. This includes:

1. Comprehensive fish health inspection requirements for all culture facilities (state, federal, private) which produce salmonid fishes for stocking in Vermont waters.
2. Regulation of the importation of all fish species and associated diseases into the State of Vermont.
3. Regulation of the movement of all fish species within the state.
4. Prevention of disease introductions from state fish culture facilities into new waters through the development of a disease history classification system for waters stocked with salmonid fishes.
5. Monitoring pathogens and parasites in wild trout populations.

In summary, potential impacts of stocking cultured trout on wild populations can be minimized by:

1. Managing Vermont's high quality wild trout populations without hatchery supplementation and by focusing on appropriate habitat protection and enhancement, and harvest regulation.

2. Managing cultured trout through judicious use of stocking locations, densities, species, strains, ploidy and disease classifications which will minimize impacts to wild trout populations.

Species Selection - Trout species selection is an important consideration when managing a fishery with cultured trout and should be based upon several factors including specific management objectives, habitat requirements, food availability, and presence of competitor and predator species, existing wild trout populations and angler preferences. In addition to the species life history requirements presented earlier, the following information should be considered when selecting a trout species for stocking.

Brook Trout were targeted by 67% of Vermont resident anglers and was selected as the most preferred species for open water fishing by this group in the *2010 Vermont Angler Survey* (Connelly and Knuth 2010). Over one-third of nonresident anglers also targeted brook trout, which ranked the third most preferred open-water species by these anglers.

This species has the most stringent water temperature requirements and therefore survival potential will be limited in marginally suitable waters. This species provides excellent opportunities for put-and-take fishing in both streams and ponds. In small ponds, brook trout will provide a fishery for both shore based and boating anglers. Maintenance stocking of brook trout is best suited for waters free of substantial competitor and predator species (Lachane and Magnan 1990, Bonney 2006). Brook trout stockings in large lakes have generally shown poor returns and should be avoided unless water specific evaluations are conducted and prove otherwise (Kirn 1999, Bonney 2006). With the exception of several coldwater ponds in the Green Mountains and Northeast Kingdom supported by maintenance stocking or wild populations, brook trout are primarily stocked to support put-and-take fisheries in Vermont.

Rainbow Trout were targeted by 67% of Vermont resident anglers and ranked behind brook trout as the most preferred trout species for open water fishing (Connelly and Knuth 2010). Rainbow trout was the trout species targeted by the greatest number of nonresident anglers (37%) and was the fourth most preferred by these anglers during open water fishing. This species was also considered preferable to the other two trout species by resident and nonresident ice anglers.

Rainbow trout are better able to withstand higher water temperatures and competition than brook trout, but are less tolerant of low pH conditions. Rainbow trout may become piscivorous at lengths of 10-12 inches (Kirn 1987, Beauchamp 1990), although a fish forage base is not necessary for this species to thrive (McAfee 1966, Hensler 1987). This species' feeding characteristics and its ability to withstand warmer water temperatures in conjunction with a longer life span, provide the potential to manage this species for large sizes. Rainbow trout can provide quality open-water fisheries for both shore-based and boating anglers, but they are generally not a major component of angler catches during the ice fishing season (Kirn 1999).

Brown Trout, although the least popular of the three trout species, ranked in the top six fish species targeted and preferred by resident and nonresident anglers in the *2010 Vermont Angler Survey* (Connelly and Knuth 2010).

Brown trout are capable of withstanding warmer water temperatures as well as pressures of angling and competition from other species (Staley 1966), and have the greatest, although still limited, potential for multiple season survival in streams and rivers (Engstrom-Heg 1990). Brown trout generally do not provide good angler catches when stocked for put-and-take fisheries in streams and rivers (Kirn 1999, Baird et al. 2006) and therefore should be avoided unless site specific evaluations suggest otherwise. In coldwater lakes and ponds, brown trout can be relatively long-lived, are opportunistic feeders and may therefore provide the greatest potential for attaining large size of the three trout species. Although they were slightly less preferred than rainbow trout by both resident and nonresident ice anglers, brown trout can provide excellent ice fishing opportunities (Kirn 1999).

Strain - The genetic strain of artificially cultured trout is known to have profound influence on trout species performance in the hatchery (egg production, age at sexual maturity, spawning time, growth rate, disease resistance, handling tolerance, etc. (Gjedrem 1976) and following stocking in the wild (growth, survival, longevity, feeding habits, migration tendencies, vulnerability to angling, etc. (Calhoun 1966, Moring 1982, Brauhn, and Kincaid 1982, Fay and Pardue 1986, Hensler 1987, Cone and Kruger 1988, Lachance and Magnan 1990)). These differences have long been recognized as opportunities for fisheries managers to tailor the use of certain strains for specific environmental conditions or management objectives (Calhoun 1966, Braun and Kincaid 1982, Moring 1982, Cone and Kruger 1988). Strain evaluations conducted in Vermont have led to changes in brook trout production strains in the late 1990s as the Rome strain showed superior hatchery and post-stocking performance to the Owhi strain in put-and-take applications (Kirn 1996).

While in-hatchery performance is an important consideration in developing a trout production strain, the post-stocking performance of the strain will ultimately determine if the goal of providing high quality recreational opportunities can be met. Field evaluation of post-stocking performance, particularly with angler creel surveys, is imperative to evaluate the success of trout stocking programs (Hudy and Berry 1983, Hartzler 1988). Periodic evaluation of strain performance should be conducted to ensure trout broodlines continue to perform as desired.

Size/Life stage – The stocking of cultured trout is conducted with a variety of sizes or life stages depending on fisheries management objectives, characteristics of the receiving water and stocking logistics.

Fry - Newly hatched trout, or fry, provide very limited management potential for establishing recreational fisheries (Everhart and Youngs 1981) primarily due to high mortality from predation, competition and environmental pressures following stocking. Best results can be expected in barren waters such as reclaimed ponds or newly formed beaver ponds with contributing watersheds devoid of trout. The use of trout fry *assumes* that adequate habitat conditions exist for juvenile and adult trout, but natural reproduction is limited by habitat constraints or the lack of adult spawners. These situations are rarely observed in Vermont, as wild trout reproduction is widely documented (Kirn 2017a). Past practice of widespread trout fry stocking in Vermont has been discontinued due to a lack of clear benefit and the potential for negative interaction with wild trout populations. When fry stocking is considered to establish resident or migratory trout populations, efforts to identify and eliminate factors precluding natural reproduction (e.g. trout passage) should also be pursued and evaluated.

Fingerlings - The stocking of fingerling trout (2-5 inches) in streams was identified as an ineffective management technique for providing recreational fisheries by the 1940s (Surber 1940, Shetter 1950, Needham 1959). The return to anglers was usually less than 3% of the total stocked, effectively raising the total cost per fish more than 30-fold (Needham 1959, Burns and Calhoun 1966, Cresswell 1981, Wiley et al. 1993). As with trout fry, fingerling stocking in streams may be justified in special cases where management objectives require establishing resident or migratory trout populations in areas where natural reproduction or recruitment of juvenile fish is limited. Fingerlings have shown greatest promise in barren or newly reclaimed ponds (Eschmeyer 1938), while stocking in waters with significant populations of competitor or predator species generally results in poor return. (Eschmeyer 1938, Borgeson 1966, Stuber et al. 1985, Nelson 1987, Wiley et al. 1993).

Fingerling trout can provide quality fishing opportunities in remote locations where transportation logistics require the use of smaller trout. Spring fingerlings stocking of high elevation ponds with helicopters (Cox 1990, MacKenzie 2017) or fall fingerling stockings with backpacks (Gerardi and Kratzer 2011) are examples in Vermont where the use of smaller trout is warranted. Cox (1990) reported gill net catches of brook trout ranging from 7 to 16 inches in length from fingerling stocking of Bourn Pond. In a study of fall fingerling brook trout stocking in Northeast Kingdom ponds, Gerardi and Kratzer (2011) observed catchable trout within the first year in five of eight ponds and multiple year survival in three of eight ponds. Likewise, MacKenzie (2017) found multiple year survival of stocked spring fingerling brook trout in some remote ponds. In both of the recent studies, ponds supporting wild brook trout populations were also identified and resulted in the discontinuation of stocking, further highlighting the need for periodic fisheries evaluations.

Catchable Trout - The rearing of trout to sizes acceptable for immediate harvest by anglers began to gain popularity in the late 1930s (Hazzard and Shetter 1939, Surber 1940). By the 1980s the stocking of catchable trout was a common practice with 43 states stocking over 50 million catchable size trout in the U.S. (Hartzler 1988) and continues to be the mainstay of the Vermont trout stocking program today. As long term survival of trout stocked in streams and rivers is seldom observed in Vermont (Kirn 1999), the stocking of catchable trout is an effective approach to provide immediate fishing opportunities and increased return of stocked trout to anglers. For maintenance stocking programs in which survival over more than one year is desired, larger fish are preferable because they have a greater variety of food resources immediately available to them, and are less vulnerable to predation (Wiley et al. 1993, Walters et al.1997).

While yearling trout, ranging from 8-11 inches, have been the primary component of catchable trout stocking, the stocking of 2-year old and larger trout has gained popularity among anglers and state fisheries agencies. Stocking of larger (12-16 inch) 2-year old trout was initiated in 1994 in Vermont with the establishment of "trophy trout" stockings in four river reaches. These stockings have resulted in very popular fisheries characterized by high angler effort and good catches of large stocked trout (Kirn 1995, Kirn 2001, Kratzer 2013, Will 2014, Ladago 2015) and led to the expansion of this program to eight river reaches and over 20 lakes and ponds. The stocking of larger trout (> 12 inches) has also been shown to reduce predation (Hyvärinen and Vehanen 2004), increase angler return rates, and result in lower overall costs per trout caught and increased angler satisfaction (Walters et al.1997, Baird et al. 2006, Losee and Phillips, 2017).

Although very popular, further expansion of the 2-year trout program must carefully consider long term impacts to hatchery production, program economics and angler expectations. The production of 2-year old trout requires extended rearing in ponds or raceways normally used to house fingerlings for yearling production, creating logistical constraints for overall production. There is also a potential danger of creating unrealistic angler expectations (Wiley 1995) to a point where what is currently a quality or "trophy" trout becomes the norm, reducing the uniqueness of this program and undermining the value of wild trout fisheries. As with other stockings, the effectiveness and economic benefits of the 2-year trout program should be periodically evaluated to insure these programs are meeting management objectives (Hartzler 1988, Johnson et al. 1995, Loomis and Fix 1997). Finally, selection of new pond sites or river reaches must carefully consider the ability of the area to accommodate high angler use and potential conflicts with private landowners (parking, trespass, litter, etc.).

In providing recreational fisheries with catchable trout, it is important to understand angler expectations and desires. The *2010 Vermont Angler Survey* provides opinions on both the smallest "keeper" size trout and the minimum size considered a "quality" trout when fishing in streams or rivers and in ponds or lakes. Table 1 presents the minimum "keeper" size and "quality" size lengths for each trout species selected by 50% or more resident anglers:

Table 1. Vermont resident trout angler responses regarding their minimum "keeper" and "quality" sized trout, by species and water type, from the 2010 Vermont Angler Survey.

Minimum "keeper" size	Streams & Rivers	Lakes & Ponds
Brook Trout	8 inches	8 inches
Brown Trout	10 inches	10 inches
Rainbow Trout	10 inches	12 inches
Minimum "quality" size	**Streams & Rivers**	**Lakes & Ponds**
Brook Trout	10 inches	10 inches
Brown Trout	12 inches	14 inches
Rainbow Trout	12 inches	14 inches

Broodstock Trout – The maintenance of trout brood lines creates the need to dispense larger adult trout which are no longer required for egg production. As these fish are not available on a consistent basis it is important to avoid setting unrealistic expectations of anglers when selecting stocking locations. These trout are often available in the fall and can be used to supplement lakes with winter trout fisheries. Select brood trout can also be used to support the 2-year old trout program when sizes are within the range of typical stockings. Very old and large trout may not be appropriate for stocking if physical condition and appearance is poor.

Timing - The timing of trout stocking can greatly influence its success. Stocking practices including fall (vs. spring) releases, stocking in upper stream reaches and stocking at low water temperatures (<50^{o}F) have been reported to increase the magnitude of post-stocking movement (Cresswell 1981, Wiley et al. 1993). Significant movement out of stocking areas may be considered an economic loss to the objective of providing recreational fishing in a specific area (Moring 1982). Stream stocking of catchable sized trout in the fall also results in reduced return rates, primarily due

to exposure to overwinter mortality factors (Needham 1959, Cresswell 1981, Wiley et al. 1993). In Vermont, as fishing effort is very low in the fall and overwinter survival of stocked trout is negligible, fall stockings in streams and rivers are expected to have limited value.
Fall stocking in maintenance ponds has been conducted to reduce fish culture stocking burdens, feed costs and predation but may result in reduced size and numbers of trout returning to the spring fishery relative to spring stockings. Fall stockings are not recommended for streams, rivers and other put-and-take waters as overwinter survival is not expected.

Unlike coldwater pond and lake fishing, which is more evenly distributed throughout the open water season, a large proportion (30-60%) of the seasonal fishing pressure on streams and rivers is normally complete by the end of May, and often two-thirds to three-quarters is complete by the end of June (Figure 7). Similar angler effort distribution occurs in New York State, where the majority of the seasonal fishing pressure on streams and rivers is complete by the end of June (Alexiades et al. 2014). The return of trout stocked in put-and-take programs may therefore be profoundly affected by when these fish are stocked. For example, a mid-June stocking may result in these fish being available for only 30 - 50% of the entire seasonal pressure.

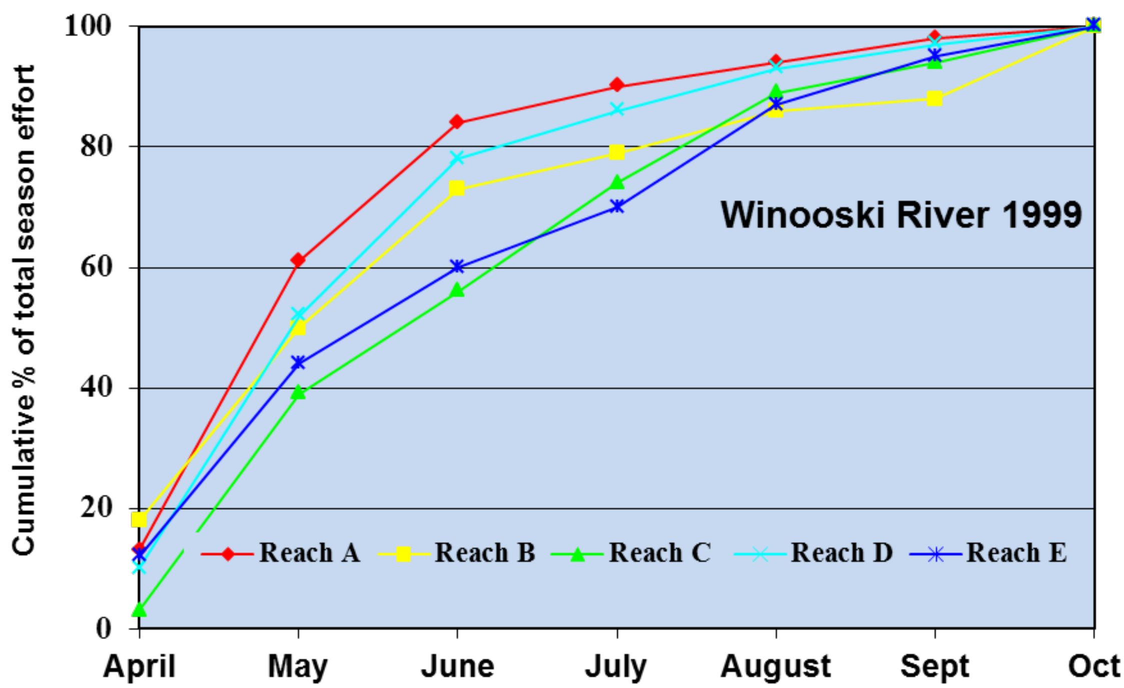


Figure 7. The cumulative monthly distribution of angler effort from five reaches of the Winooski River.

Small warmwater ponds managed with put-and-take stockings of trout are also likely to follow the river and stream angling distribution pattern (Table 2). The waters in the example below also support warmwater (bass, panfish) fisheries which likely account for most of the effort beyond mid-June.

Table 2. The cumulative monthly distribution of angler effort from three put-and-take trout ponds.

Percent of Total Angling Effort – P&T Ponds									
Water	Acres	Apr	May	June	Jul	Aug	Sept	Oct	Angler hr/ acre
Baker Pond	35	0.0	32.9	28.8	14.7	20.0	3.4	0.0	177.5
Rood Pond	23	5.1	39.2	28.5	12.5	7.8	5.7	1.2	260.4
Sunset Lake	25	4.2	21.5	27.2	26.9	12.4	6.1	1.7	380.1

Stocking too early can also reduce stocking success due to increased movement or mortality from high flows, suspended sediment and cold temperatures. In most Vermont rivers, spring runoff or the threat of high flows does not generally subside until approximately May 1(Figure 8). Prior to this time, streams and rivers are subject to rapid increases in flow as soils are often saturated from snowmelt, and the lack of foliage limits the uptake of additional precipitation by trees and other vegetation.

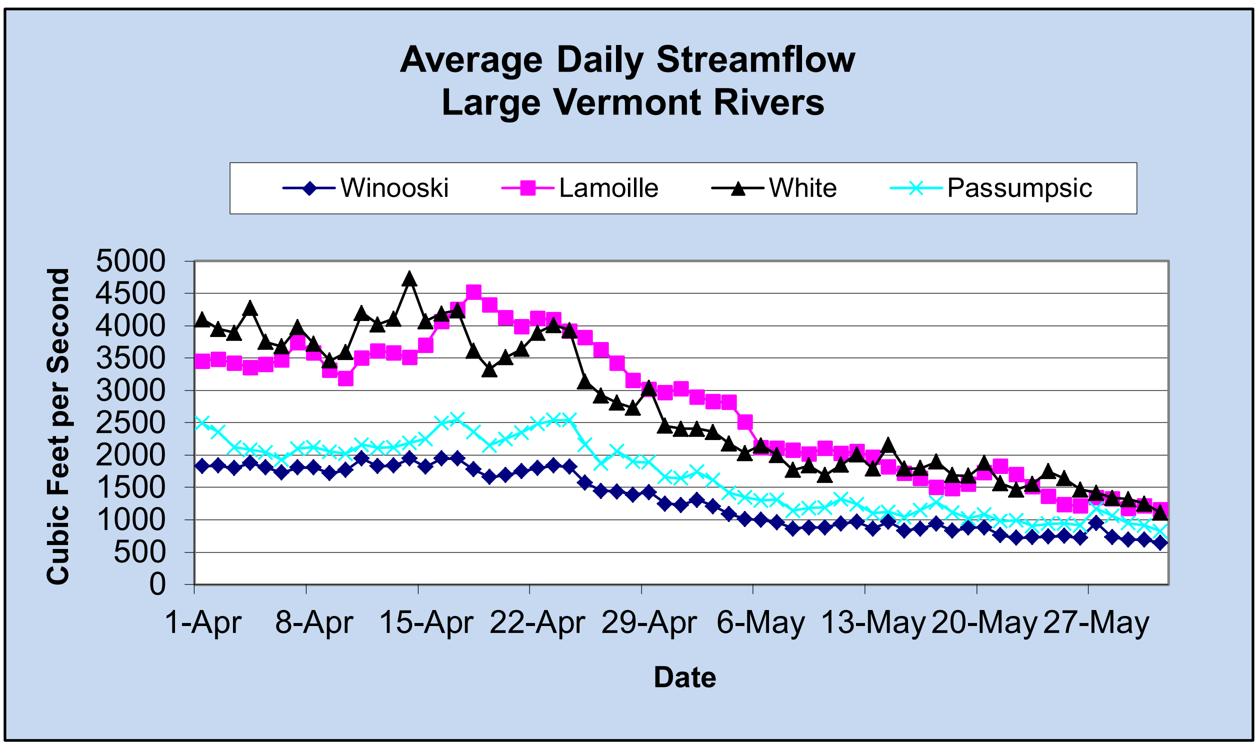


Figure 8. Average daily spring flows from four large Vermont rivers (source: USGS 1986-2016).

Post-stocking mortality may further reduce the potential return of stocked fish, particularly in waters where water quality rapidly diminishes during the summer months. This is evident from annual monitoring of Winooski River (Jonesville) water temperatures which exceeded 75°F as early as June 12th and by June 28th in 7 of 12 years (1998-2010). Maximum stream temperatures, particularly in large rivers, can often reach 80°F in the summer.

Considering the constraints of high flows and low water temperatures early in the season, rapidly warming water temperatures, the early season distribution of angling effort and the limited potential for long term survival of stocked trout in streams and rivers, a relatively narrow "window of opportunity" is available to optimize the return of catchable-size trout stocked for immediate angling in many waters. This situation is particularly true for Vermont's larger rivers.

Fishing Pressure - Fishing pressure is an important component of any stocking recommendation, particularly for programs where catchable-sized trout are stocked for immediate angling. For these programs, the number of fish stocked is often directly proportional to the amount of fishing pressure expected to exploit them. A direct correlation between stocking density and angler success, however, is not necessarily supported by direct fisheries evaluations (Figure 9 and 10). Hyman (et al. 2016) did not find stocking density to be related to angler catch rates in put-and-take stream and lake fisheries in Virginia. Similar observations are apparent in Vermont where trout evaluations to date have not shown a strong correlation between stocking density and angler catch rates or return of stocked trout in put-and-take stream fisheries.

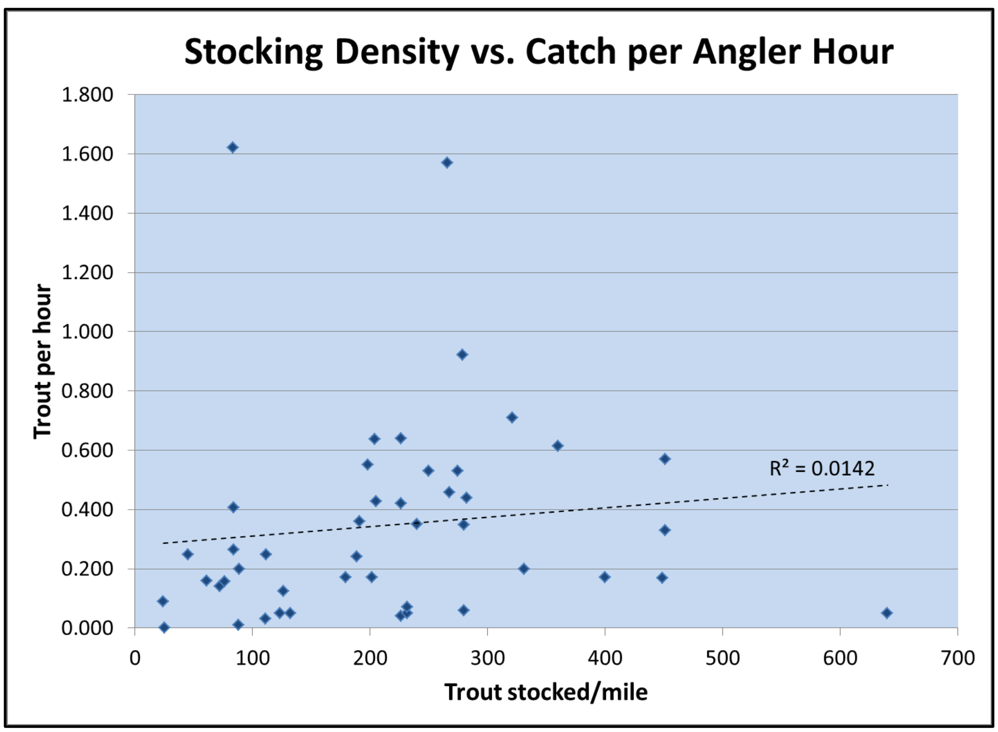


Figure 9. Comparison of yearling put-and-take trout density vs angler catch rate from creel surveys of 27 stream reaches on Vermont streams and rivers from 1986-2015.

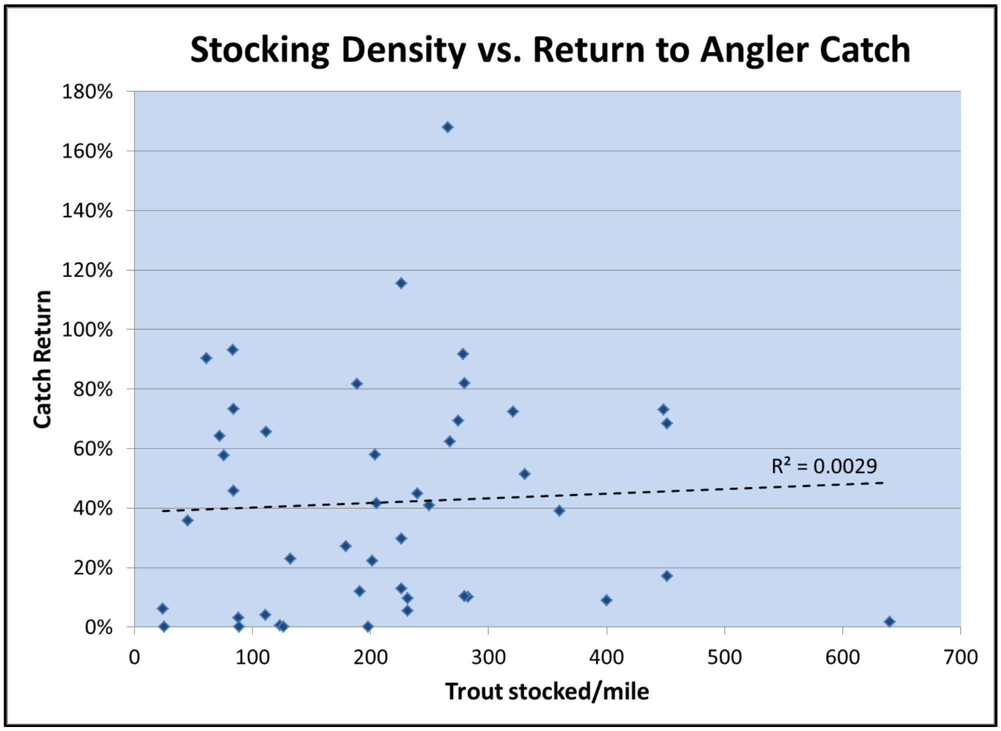


Figure 10. Comparison of yearling put-and-take trout density vs percent angler catch return from creel surveys of 27 stream reaches on Vermont streams and rivers from 1986-2015.

Past angler creel surveys conducted in Vermont provide a good indication of the range of fishing pressure that can be expected in our stocked fisheries (Table 3). It should be noted that even very high and exceptional angler effort in Vermont waters are substantially lower than what is seen in larger, more populated states. As many of these surveys are from the 1980s and 1990s it will be important to periodically update creel survey information to account for broad changes in angler participation. For example, a 2015 creel survey of the Winooski River showed an overall decline of 38% in angler effort, with 9 of 10 sections declining between 15-70% from a similar survey conducted in 1999 (Ladago 2016). Similar observations were recently made in New York where Alexiades et al. (2014) reported pronounced declines in angler effort in stocked trout stream fisheries since the 1970s. The use of dated assumptions of fishing effort can result in less effective stockings and wasted resources.

Similar angler effort information is available for lakes and ponds, although the presence of other fisheries (e.g. bass, pike, pickerel, panfish) often confounds the actual effort expended on stocked trout. In addition, some small ponds may only support a few weeks of trout fishing as waters warm beyond trout tolerances by mid-June.

Table 3. Examples of fishing pressure levels observed in Vermont streams and rivers stocked with put-and-take trout from 1986 through 2017.

Category	Angler hours/mile	Examples (Yearling Trout Stockings)
Very low	<100	Mad (Warren), Lamoille (Hardwick), Waits (Topsham), Ottauquechee (Bridgewater), White (Rochester)
Low	100-249	Mad (Waitsfield), Winooski (Mont-Mdsx) Waits (E. Corinth)
Moderate	250-399	New Haven (abv Bristol), Lamoille (Wolcott), Poultney, Ottauq (Woodstock), Winooski (Marshf-E. Montp)
High	400-749	White (Bethel-Stockbridge), Lamoille (Morrisv), New Haven (blw Bristol), Mettawee, Winooski (Mddlsx)
Very High	750-999	White (Sharon-Royalton), New Haven (NH Mills), Lamoille (Dogs Head),
Exceptional	1000+	Winooski (Bolton– Richmond)

Desired Catch and Return Rates - Angler catch rates (trout caught per angler-hour) and the proportion of stocked trout returned to the angler (in number or weight) are standard measures of success for stocking programs. For put-and-take trout fisheries where little or no contribution of stocked fish is expected in subsequent years, target catch and return rate are particularly important in defining the appropriate number of fish to stock. For these programs, a target catch rate should attempt to define a "reasonable" rate, considering that many anglers will catch nothing and a few skilled anglers will greatly exceed this rate (Needham 1959, Butler and Borgeson 1966, Engstom-Heg and Hulbert 1982).

Minimum return rates (proportion of stocked fish returned in number or weight) are also a common measure of success used by fisheries agencies. For example, Wyoming required a minimum 50% *harvest* of catchable trout to be considered a successful stocking program (Stone 1995). For maintenance stockings, where multiple year survival is expected, the use of a proportion of the weight of stocked trout returned to the angler is also used (Engstom-Heg and Hulbert 1982).

The success of put-and-take stocking of catchable trout has been historically judged by the proportion of stocked fish *harvested* by anglers (Needham 1959, Cresswell 1981) and unharvested trout were considered “wasted” (VDFG 1973). However, angler attitudes and behaviors have changed dramatically over time with the practice of catch-and-release becoming more prevalent in our stocked fisheries. A clear example of this trend is seen in the White River, where several angler creel surveys have been conducted from 1972 through 2017. In 1972, only 19% of all trout caught by anglers were released, with many of these trout being of sublegal size (6-inch minimum length limit). Since that time, catch-and-release rates of trout have steadily increased to 44% in 1986, 66%

in 1992, 68% in 2001 and 81% in 2017 (Figure 11). Even "trophy" stockings in rivers generate a high level of catch-and-release fishing, further extending the value of individual trout which are repeatedly caught (Will 2014, Ladago 2015). The common practice of catch-and-release trout fishing also confounds creel survey results, as few trout are available for evaluation of size, age and origin (Alexiades et al. 2014). It will be important to account for these changes in angler attitude and behavior to set appropriate management goals and criteria for trout stocking programs.

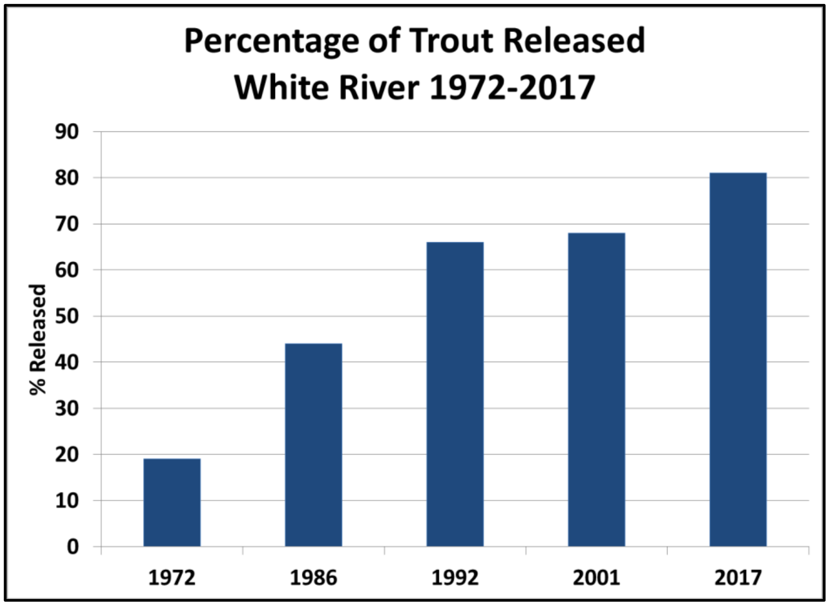


Figure 11. The percentage of yearling trout released by anglers observed in angler creel surveys of the White River conducted from 1972 – 2017.

The return to the angler of stocked catchable-size trout is quite variable and is dependent on a host of factors including species, strain, fishing pressure, size and condition of fish at stocking, timing of stocking, water temperature and flow at stocking, and angler characteristics. Angler creel surveys conducted in Vermont waters provide insight into the relative return of stocked trout for a variety of fisheries.

Streams & Rivers:

Creel surveys of put-and-take stocking of yearling trout in Vermont rivers and streams indicate relatively poor returns in waters with low fishing pressure (<250 angler-hours/mile) and those stocked with brown trout (Table 4; Kirn 1999). Rainbow trout provide the most consistent return to the angler with half of the surveys providing an angler catch return of 50% or greater. On the other hand, brown trout provided a 50% return in only 29% of surveys, and less than 25% return in 53% of the surveys. Baird et al. (2006) observed similar results in a thermally impaired Adirondack river, where angler returns of stocked brook trout and rainbow trout were substantially higher than stocked brown trout.

Table 4. The percentage of yearling stocked trout caught by anglers in streams subject to a range of fishing effort levels from surveys conducted in the late 1980s through 2017.

Fishing Effort (Streams & Rivers)	% Return of Stocked Yearling Trout to Angler Catch Mean (range)		
	Brook Trout	Brown Trout	Rainbow Trout
Low (<250 hr/mi)	33 (0-93)	21 (0-46)	21 (0-73)
Moderate (250-399 hr/mi)	58	52 (27-66)	75 (17-168)
High (≥400hr/mi)	4	31 (1-82)	53 (9-116)
% surveys ≥50% return	33	29	50
% surveys <25% return	50	53	32
Number of surveys	6	17	22
Total trout stocked	6,215	28,633	46,318
Total Angler Interviews	702	3,955	4,214

Creel surveys tend to focus on Vermont's larger, more popular fisheries and therefore represent best case scenarios for the performance of stocked trout. Stockings of waters supporting marginal fisheries are likely to show lower returns than those reported in Tables 4 through 8. This is supported by Kratzer (2016) who conducted angling effort estimates on several Northeast Kingdom streams that were annually stocked with yearling trout and concluded that stocking should be discontinued in four of eight stream reaches due to low fishing effort.

In addition to higher overall returns, rainbow trout tend to support angler catches over a longer season compared to brown trout when stocked in the same stream reaches, where very few brown trout are observed later than June or July (Table 5). Two-year old brown trout stocking in streams have revealed similar tendencies, with substantially lower returns after the first few weeks following stocking (Kirn 1995, Will 2014, Ladago 2015).

Table 5. Monthly catches of yearling rainbow trout and brown trout stocked in the same river reaches and evaluated with angler creel surveys.

Water Year	SPP	Apr	May	Jun	Jul	Aug	Sept	Oct	Total	# Stocked
White 1998	BNT	0	17	71	30	16	3	3	140	1200
	RBT	1	109	131	55	104	32	14	446	1500
White 1997	BNT	1	0	13	10	3	2	0	29	700
	RBT	0	38	112	53	99	27	10	329	1700
White 1995	BNT	0	0	13	47[1]	2	4	0	66	1200
	RBT	0	44	94	55	17	21	8	239	1200
Ottauque-chee 1997	BNT	0	0	6	1	1	0	0	8	1450
	RBT	0	68	55	14	2	1	0	140	2150
Winooski 1991	BNT	6	1	6	3	2	2	0	20	3500
	RBT	4	1	17	7	3	0	0	22	3500
Winooski 1999	BNT	4	5	4	0	0	0	0	13	700
	RBT	1	8	32	3	14	2	9	69	700
Waits 2000	BNT	0	28	15	2	0	0	0	45	1300
	RBT	0	45	27	12	0	0	0	84	1300

[1] Two anglers reported 40 BNT which were likely misidentified Atlantic salmon juveniles.

As reported earlier, multiple year survival of stocked trout in rivers and streams is uncommon in Vermont (Table 6; Kirn 1999) as well as other states (Wiley 1995, Dillon et. al. 2000, High and Meyer 2009, Alexiades et. al 2014) and therefore should not be expected to contribute to the fishery beyond the year of stocking unless direct evaluation indicates otherwise. Table 6 highlights returns of stocked trout in Vermont rivers in which marking of stocked trout was conducted the year prior to the survey.

Table 6. Angler catch of yearling that were trout stocked in the previous season.

Water/Year	Number Stocked Prior Year	Number Observed	Number of Anglers Interviewed
New Haven River / 1987	3000	8	162
New Haven River / 1988	3000	3	364
White River / 1991	6000	0	298
White River / 1992	6800	0	194
Lamoille River / 1996	5000	0	585
Ottauquechee River / 1997	3900	0	91
White River / 1998	2800	0	626
Winooski River / 1999	10050	7	1117
Waits River / 2000	6800	0	194
Winooski River / 2015	9800	2	711
White River / 2017	8200	0	852
Total	***65350***	***20***	***5194***

Lakes & Ponds:

Full season creel surveys for small put-and-take ponds are very limited in Vermont, although observations associated with other studies suggest that these stockings can provide popular early season fisheries in some waters (Kirn 1996, Kirn 2011). However, effort estimates with trail cameras in small put-and-take trout ponds in northeastern Vermont resulted in discontinuation of stocking in two of four ponds due to very low fishing effort (Kratzer 2016c).

Creel surveys for larger lakes receiving stockings of brook, brown and rainbow trout have also provided compelling results for future management (Kirn 1999). Creel survey evaluations of brook trout stocking in large lakes has demonstrated very poor returns (Table 7).

Table 7. The percentage of yearling brook trout stocked in large lakes which contributed to angler catch and harvest.

Lake (years)	Total number Brook Trout stocked	% Return to Angler Catch Mean (range)	% Return to Angler Harvest Mean (range)	Angler Interviews
Open Water Season				
Lake Seymour (1989,1991,1993)	5500	4 (<1-11)	4 (0-8)	2830
Somerset Reservoir (1991,1992)	34500	<1 (0-1)	0	352
Big Averill Lake (1993)	2000	<1	<1	371
Totals	***42000***	***3(0-11)***	***1(0-8)***	***3553***
Ice Fishing Season				
Lake Seymour (1989,1991,1992)	1350	<1 (0-1)	<1 (0-1)	1041

Brown trout yearling returns, in number, are poor in open water and winter fisheries, averaging 3% or less (Table 8). Return in weight, however, demonstrates the ability of brown trout to survive multiple seasons and grow to large sizes, with greater returns observed during the winter. Conversely, rainbow trout yearlings provide higher returns in both number and weight during open water fisheries but very poor returns in the winter (Table 8).

Table 8. The percentage of maintenance stockings of yearling brown trout and rainbow trout which contributed to angler catch and harvest in lakes.

Season	Total Yearlings Stocked		% Return Angler Catch	% Return Angler Harvest	% Return Weight Stocked	Number of Lakes/ Surveys	Number of Angler Interviews
	#	Lbs	Mean (range)	Mean (range)	Mean (range)		
Brown Trout							
Ice	52183	8284	5 (1-9)	3 (1-7)	35 (6-144)	7/15	7093
Open	16233	2531	2 (1-2)	1 (1-2)	20 (3-36)	3/4	2215
Full	16233	2531	3 (2-4)	3 (2-3)	39 (15-47)	3/4	4882
Rainbow Trout							
Ice	74085	25775	2 (0-8)	1 (0-4)	4 (0-13)	12/14	5134
Open	24833	8830	28 (6-54)	18 (6-32)	51 (10-100)	8/9	5247
Full	38538	14866	38 (0-134)	19 (0-41)	53 (0-109)	8/14	12926

Biological Potential (Carrying Capacity) - The ability of a given body of water to sustain fish populations is influenced by a host of factors, including the physical habitat available for each life stage, environmental conditions (temperature, water chemistry, flows, etc.), food availability, and the presence of competitor and predator populations (Wahl et al. 1995). Even for short-term put-and-take fisheries, stocking densities of cultured trout in waters supporting wild populations should reflect the capacity of the water to support both trout components (Wiley 1995). This is particularly important with the increasing practice of catch-and-release fishing, which can greatly extend the time trout remain in a waterbody following stocking.

The biological carrying capacity of a waterbody becomes a significant consideration in maintenance stocking programs, where trout growth and survival are primary management objectives (Wiley 1995). Because each waterbody's ability to produce fish biomass is limited, stocking recommendations must carefully balance the production of desired population size versus the potential growth of individual fish. It is important to realize that for populations maintained through stocking, annual recruitment of trout is independent of habitat and forage abundance. Overstocking may negatively impact forage abundance resulting in reduced growth and survival of stocked trout. On the other hand, stocking too few fish may under-utilize the waters' full potential for trout production. Further confounding these factors are natural fluctuations in forage populations, influences from competitor and predator populations, natural and angling mortality, as well as external influences such as lake and reservoir drawdowns.

Ecological Considerations:

While stocking of trout is a common management tool to enhance recreational opportunities, careful consideration should always be made to ecological influences that stocking may have on a given waterbody (Ham and Pearsons 2001). For example, Eby et al. (2006) describe how stocking can influence the distribution and abundance of native species, cause shifts in community structure and species richness, and influence ecosystem processes such as nutrient cycling and food web interactions. Understanding the aquatic community structure and how stocking can influence ecological interactions should be considered when implementing any stocking program.

Predation – Predation on stocked trout can have profound effects on the success of stocking programs. Northern pike (*Esox lucius*) have been implicated in significant predation of stocked trout (McMahon and Bennett 1996, Hyvärinen and Vehanen 2004), as have walleye (*Sander vitreus*), black bass (*Micropterus spp.*), loons (*Gava immer*) and cormorants (*Phalacrocorax auritus*) (Modde et al. 1996, Ross and Johnson 1999, Yule et al. 2000, Beckman et al. 2006, Ivasaukas and Bettoli 2011). Mortality rates of stocked trout as high as 50% have been reported from predation by northern pike (Hyvärinen and Vehanen 2004) and birds (Beckman et al. 2006). Predators can be size selective (Walters et al. 1997, Hyvärinen and Vehanen 2004) or, in the case of common loons, prefer pelagic species such as rainbow trout (Matkowski 1989). Alternative stocking strategies such as offshore stocking (Ross and Johnson 1999), stocking at larger sizes (MacMahon and Bennett 1996, Walters et al. 1997, Hyvärinen and Vehanen 2004) and the use of less susceptible species (Matkowski 1989) can improve survival of stocked trout in certain cases. In situations where predation cannot be mitigated with reasonable measures, management for alternate (non-trout) fisheries may be warranted.

Angler and Stocking Access - Access to public waters is not assured in Vermont. While VFWD owns and maintains 170 developed access areas, primarily on lakes and ponds, access to streams and rivers is more tenuous and relies on public lands, easements and rights-of-way, and the generosity of private landowners. Unfortunately, increased posting has led to the loss of access to stream and river fisheries throughout the state. Maintaining good relationships with private landowners will be critical to maintain or improve angler access in future years.

Adequate access for stocking is also important, as it will control the ability to effectively stock the desired number of trout throughout a reach of stream or river. Although extensive movements of stocked trout have been documented, a reasonable distance between stocking sites for streams and rivers is 0.5 to 1.0 miles to account for more typical post-stocking movements (Cresswell 1981, Kirn and McMenemy 1988, Baird et al. 2006).

Recommendations

Guidelines for Stocking Cultured Trout in Vermont Waters

Where to stock:

Management programs requiring cultured brook, brown and rainbow trout will be prioritized for stocking as follows:

1) Restoration or special trout evaluation programs. **[REP]**

2) Maintenance stocking programs in waters meeting return and survival objectives (50% return of weight stocked, multiple age classes in catch). **[M1]**

3) Put-and-take stocking in:
   a. streams subject to high fishing pressure (>400 angler-hours/mile/year) and where wild trout population levels are considered inadequate to sustain the fishery (<20 lbs/acre, <200 trout/mile ≥ 6 in).**[PT1]**

   b. Put-and-take stocking in ponds subject to high fishing pressure (≥100 angler-hours/acre/year) and where other sportfish populations cannot adequately sustain the fishery. **[PT1]**

4) Put-and-take stocking in:

   a. streams subject to moderate fishing pressure (250-399 angler-hours/mile/year) and where wild trout population levels are considered inadequate to sustain the fishery (<20 lbs/acre, <200 trout/mile ≥ 6 in). **[PT2]**

   b. ponds subject to moderate fishing pressure (25-99 angler-hours/acre/year) and where other sportfish populations cannot adequately sustain the fishery. **[PT2]**

5) Put-and-take stocking in:

   a. streams subject to low fishing pressure (100-249 angler-hours/mile/year) and where limited angling opportunities would exist without stocking **[PT3]**

   b. streams subject to high fishing pressure (>400 angler-hours/mile/year) and where very good wild trout population levels (≥200 trout/mile ≥ 6 in; ≥20 lbs/acre) are present but cannot adequately sustain the fishery **[PTW1]**

   c. ponds subject to low fishing pressure (5-25 angler-hours/acre/year) and where limited angling opportunities would exist without stocking **[PT3]**

6) Stocking of cultured trout should not be conducted in the following waters without specific justification **[NSW]**:

a. Waters meeting "wild trout management" designation.

b. Waters which do not maintain environmental conditions to support trout year-round <u>and</u> where other significant sport fisheries exist.

c. Waters where fishing effort greater than 100 angler-hours/mile/year (<u>streams</u>) or 5 angler-hours/acre (<u>ponds</u>) cannot be sustained with stocking.

d. Waters where stocking has been documented to not substantially contribute to the fishery.

e. Waters without public access.

What to stock:

The following guidance is based upon a compilation of field evaluations in Vermont and studies from other states and provinces. It is recognized that natural systems can vary in their response to similar management actions. Therefore these general rules may not necessarily apply where water specific evaluations indicate otherwise or where other compelling factors justify alternate management approaches.

Brook trout are most appropriate for put-and-take stocking of small/moderate sized streams and ponds where an early season, open water fishery is desired. Brook trout should also be considered where pH levels are too low to support brown trout or rainbow trout. Brook trout should not be stocked in large lakes unless substantial contribution of stocked trout to fisheries is documented through direct evaluation.

Brown trout are best suited in lakes and ponds with suitable habitat conditions to support multiple year survival and those waters open to ice fishing for trout. Brown trout should generally not be stocked in streams or rivers for put-and-take fisheries unless previous evaluation has indicated substantial return to anglers. When stocked in streams or rivers, brown trout returns decline substantially a few weeks following stocking. Although very limited, brown trout have the greatest chance of surviving overwinter in streams and rivers.

Rainbow trout provide the greatest returns for put-and-take stocking in streams and rivers and for both put-and-take and maintenance stocking for open-water fisheries in lakes and ponds. Rainbow trout generally provide poor ice fishing opportunities, although limited returns may supplement other trout species targeted in the winter (e.g. lake trout, brown trout).

Triploid trout should be used in all stockings where direct interactions with wild trout stocks are expected. This includes all stream and river stockings and select lakes and ponds supporting substantial wild trout populations. Unless genetic interactions are a major concern, triploid trout should generally be avoided in maintenance stocking of lakes and ponds where field evaluations have suggested by poorer performance compared to diploids.

How many to stock:

Once a body of water is identified as a candidate for stocking, it is necessary to have a rational basis to determine the number of fish to stock, as well as specific goals to weigh the success of a given program. Due to distinct differences in management objectives between maintenance stocking and put-and-take stocking, guidelines and goals will differ. For both stocking programs it is essential that stocking guidelines be relatively straightforward and provide adjustments for substantial differences in angling and biological characteristics.

A. Maintenance Stocking programs assume growth and survival of stocked trout, and therefore also must consider the broader fish community including forage, competing or predatory species as well as angler characteristics such as effort and harvest. Maintenance stocking is appropriate for *coldwater lakes and ponds* which are primarily suited for and inhabited by salmonid fishes, and *two-story lakes and ponds* which maintain suitable salmonid habitat year-round and which also sustain significant coolwater and/or warmwater sportfish populations (Engstrom-Heg 1979). The prior maintenance stocking approach incorporating the Ryder (1965) Morphoedaphic Index as an index of lake productivity (Engstrom-Heg 1979, VFWD 1993) resulted in unrealistic stocking recommendations for many waters, therefore a simplified approach has been developed. The goal for coldwater and two-story lakes and ponds is an annual return of **≥50% of the weight** of stocked trout with a catch comprised of two or more age classes.

Fingerlings: Spring and fall fingerling stocking in Vermont is limited to remote brook trout ponds and therefore clear stocking guidelines have not been developed. Stocking densities generally range from 35-45 trout/acre for fall fingerlings and 110-150 trout/acre for spring fingerlings, which are substantially smaller and therefore expected to exhibit lower survival. Trout mortality (including predation) and condition, existing fish community and expected fishing pressure should also be considered when evaluating stocking rates for these waters.

Yearlings: Unlike put-and-take stockings, maintenance stocking contributes to the fishery for several years as trout survive and grow to larger sizes. As the influence of an individual stocking continues beyond the year of stocking, stocking rates must also consider the longer term effects on growth and survival of stocked trout, as well as competing and prey species. Over-stocking can result in poor survival and growth of stocked trout, excessive predation of prey species and wasted fish culture resources (Negus 1995).

Yearling brook, brown and rainbow trout stocked in Vermont are generally 8-11 inches and are also available for immediate harvest, as most waters do not have minimum length limits. Therefore, most maintenance stockings also support a put-and-take component through the first open-water season. To account for the dual purpose of annual stockings in maintenance lakes and ponds, the following approach provides a modest maintenance stocking rate of 1 trout per acre *plus* a put-and-take component based upon:

- Estimated open-water fishing pressure dedicated to trout fishing,
- Estimated loss due to predation by large coolwater/warmwater fishes (pike, bass, walleye) and birds (loons, cormorants),
- A target catch rate of 0.5 trout per angler-hour,
- A maximum stocking rate of 10 trout per acre to minimize the risk of over-stocking.

The lack of widespread and up-to-date open-water fishing pressure estimates from coldwater and two-story lakes and ponds will generally require estimation based upon past surveys until additional new creel surveys are conducted. Table 9 provides general categories of open-water fishing pressure observed in Vermont coldwater and two-story fisheries. As these waters generally support a diversity of fish species, further adjustment to estimate the fishing effort dedicated to brook, brown and rainbow trout will be necessary.

Table 9. Open-water fishing effort estimates from creel surveys conducted in Vermont lakes from 1989-1996. Effort estimates include all species and therefore must be adjusted for trout angling only.

Open Water Fishing Effort	Total Angler Hour/Acre	Examples
High	20-25	Fairlee, Harveys , Caspian
Med	15-19	Bomoseen, Crystal, Willoughby
Low	10-14	Maidstone, Little Averill
Very Low	5-9	Harriman

Maintenance Stocking Formula: $S = M + ((P_{T*}Q)/ M_P)$

Where:
S = Stocking rate as number of trout stocked per acre **(maximum = 10)**
M = Maintenance stocking rate of 1 trout per acre
P_T = estimated fishing pressure dedicated to brook, brown and rainbow trout during the open-water season (angler-hours/acre)
Q = target catch per unit of effort (0.5 trout/angler-hour)
M_P = Predation mortality factor

- 0.8 = low (20%)
- 0.7 = moderate (30%)
- 0.6 = high (40%)

Example:

	Maintenance Stocking Rate (**M**)	= 1 trout/acre
	Estimated Trout Pressure (P_T)	= 6 angler hrs/acre
	Catch/Angler Hour (**Q**)	= 0.5
	Mortality from Predation (M_P)	= 0.7 (30%)

Put-and-Take Stocking Rate (PTS) = $(P_TQ/ M_P) = (6*0.5)/0.7 = 4.3$ /acre

Final Stocking Rate (S) = M + PTS = 1 + 4.3 = **5.3 /acre.**

Additional adjustments to the stocking rate may be warranted to account for coldwater habitat, other salmonid stocking (e.g. lake trout, landlocked salmon, two-year old trout), wild trout abundance, forage abundance, growth and condition of stocked trout, and other results from prior fisheries evaluations.

B. Put-and-Take Stocking - While this type of stocking is largely independent of growth and survival considerations, fisheries managers must also account for several factors when developing specific stocking recommendations. Of particular importance are fishing pressure, existing (wild or holdover) trout populations, target catch and return rates and angler access.

Kelly (1965) developed a formula for stocking streams with catchable size trout which, when combined with an upper stocking limit based upon the biological potential of Vermont streams, should provide a relatively straightforward approach to stocking for immediate angler catch while accounting for:

- Existing wild or holdover trout
- Fishing pressure
- Potential trout carrying capacity
- Target catch and return rate

Put-and-Take Stocking Formula (Kelly 1965): **S = PQ/ R - (W + X)**

Where:
S = number of trout stocked (per mile or acre)
P = estimated fishing pressure (angler-hours/mile or acre)
Q = target catch per unit of effort (trout/angler-hour)
W = abundance of wild trout ≥6” (per mile or acre)
X = abundance of holdover trout (per mile or acre)
R = return of trout stocked (as percent)

Example:		
	Estimated Pressure (**P**)	= 250 angler hrs/mi
	Catch/Angler Hour (**Q**)	= 0.5
	Wild Trout ≥6”/Mile (**W**)	= 100
	Holdover Trout (**X**)	= 0
	Return of Stocked Trout (**R**)	= 0.50

Base Stocking Rate (BSR) = PQ/R = (250*0.5)/0.5 = 250 /mi.

Adjusted stocking rate = BSR - (W + X) = 250 - 100 = **150 /mi.**

Additional Put-and-Take Stockings Guidelines:

- Use 0.5 trout/angler-hour as target catch rate (**Q**). This represents a good average catch rate which expert anglers may greatly exceed.

- Use return rates (**R**) of 50%. These rates represent "good" returns observed in Vermont in the past.

- Do <u>not</u> stock streams/rivers resulting in <u>total</u> (wild and stocked) trout densities exceeding **30 lbs/acre or 400 trout/mile.** These criteria reflect stream densities observed in Vermont's best wild trout streams. Stocking recommendations exceeding these levels should be limited to streams with very high fishing pressure and should be conducted in two stockings over a 10-14 day interval.

- Do <u>not</u> stock over **50 lbs/acre** in ponds. Stocking recommendations exceeding this level should be limited to put-and-take ponds with very high fishing effort and should be conducted in two stockings over a 10-14 day interval.

- Trout stocking numbers should be further adjusted for the availability of stocking locations/angler access areas. For example, if only 2 stocking locations are available within a 5-mile stream segment, a stocking recommendation based upon 5 stream miles would be inappropriate, as it would result in extremely heavy stocking in the 2 locations. Therefore, final stocking allocations should be based upon the calculated stocking rate and a stream segment length **adjusted for angler access**. *This should be accomplished by subtracting stream sections inaccessible for stocking which measure ≥ 1.5 miles in length.* [When measuring distance between stocking areas, each stocking site should be considered to represent 0.5 mi of stream (i.e. 0.25 mi upstream and downstream of the stocking site)].

- To avoid exceeding stocking criteria for total (stocked + wild) trout densities (**30lbs/acre, 400 trout/mile >6"**), the stocking guidelines provided in Table 10 for individual stocking sites should be followed for yearling trout stocking. These guidelines are based upon an assumption that the majority of stocked trout will generally remain within 0.25 miles upstream and downstream of the stocking site (i.e. 0.5 stream miles per stocking site). The example below assumes no wild trout ≥ 6 inches occur in the stream reach.

Table 10. Maximum yearling trout stocking rate per site based upon stream width and trout size.

Mean Stream Width (ft)	Maximum Stocking per Site	
	8" trout (3.4 trout/lb)	10" trout (2.3 trout/lb)
10	60	40
20	125	85
30	185	125
40	200	165
50+	200	200

- **Two-year old trout:**
  - Put & Take Stocking rates:
    - Rivers – maximum of 500/mile. This density will generally exceed the 30lb/acre threshold so should be distributed in two or more separate stockings conducted 10-14 days apart.
    - Ponds – should contribute no more than 25% of the total trout stocking (yearlings and 2-year old trout).
  - Site selection characteristics:
    - Adequate public access to support a high level of fishing effort;
    - Adequate habitat conditions to support large trout for at least 2 months;
    - Limited capability to produce large trout through wild production or holdover of stocked of yearling trout.

- Stocking of trout in waters with low fishing pressure, or those supporting moderate levels of wild trout should be further scrutinized and limited to waters where substantial contribution of stocked trout to fisheries is documented.

- Stocking of small lots (≤200 trout) or low densities (≤100/mile) of trout should generally be avoided due to the minimal potential benefit to angling while creating additional transportation burdens on fish culture staff during a compressed stocking season.

C. What size to stock:

Fry are generally not recommended as natural reproduction is not normally a limiting factor in Vermont. Best results can be expected in barren waters such as reclaimed ponds or newly formed beaver ponds with contributing watersheds devoid of trout.

Fingerling trout should be primarily used in remote ponds where natural reproduction is absent or limited, competing or predatory fish species occurrence is low, transportation of yearling trout is not feasible due to access limitations and fisheries evaluations indicate that these stockings support a recreational fishery.

Fry or fingerling trout should only be considered in streams where natural reproduction is determined to be the factor limiting trout persistence and where post-stocking evaluations are conducted to determine project success. Where establishment of a self-sustaining population is the goal, wild trout transfers should be considered and project success evaluated.

Catchable-size trout stocking (yearling and two-year old) should continue to receive priority for both maintenance and put-and-take stocking programs. Fish culture production should target the minimum size most Vermont anglers would consider keeping for the majority of the state's stocking needs. Likewise, the minimum size most anglers would consider a quality trout should form the target size for "special" *quality size* management programs which require stocking large cultured trout for immediate angler catch. Based upon the results of the *2010 Vermont Angler Survey* and realistic production capabilities, these target sizes are presented in Table 11:

Table 11. Trout culture size goals for yearling and two-year old trout.

Catchable (yearling)	Streams & Rivers	Lakes & Ponds
Brook Trout	8 inches	8 inches
Brown Trout	10 inches	10 inches
Rainbow Trout	10 inches	10 inches
Quality (2-year)	**Streams & Rivers**	**Lakes & Ponds**
Brook Trout	10 inches	10 inches
Brown Trout	12 inches	14 inches
Rainbow Trout	12 inches	14 inches

Broodstock trout are generally available in the fall and on an inconsistent basis, so should target waters which provide a winter trout fishery and where the larger trout are not likely to raise unrealistic angler expectations.

D. When to stock:

Short-term survival anticipated for put-and-take trout stocking necessitates stocking as early in the spring as environmental conditions allow (i.e. after spring runoff) to provide the greatest availability of these fish to anglers. While this factor is not as significant a problem for maintenance programs, these stockings must also be conducted before elevated water temperatures result in significant handling, transporting and post-stocking mortality. These factors necessitate nearly all stocking be complete by the end of May.

Guidelines for the Distribution of Cultured Trout

To facilitate stocking schedules that will maximize benefits for Vermont anglers, fisheries and fish culture managers should use the following categories to prioritize and conduct individual trout stockings:

1. **Put-and-Take Stocking in Larger Rivers** - Annual stocking schedules should place priority on these waters. These fisheries are characterized as being heavily dependent upon cultured trout and receiving relatively high fishing pressure, which is often heavily skewed toward the first 2.5 months of the season (approximately 2/3 to 3/4 of the annual fishing pressure is complete by the end of June). Stocking of these waters should be conducted as soon as spring runoff has subsided and water temperatures near 50^{o}F. Because water quality, as well as angling effort may quickly diminish in many cases, these fisheries offer a very limited "window of opportunity" for stocking to provide maximum benefit to the angler.

2. **Put-and-Take Stocking in Small Ponds** - These fisheries result in angling effort distributions similar to those described in 1, and often are subject to rapid deterioration of water quality which can support trout. Where possible (as determined by the district fisheries biologist) these waters can be stocked as early as open water allows or through the ice during the spring.

3. **Put-and-Take Stocking in Smaller Rivers/Streams with Moderate Wild Trout Populations** - These waters have existing wild trout populations capable of providing angling opportunities, generally receive modest angling effort, and maintain acceptable water quality for trout year-round. Therefore, the timing of stocking for these waters is not as critical as 1 or 2. However, as the distribution of angling effort will generally reflect those of 1 and 2, early stocking will be very important to provide the greatest benefit of these fish.

4. **Maintenance Stocking in Lakes/Ponds** - As the stocking of these waters is not primarily intended to provide an immediate fishery, stocking early in the fishing season is not critical. However, it is extremely important that these fish are stocked under water quality conditions which are favorable to post-stocking survival. Like 2, these waters may be stocked as soon as open water allows (or through the ice).

Additional Guidelines:

a. Stream stocking of put-and-take trout should be conducted at frequent intervals (0.5-1 mile) as public access allows. This practice will reduce the potential for competitive impacts of stocked fish on wild populations as well as spread angler effort over a wider area, thereby reducing the potential for social conflicts.

b. Stocking procedures should strive to minimize stress of cultured trout which may result in post-stocking mortality and reduced angling opportunity. *Standard Operating Practices for Stocking Cultured Trout and Salmon* (Miller and Kirn 2017) were developed to address a variety of stocking considerations in Vermont including handling, temperature and tempering, bridge stocking, streamflow conditions and biosecurity. These practices should be reviewed periodically to evaluate general compliance and effectiveness.

E. Stocking evaluations:

Periodic evaluation of stocking programs will be necessary to ensure fisheries management goals are being met and fish culture expenditures and efforts are efficiently utilized. The use of outdated information and unfounded perceptions will ultimately compromise the ability of fisheries managers to effectively use cultured trout, thereby wasting valuable Department resources. As described earlier, changing angler behaviors such as an increase in catch-and-release practices and decreased angler effort can significantly influence the success of fisheries management programs. Where direct evaluation of trout stocking reveals low angler return, alternative management strategies, which may include the elimination of stocking, should be implemented.

VIII. Management of Angler Harvest

A major component of recreational trout fisheries management involves the regulation of trout harvest by anglers. These regulations fall into four categories: **creel limits** which regulate the number of trout an angler can harvest daily; **length limits** which regulate what size trout an angler can harvest; **season restrictions** which regulate when an angler can fish for or harvest trout; and **gear restrictions** which regulate how an angler may pursue trout.

While harvest regulations are applied for a variety of biological, social and political reasons (Everhart and Youngs 1981, Isermann and Paukert 2010, Radomski et al. 2001), the following must exist for regulations to influence a fish population or fishery:

- Fishing mortality (harvest and hooking mortality) must be a significant component of the total mortality of a population; and
- Regulations must address specific fish population and fisheries characteristics of the target water; and
- Angler compliance must be high.

Harvest regulations will have little benefit where trout populations are limited by natural (non-fishing) mortality (Isermann and Paukert 2010). These natural limitations led Kulp and Moore (2005) to conclude that a wide variety of harvest regulations applied in the Great Smoky Mountains National Park had failed to produce changes to rainbow trout populations over a 70-year period. Likewise, slow growth and high natural mortality has been shown to limit the effectiveness of restrictive harvest regulations on upland brook trout populations (Hunt 1970, Claussen 1980, Habera and Strange 1993, Detar et al. 2014, Kirn 2017a). In addition to formal regulations, Cooke et al. (2013) stresses the importance of public outreach and education as a means to promote voluntary changes in angler behavior.

Decreases in angling effort in some waters (Alexiades et al. 2014, Ladago 2016) and an increase in the voluntary practice of catch-and-release angling may also limit the effect of additional harvest regulations. For example, creel surveys conducted on the White River in Vermont have revealed an increase in the proportion of trout released from 20% of all trout caught in 1972 to 81% in 2017 (see Section VII, Figure 11).

Creel Limits

Creel limits regulate the daily harvest of trout by individual anglers and primarily serve to restrict excessive harvest by individual anglers and distribute the trout resource among anglers (Lackey and Nielson 1980, Hunt 1975, Engstrom-Heg 1981, Nehring 1987, Wright 1992, Isermann and Paukert 2010), although Radomski et al. (2001) submits there is no evidence to support the latter. It is widely accepted that creel limits have little effect in controlling the annual harvest of trout in a given water (Hunt 1975, Nehring 1987, Radomski et al. 2001, Cook et al. 2001, Isermann and Paukert 2010). This is primarily because: 1) creel limits do not control angling effort, and 2) most creel limits greatly exceed the average daily trout catch. This was evident in an evaluation of the Dog River where no change in annual harvest was observed despite a reduction in the creel limit from12 trout/day to 6 trout/day (Kirn 1997). Even extremely low creel limits (1-2 trout/day), have not been effective in reducing annual trout harvest in some studies (Nehring 1987).

In addition to moderating harvest by individual anglers, creel limits may provide other intrinsic values. Creel limits may provide a goal or measure of success for anglers; infer a "value" for a given species; and may promote enjoyment of "catch-and-release" fishing where low creel limits are used (Hunt 1975, Cook et al. 2001). Cook et al. (2001) suggest that creel limits may over-exaggerate the biological capacity of waters and negatively impact angler satisfaction if too difficult to attain. They recommend creel limits be based upon a reasonable expectation of catch that more anglers can achieve. Finally, creel limits may serve to remind anglers that fisheries resources are finite (Radomski et al. 2001) and serve to instill a conservation ethic. Vermont's daily creel limits are provided in Table 12.

Table 12. Vermont's daily creel limits for trout in streams & rivers, and lakes & ponds.

Species	Streams & Rivers	Lakes & Ponds
Brook trout	12	6
Brown Trout	6	6
Rainbow Trout	6	6
Aggregate Limit	12 total, of which up to 6 can be brown and/or rainbow trout	6

The *2010 Vermont Angler Survey* provides insight into angler support for these limits (Table 13; Connelly and Knuth 2010). Approximately two-thirds of Vermont resident anglers who expressed an opinion on trout stream creel limits supported the current trout regulations, while nonresident anglers were more evenly split. In all cases, those anglers that disagreed largely favored lower limits (>85%).

Table 13. Vermont resident and nonresident trout angler opinions from the 2010 Vermont Angler Survey on trout creel limits. Note: 'No Opinion' responses bring totals to 100% but are not shown.

Streams & Rivers Creel limits	Vermont Residents (%)		Nonresident Anglers (%)	
Species	Agree	Disagree	Agree	Disagree
Brook Trout	56.6	33.6	40.6	48.5
Brown Trout	59.9	29.0	41.3	46.8
Rainbow Trout	60.1	28.8	43.2	44.0
Aggregate	58.0	29.6	44.8	41.2

Resident angler disagreement was highest for the brook trout creel limit (33.6%) which has been consistent since the first statewide angler survey conducted in 1991 (Figure 12). While the angler agreement for this limit has fallen slightly over the years, it has been replaced with a higher level of "no opinion" responses rather than an increase in angler disagreement.

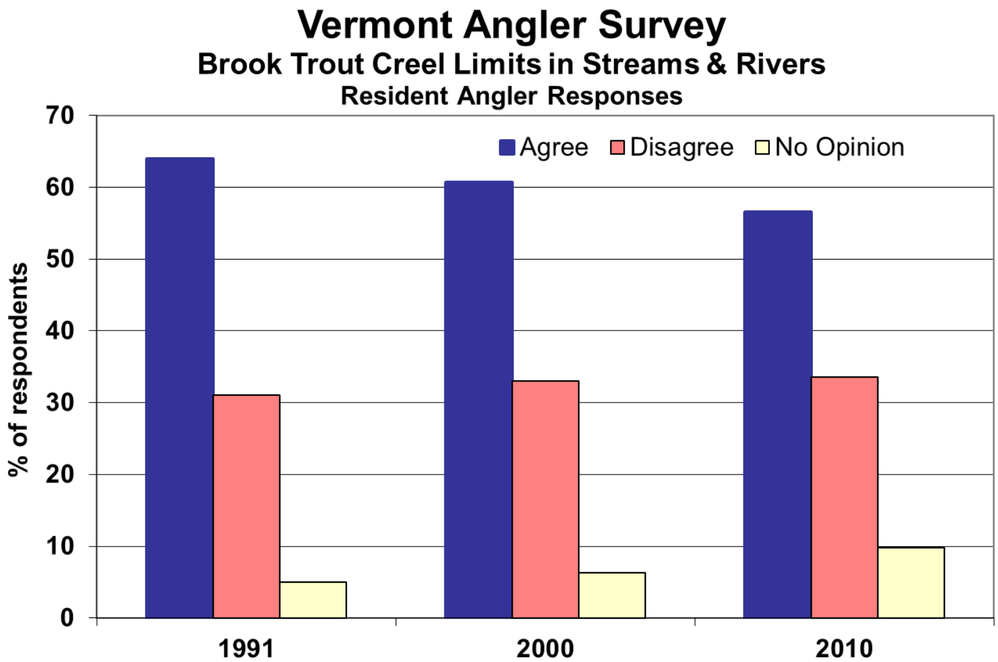


Figure 12. Vermont resident trout angler opinions on brook trout creel limits in streams from the 1991, 2000 and 2010 Vermont Angler Survey.

Differences in opinions within Vermont resident anglers on brook trout creel limits align clearly with angler motivation and gear use (Figure 13). Fly anglers, who account for less than 20% of resident trout stream anglers, were strongly opposed to the current 12 brook trout limit (65% disagree) and indicated they were less likely to keep trout. Bait and bait/lure anglers, accounting for 63% of resident trout stream anglers, strongly supported the current limit (66%) and were harvest oriented. This tendency for bait anglers to be more harvest oriented than fly anglers is well documented in Vermont creel surveys (Kirn 1998a, Kirn 2000b, Kirn 2003, Ladago 2016) and statewide angler surveys (Connelly and Knuth 2010). It should be noted that over 45% of nonresident trout stream anglers fish primarily with flies, which likely influences their higher level of disagreement with the current brook trout creel limit.

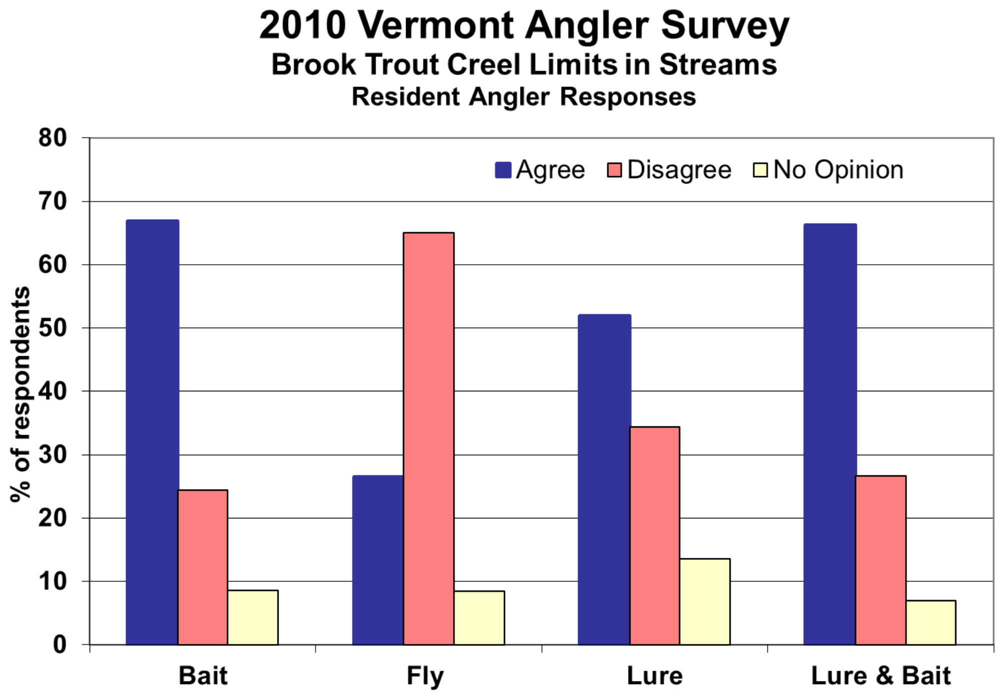


Figure 13. Vermont resident trout angler opinions from the 2010 Vermont Angler Survey on brook trout creel limits in streams partitioned by angler gear type.

While the Vermont daily creel limit for brook trout is high compared to neighboring states, further restricting the harvest in Vermont's numerous upland brook trout streams would appear unnecessary from a biological standpoint at this time. A recent study of wild brook trout populations in Vermont streams indicated that populations were relatively stable over a period of five decades as evidenced in this evaluation of 150 sites sampled in 138 streams within 17 watersheds (Kirn 2017a). Present-day brook trout populations were characterized by abundant natural reproduction and multiple age-classes, including the contribution of older, larger fish. These streams generally contain dense populations of slow-growing, short-lived wild brook trout and experience low and diffuse fishing effort. These populations do not normally require restrictive harvest regulations because of their inherent high natural mortality (Habera and Strange 1993, Habera and Moore 2005). Further supporting this conclusion is a study of catch-and-release regulations on Pennsylvania headwater streams, where Detar et al. (2014) found no improvement of adult or large brook trout, citing slow growth and low angler use as likely causes. Likewise, a 24-year evaluation of brook trout populations in Maine indicated that the reduction of creel limits from 10 to 5 trout per day had little influence on these populations (Ashe and DeGraaf 2015). Brook trout populations have also been found to be resilient to angler harvest due to their ability to mature at young ages. For example, a study to remove nonnative brook trout from western Canadian streams through targeted angling concluded that selective harvest had little effect on brook trout populations (Paul et al. 2003).

Vermont resident anglers were consistently supportive of trout creel limits in lakes and ponds, with over 64% agreement for all species and aggregate limits (Table 14). Nonresident anglers were again more conservative in their opinions and split in their support.

Table 14. Vermont resident and nonresident trout angler opinions from the 2010 Vermont Angler Survey on brook trout creel limits in lakes and ponds.

Lakes & Ponds Creel limits	Vermont Residents (%)		Nonresident Anglers (%)	
Species	Agree	Disagree	Agree	Disagree
Brook Trout	66.2	25.4	44.7	35.9
Brown Trout	64.5	26.8	39.3	40.1
Rainbow Trout	65.2	26.8	37.1	41.9
Aggregate	64.3	26.0	45.2	34.0

Length Limits

Length limits are widely accepted as an effective tool for managing trout harvest (Hunt 1975, Engstrom-Heg 1981, Nehring 1987). Length limits are sometimes applied to encourage natural reproduction by protecting long-lived species (e.g. lake trout, sturgeon) from harvest until after they become sexually mature. Minimum length limits have also been used in Vermont and other states to protect immature migratory salmonids from angler harvest prior to their outmigration as smolts. Size restrictions, including minimum length limits and protected slot limits, when properly applied, have also been successful in promoting desired changes in trout population size structure.

It is important to realize, however, that for size limits to be effective in altering population structure, mortality from angling (i.e. harvest and hooking mortality) must comprise a significant component of the total annual mortality in a given trout population. Barnhart and Engstrom-Heg (1984) considered harvest protection of brown trout to be unnecessary in New York streams to ensure successful reproduction or stock maintenance where angling pressure is less than 150 hours/acre/season. However, fishing pressure as low as 50/hours/acre/season led to overexploitation of brown trout populations in several large rivers in Colorado, while angling pressure of 200-300 hours/acre/season severely reduced the number of trout 10 inches and larger (Nehring 1987). Wild rainbow and brook trout are more vulnerable to angling than brown trout (Varley 1975, Engstrom-Heg and Hulbert 1982, Heidinger 1999) and therefore may be subject to over-exploitation with lower angling effort. Sánchez-Hernández et al. (2016) also caution that minimum length limits may unintentionally lead to declines in recruitment if larger trout are harvested. They encourage the protection of larger individuals through protected slot limits to reduce this risk.

Trout growth potential must also be sufficient to enable trout to reach desired sizes prior to substantial losses from natural mortality. Due to major differences in population dynamics (growth rates, natural mortality rates) and recreational fishery characteristics (fishing pressure, harvest rates) among the state's trout waters, a statewide minimum length limit would result in a wide range of effects on different trout populations, and among trout species within an individual water. This is illustrated by a statewide nine-inch minimum length limit on brown and rainbow trout in New York State's streams and rivers which did not provide uniform protection of these trout resources (Engstrom-Heg and Hulbert 1982). While some populations benefited from the minimum length limit, fishing quality declined in many waters and the statewide limit was subsequently removed. In Vermont, a statewide six-inch minimum length limit in place until 1974 provided very little protection for wild brook trout populations (Claussen 1980). Slow growth and high natural mortality characteristic of these populations, not angler harvest, apparently precluded trout from attaining large sizes. Hunt's (1970) evaluation of a six-inch limit on brook trout in Michigan resulted in similar conclusions. Therefore, to be effective in achieving a desired change in a trout population, a length limit must be tailored to an individual water or to a group of waters with similar biological and fishery characteristics.

Season Length

From a strict biological standpoint, season closures are primarily justified to protect trout during times when they may be particularly vulnerable to angling (Engstrom-Heg 1981, Everhart and Youngs 1981, Isermann and Paukert 2010). However, season closures also allow for shifts in fish and wildlife law enforcement priorities, and create a psychological goal for anglers anticipating an "opening day." Like creel limits, season restrictions may have little effect on annual harvest of trout as the level of angling effort within the open season is not controlled.

In Vermont, the current open-water trout fishing season (second Saturday in April through October 31st) has little to do with protecting trout during their spawning seasons. Only early spawning rainbow trout and late spawning brown trout are afforded protection under the existing season. Where spawning concentrations of trout do occur in Vermont, they are protected by water specific regulations including season closures. These areas are primarily associated with migratory runs of trout from large lakes or rivers such as Lake Memphremagog, White River, Winooski River and Batten Kill. Adult rainbow and brown trout inhabiting large rivers often migrate into smaller tributaries to spawn, where they may become more vulnerable to angler harvest. Loss of these fish will generally not impact annual reproductive success of the population, but may impact specific management objectives for the mainstem fishery (e.g. quality trout management). In addition to specific spawning stream regulations, the VFWD Commissioner has the authority to close spawning waters under Title 10 V.S.A. §4140.

Extended season trout fishing regulations have been adopted for several larger rivers to expand fishing opportunities beyond the traditional open-water season. During the expanded season, these waters are restricted to catch-and-release (no-harvest) of all trout and require the use of artificial flies and lures to minimize potential mortality. While only limited fishing activity is expected during this time period, the expanded season provides additional fishing opportunities in years with favorable early spring or late fall conditions.

Vermont's current ice fishing season for trout (third Saturday in January through March 15th) also lacks a firm biological basis. Only larger lakes (>100 acres) have been open to ice angling for trout on the premise that these waters can handle the biological and social demands of increased angling effort (Stewart 1966). These fisheries tend to support stocked or wild populations of rainbow trout and brown trout and have become very popular. The relatively short winter fishery contributes only a minor component of the annual harvest of rainbow trout, which appear less vulnerable during the winter, while brown trout often provide relatively good catches, including large individuals (Kirn 1999, Ladago 2014).

Gear Restrictions

The regulation of terminal tackle (e.g. natural bait, artificial flies and lures) has become a major component in managing recreational trout fisheries and is often applied in conjunction with length limits or catch-and-release regulations in an attempt to maximize survival of released fish (Noble and Jones 1999). Differences in hooking mortality associated with terminal tackle have been widely studied and can have profound effects on the success of management strategies requiring the release of fish. The greatest potential for hooking mortality occurs when trout are deeply hooked, resulting in injury to one or more vital organs (Wydoski 1977, Mongillo 1984, Taylor and White 1992, Bartholomew and Bohnsack 2005) and is more likely to occur when fishing with bait versus with artificial flies or lures. Taylor and White (1992), for example, reported average mortalities from bait to be 30.3%, 14.4% and 41.0% for brook, brown and rainbow trout, respectively, vs. 3.4%, 1.0% and 6.9% when caught with artificial flies and lures. In addition, the following conclusions were drawn from comprehensive reviews of hooking mortality studies by Wydoski 1977, Mongillo 1984, Taylor and White 1992, Bartholomew and Bohnsack 2005:

- Differences in hooking mortality between barbed and barbless hooks on artificial flies and lures are generally reported as negligible or inconclusive (also see Schill and Scarpella 1997). [While barbless hooks also result in injuries, some studies suggest that barbless hooks can greatly reduce handling time and air exposure and therefore the likelihood of mortality (Meka 2004, Cooke and Suski 2005, Pelletier 2007)].
- Cutting the line on deeply hooked fish greatly increased survival.
- Fish size and hook size were not significant mortality factors.
- Too few studies were available to adequately assess the effect of treble hooks vs. single hooks.
- Depth of capture, warm water temperatures, duration of air exposure and extended playing and handling times were significant mortality factors.
- Hooking mortality studies, which often release fish into holding pens, may underestimate mortality associated with post release susceptibility to predation during the recovery period.

According to the *2010 Vermont Angler Survey*, resident trout anglers fishing in streams & rivers primarily used bait or baited lures while less than 20% each fished with artificial flies or lures (Table 15; Connelly and Knuth 2010). It is therefore important to understand gear use characteristics when considering bait restrictions for specific trout stream fisheries (Kirn 1998b).

Table 15. Vermont resident and nonresident trout angler primary gear type used in streams and rivers from the 2010 Vermont Angler Survey.

Gear – Streams & Rivers	Vermont Residents (%)	Nonresidents (%)
Bait	51.0	29.2
Flies	18.8	45.8
Lures	18.1	20.8
Lures with bait	12.1	4.2

Managing angler trout harvest with the four regulation categories previously discussed, is applied at two levels in Vermont, as in most states: 1) Statewide in the form of statewide **General Regulations**; and 2) tailored to a specific water or a group of similar waters as **Specialized Regulations**.

General Regulations

As previously discussed under "Length Limits," regulations widely applied across the state may provide little management value due to substantial differences in trout resources and fishery characteristics across a wide geographic area and subject to annual variations in environmental conditions. However, these regulations can be used to provide a very basic level of protection for a species, or to address social or ethical concerns of the angling public.

Specialized Regulations

Unlike general regulations, specialized regulations are tailored to the biological and fishery characteristics of a target water, or group of similar waters, and are intended to produce specific responses in the trout population. These regulations are generally used to 1) protect or enhance spawning adults and smolts, or 2) increase angling quality by improving the size and/or number of trout available to anglers.

Spawning Stock Protection: A few of Vermont's large lakes produce substantial migratory runs of rainbow trout and brown trout, which result in concentrations of adult trout in tributary streams, potentially vulnerable to overexploitation. The stream residency of these migratory populations is regulated, where necessary, by a combination of minimum length limits, lower creel limits or in some cases, season closures. Minimum length limits serve to protect juvenile trout from angler harvest prior to their lakeward migration, while lower creel limits are designed to limit excessive harvest of adult trout by individual anglers. Likewise, wild trout from large rivers managed with restrictive harvest regulations may utilize smaller tributary streams for spawning; leaving them temporarily unprotected from the mainstem regulations. Seasonal closures in designated spawning tributaries provide for undisturbed trout spawning areas and protect adult trout from harvest.

Quality Trout Management: Angler harvest regulations have been successfully used throughout the U.S. to improve the quality of trout fishing by increasing trout densities or the number of large trout available to anglers (Barnhart and Roloefs 1977, 1987; Richardson and Hamre 1984). Catch-and-release regulations include no-harvest regulations where all trout must be released, and special length limits, such as minimum length, maximum length or slot limits, where a specific segment of the trout population must be released. In addition to specific length limits, quality trout management strategies often include reduced creel limits and gear restrictions allowing the use of artificial flies and lures only (Barnhart 1989, Carline and Beard 1991, Wright 1992). The restriction of bait angling in these waters is often required to minimize hooking mortality. The use of specialized trout harvest regulations to improve trout population or size structure will not be effective for stocked trout in waters with limited potential for multiple year survival (e.g. streams and rivers, warmwater lakes and ponds). Quality trout management in these waters, when appropriate, will rely on the stocking of quality sized trout (see section VII).

Dramatic improvements in angler catch rates and numbers of large trout following the implementation of catch-and-release regulations have been reported for trout rivers in Montana (Wells 1987), Colorado (Nehring 1987), Wisconsin (Hunt 1987), New York (Barnhart and Engstrom-Heg 1984), as well as in other states (Barnhart and Roelofs 1987). In Pennsylvania, a no-harvest regulation on a highly productive limestone stream also resulted in substantial increases in brown trout biomass and angler catch rates without additional gear restrictions (Carline and Beard 1991). Schill (1996) also suggests that the use of bait may be compatible with catch-and-release fishing regulations where bait fishing activity is low or where fishing techniques (e.g. tight-line vs. slack-line, cutting line on deeply hooked trout) can be modified to minimize mortality.

Despite many reported successes, catch-and-release regulations cannot improve a stream's natural capacity to support trout. In Wisconsin, restrictive regulations did not lead to improvements in a wild brook trout fishery due to overriding influences of natural mortality (Hunt 1977), while habitat limitations may have prevented an increase in the number of large brown trout under special harvest restrictions (Hunt 1981). While catch-and-release regulations in New York generally resulted in increased catch rates and an increase in two and three year old trout, stream productivity and habitat limitations were cited as probable causes for the lack of larger trout (> 14 in) produced under these regulations. As described earlier in Section VII, the substantial increase in the voluntary practice of catch-and-release by Vermont anglers may further limit the effect of these regulations as relatively few anglers choose to harvest trout (Figure 11).

In Vermont, catch-and-release regulations for wild trout fisheries have seen limited success. A no-harvest regulation on a 3.5-mile section of the New Haven River did not increase trout density or the number of large fish, apparently due to habitat limitations (MacKenzie 1990). The Dog River (Kirn 2016a) and Batten Kill (Cox 2006) both saw declines in wild trout population densities despite the application of restrictive trout harvest regulations. In the case of the Batten Kill, an increase in large brown trout (>18 inches) was observed following further restriction to a no-harvest regulation without bait restrictions. Substantial improvements in angler catch rates of wild trout have not been observed in special regulation sections within the Winooski River (Ladago 2016) or White River (Kirn 2000a, Kirn 2003). Despite these results, 80% of White River anglers supported the continuation of the regulation (Kirn 2000a). No-harvest regulations have also been used in Vermont as a conservative management approach to reduce additional fishing mortality on wild trout streams which have experienced population declines from unknown causes (Cox 2006, Kirn 2016a).

The potential movement of trout is an important consideration in determining the length of stream subject to specialized regulations (Nehring 1987, Barnhart 1989, Cox 2016). The Michigan Department of Natural Resources (MDNR 2015) provides specific guidance to fisheries managers:

"Seasonal movements of trout within streams may be extensive depending upon their needs for foraging, spawning, thermal refuge, or other life history requirements. The length of stream on which more restrictive regulations are applied should be large enough to buffer effects of angling mortality on trout whose range of movement exposes them to higher angling mortality in adjacent stream reaches." In a telemetry study of large wild brown trout on the Batten Kill in Vermont, Cox (2016) observed variable but in some cases extensive daily and seasonal movements, including one individual fish which travelled over 9 miles to a spawning site. These observations led Cox (2016) to conclude that the original two-mile specialized regulation section was inadequate to protect adult wild brown trout.

The variability of population responses to specialized regulations requires long term evaluations to determine if management objectives have been met. Nehring (1987) discussed several parameters that could control the response of a stream trout population to specialized regulation management. These included the reproductive potential of the species and stream, hydrographic patterns, habitat suitability, daily and seasonal water temperature patterns, species composition and vulnerability to angling, fishing pressure and trout harvest.

Although studies of specialized catch-and-release regulations have predominantly focused upon wild trout stream fisheries, there is also potential for these regulations to improve lake/pond fisheries. Greater longevity, higher growth rates and lower natural mortality often associated with lake/pond trout populations may in fact afford greater potential for developing quality fisheries <u>provided</u> that angling mortality is great enough to influence population structure. The potential for multiple season survival in many lakes/ponds also enables quality fisheries to be built upon maintenance stockings of cultured trout. This aspect may further enhance the potential for success because trout can be stocked at a size where only one or two years of protection from harvest is necessary to reach desired sizes. Quality management strategies which require restrictions on bait angling may, however, be more difficult to implement on lakes/ponds because of conflicts with other coolwater or warmwater fisheries.

Barnhart (1989) summarized several criteria suggested for the selection of waters for catch-and-release management (e.g. no harvest, minimum length limits, slot limits) as follows:

"1) The waters should be productive enough to elicit a response by the trout population. This means high carrying capacity for trout, suitable temperatures, abundant food, and habitat for trout of all sizes, so that the fish have good growth rates and low natural mortality. Some states may have a few waters that are highly productive but experience only moderate fishing pressure; these areas probably need no special regulations.

2) Catch-and-release waters should be easy to fish with flies and artificial lures, and angler access should be assured.

3) Fish longevity is important; fish should live long enough to respond to reduced fishing mortality. To insure increased survival, hooking mortality must be low, which often means a restriction on angling with bait. The consensus was that hooking mortality is trivial in most catch and release trout fisheries in which flies and lures are used, whether the hook is single, treble, *barbed or barbless. Barbless hooks may be preferred to barbed ones because they require less handling of hooked fish and they are certainly easier to remove from hooked anglers.*

4) Catch-and-release regulations are often appropriate to protect a unique species or a species especially vulnerable to overharvest at some period in its life history. Some fish are especially vulnerable on their spawning runs, and overharvest could endanger future year classes.

5) There should be good public support for the catch and release fishery, because compliance with regulations by anglers is essential."

Both resident and nonresident anglers responding to the *2010 Vermont Angler Survey* indicated overwhelming support for the concept of implementing some types of specialized regulations to improve trout fishing quality in rivers/streams and lakes/ponds (Tables 16 and 17). Less than 10% of the resident respondents and 7-12% of the nonresident respondents did not support the use of any specialized regulation (Connelly and Knuth 2010).

Table 16. Vermont resident and nonresident trout angler opinions from the 2010 Vermont Angler Survey on the use of specialized regulation options in streams and rivers.

Specialized Regulation Option – Streams & Rivers	Vermont Residents (%)	Nonresidents (%)
Special Length Limits	63.6	67.4
Lower Creel Limits	50.7	61.4
Catch & Release – all fish must be released	34.3	52.3
Artificial Flies and Lures Only	29.1	54.5
Do not support any option	9.9	6.8

Table 17. Vermont resident and nonresident trout angler opinions from the 2010 Vermont Angler Survey on the use of specialized regulation options in lakes and ponds.

Specialized Regulation Option – Lakes & Ponds	Vermont Residents (%)	Nonresidents (%)
Special Length Limits	62.2	67.9
Lower Creel Limits	39.7	42.0
Catch & Release – all fish must be released	24.0	32.4
Artificial Flies and Lures Only	27.9	32.4
Do not support any option	9.9	11.6

Resident and nonresident anglers differed in their support for various regulation options. Length limits were the most favored regulation of resident anglers, selected by 63% of these respondents, followed by lower creel limits (50%), and "catch-and-release" (i.e. no-harvest; 34%) and "artificials only" (29%). Nonresident anglers, on the other hand, were generally more favorable than resident anglers of specialized regulation options in streams and rivers and showed similar support in lakes and ponds. These results have been generally consistent over the 1991, 2000 and 2010 statewide angler surveys (Connelly and Knuth 2010).

As with creel limits, support for specialized regulation options in streams or rivers clearly differed by angler type as described by their preferred gear (i.e., bait, fly, lure, lure with bait; Table 18). Fly anglers were by far the group most favorable to all specialized regulation options. Lure anglers were substantially less favorable to the "catch-and-release" and "artificials only" options, while bait and lure with bait anglers showed little support for these options. Resident anglers primarily using bait, lures, or lures with bait favored length limits and to a lesser degree, lower creel limits.

Table 18. Vermont resident trout angler opinions from the 2010 Vermont Angler Survey on the use of specialized regulation options in streams and rivers partitioned by angler gear type.

Streams & Rivers	Resident Anglers by Gear Type % Supporting Option			
Specialized Regulation Option	**Bait**	**Fly**	**Lure**	**Lure with bait**
Catch & Release – all fish must be released	24.7	67.6	35.5	24.1
Artificial Flies and Lures Only	16.2	71.8	36.6	16.7
Special Length Limits	57.4	70.6	61.0	52.8
Lower Creel Limits	42.3	67.6	51.7	36.1
Do not support any option	13.0	3.4	8.7	14.8

Recommendations

General Regulations: Based upon the previous review of their biological and management values, as well as the opinions of Vermont anglers, there is little reason to change Vermont's existing general trout regulations. These regulations provide an adequate level of protection for the majority of Vermont's trout resources and appear in line with the desires expressed by the majority of anglers. Changes in angler opinion, trout fishery characteristics or evolving threats to trout resources may require re-evaluation of these regulations. The general regulations for brook, brown and rainbow trout are summarized in Table 19.

Specialized Regulations:

***Spawning Stock Protection*:** The current use of specialized regulations has been an effective approach to protect migratory spawning stocks of trout in specific waters of concern. Where deemed necessary, the open-water season for trout is closed until June 1st to protect spawning concentrations of rainbow trout from angling and closed after September 30th to protect brown trout. Spawning water closures or other restrictions should be considered for tributaries of lakes and rivers managed with specialized regulations to improve wild trout fisheries.

Ten-inch minimum length limits appear to adequately protect both rainbow and brown trout juveniles from harvest prior to their downstream migration to large lakes. Future need for spawning run protection should be consistent with existing regulations where possible.

Table 19. General regulations for brook, brown and rainbow trout in Vermont streams & rivers; and lakes & ponds.

General Regulations	Streams & Rivers	Lakes & Ponds
Open-water Season		
Waters	All	All (except Lake Champlain)
Creel limits	12 trout in aggregate of which not more than 6 may be brown and/or rainbow trout	6 trout in aggregate (select lakes with 2-trout aggregate limit)
Length Limit	None	None
Season	Second Saturday in April through October 31st, both dates inclusive.	Second Saturday in April through October 31st, both dates inclusive.
Gear Restrictions	None	None (use of fish as bait prohibited in select waters)
Ice Fishing Season		
Waters	None	Select waters– see VT Fishing Regulations
Creel limits	Not Applicable	6 trout in aggregate (select lakes with 2-trout aggregate limit)
Length Limit	Not Applicable	None
Season	Not Applicable	Third Saturday in January through March 15th, both dates inclusive
Gear Restrictions	Not Applicable	None
Extended Season		
Waters	Select waters– see VT Fishing Regulations	None
Creel limits	0 – Catch-and-release	Not Applicable
Length Limit	Not Applicable	Not Applicable
Season	November 1 through the day before the open-water season	Not Applicable
Gear Restrictions	Artificial flies and lures	Not Applicable

Quality Trout Management: Considering the widespread support expressed by Vermont anglers, the use of specialized regulations to provide for quality trout angling should be pursued where biological and fishery characteristics indicate this type of management will be effective. While this management approach has increased angler catch rates and the size and/or numbers of trout in many waters throughout the U.S., failure to meet management objectives have been common where factors other than angling mortality control the trout population. Criteria summarized by Barnhart (1989; page 75-76) should be considered when identifying potential waters for specialized regulations. In addition, it should be realized that in productive waters subject to modest levels of angler pressure or trout harvest, it may be possible to provide quality trout angling with general regulations.

To manage for a quality trout fishery, some measure of "quality" is necessary. Respondents of the Vermont Angler Survey provided a definition of this measure when indicating the minimum length they would consider a quality size for each trout species in streams/rivers and lakes/ponds. The following lengths meet the majority of respondent's opinions of a quality size trout and will form the basis for length goals to target in specialized quality trout management strategies (Table 20).

Table 20. Quality size goals for brook, brown and rainbow trout in Vermont streams & rivers; and lakes & ponds.

Quality Size	Streams & Rivers	Lakes & Ponds
Brook Trout	10 inches	10 inches
Brown Trout	12 inches	14 inches
Rainbow Trout	12 inches	14 inches

To meet these quality size objectives, growth potential must be sufficient to enable trout to reach the desired size prior to substantial influences of natural mortality. Past studies of trout populations in Vermont reveal a general paucity of trout reaching ages 4 and older. Therefore, in waters selected for quality management, the majority of trout should be able to reach the desired length as 3 year old fish. For most stream populations of brook trout, however, management strategies to increase trout to 10 inches or greater will not be feasible due to their inherent slow growth and short life cycles.

Although wild populations of rainbow and brown trout may have management potential for meeting quality size objectives in selected rivers/streams, as will all three species in specific lakes/ponds, quality trout fisheries can also be provided in other waters through the use of cultured trout. The popular "trophy trout" program was initiated in 1994, and is comprised of stocking 2-year old trout in several river reaches and has since expanded to small lakes and ponds. Advantages of this program are that restrictive regulations (e.g. length limits, gear restrictions) are not required and long-term evaluations are not necessary. Due to the high cost of rearing trout to the target quality sizes, these programs should only be conducted in areas which will provide a high return of stocked fish. Waters should be large enough and maintain suitable conditions to support these large trout for an extended period of time. These waters should also be capable of supporting high angling pressure without resulting in social conflicts. Lower creel limits may be appropriate to avoid excessive harvest of large stocked trout by individual anglers.

In addition to providing for larger trout or more trout, quality trout management should consider angler catch rates. Nehring (1987) identified 0.7 trout/angler-hour as a catch rate objective for Colorado's "Gold Medal Trout Management Program." In a review of "special opportunity regulations" emphasizing catch-and-release, Hunt (1991) identified catch rates ranging from 0.22 - 2.50 trout/angler-hour. While target catch rates are a reasonable goal, the influence of variable environmental conditions (flows, temperature) can greatly influence fishing conditions, and therefore fishing effort, in a given year (Kirn 2003).

It should also be recognized that managing waters with specialized regulations to sustain wild trout fisheries provides diversity and quality to Vermont's trout fishery. While there are abundant small to moderate sized streams which support robust wild trout populations, there are relatively few opportunities to manage larger streams and rivers or lakes and ponds for wild trout. These situations should be fully considered for specialized regulations where they can contribute to the ability to manage waters for wild trout, even if high catch rates are not feasible.

Although specialized regulations are designed to specific characteristics of a trout population and fishery, small differences in length (e.g. 13 vs. 14 in) or creel limits (e.g. 2 vs. 3 fish) may provide only minor management value. In addition, a wide variety of trout regulation options may become cumbersome and confusing to anglers, reducing participation and support (Isermann and Paukert 2010). Therefore, statewide efforts to promote quality trout angling opportunities should attempt to balance these needs by striving for a standard set of specialized regulation options which can be applied throughout the state (Engstrom-Heg 1981).

Quality Trout Regulation Considerations

***Specialized Regulations*:** Several Quality Trout regulations have been initiated in Vermont streams, rivers, lakes and ponds, including one or a combination of no-harvest, minimum length, slot limits, reduced creel limits and gear restrictions. When feasible, standardization of specialized regulations is desirable to minimize overall complexity of fishing laws. However, it is also recognized that the public process associated with the development and passage of fishing regulations may make this difficult to accomplish in all cases.

Gear Restrictions in the form of artificial flies and lures only will often be required in addition to these regulation options to ensure increased survival of released trout. Situations where low bait fishing use is anticipated, or where fishing methods minimize fishing mortality should be considered on a case-by-case basis.

Season Length may be expanded (e.g. year-round) in conjunction with some specialized regulation options to provide additional angling opportunities.

General Regulations: In some highly productive waters subject to low or moderate angling pressure and low trout harvest, quality trout angling may be provided without additional restrictive regulations.

Regulation Section Length: The length of the regulation should consider the potential for extensive movements of trout both seasonally and on a daily basis.

Spawning Tributaries: As above, the seasonal movement of trout outside a specialized regulation water to spawning tributaries may leave them vulnerable to exploitation and compromise management objectives. In these cases, additional spawning water protections should be considered.

Angler Harvest: The increased practice of voluntary catch-and-release by anglers has greatly reduced the magnitude of trout harvest and therefore may limit the ability of restrictive regulations to alter population abundance and structure.

Survival of Stocked Trout: For stream fisheries, where survival of stocked trout is very limited, the use of restrictive regulations may be of limited value, other than to reduce excessive harvest by individual anglers, as in the case of two-year old trout stockings in select rivers.

IX. Trout Management Plan Goals, Objectives and Strategies

The following program goals, objectives and strategies have been identified as necessary to meet the Department's overall goal to manage the state's trout resources to support wild trout populations and a diversity of quality recreational opportunities.

Program Goal: *Protect, restore and enhance trout habitat.*

Objective 1: Consistently and effectively participate in environmental regulatory processes to protect and restore aquatic habitat.

Strategies:

1. Review and comment on state and federal permit applications involving riparian and aquatic habitats.

2. Participate in hydropower licensing review.

3. Develop guidelines and policy statements to clarify the Department's position on aquatic habitat issues.

4. Ensure that permit condition language is clear and enforceable.

Objective 2: Effectively advocate for habitat protection with other agencies, developers, private land owners and the public.

Strategies:

1. Work with the other departments of the Agency of Natural Resources in the development of policies, regulations and laws related to aquatic habitat.

2. Encourage enforcement of existing environmental laws.

3. Testify before the legislature on bills that could affect aquatic habitat.

4. Work with state and federal agencies, natural resource organizations and local governments to encourage sound land-use practices in and around streams/rivers and lakes/ponds.

5. Continue information and education programs to encourage the protection of trout habitat. Re-evaluate current programs and adjust activities as necessary to maximize their effectiveness.

<u>Objective 3</u>: Develop a program to restore damaged trout habitat. Evaluate the effectiveness of habitat enhancements.

<u>Strategies</u>:

1. Develop a long-range plan for trout habitat restoration/improvement to be implemented under a Federal aid project.

2. Investigate the feasibility of establishing and funding separate staff positions and a separate unit to address the habitat protection, restoration and enhancement goals.

3. Develop outreach and incentives to encourage good riparian stewardship by private landowners.

4. Partner with other state agencies, federal agencies, and non-profit organizations to identify opportunities and implement trout habitat restoration and enhancement.

5. Restore brook trout pond habitats by eliminating introduced fish species that prey upon brook trout or that compete with them for food and habitat.

6. Monitor the effects of habitat protection and enhancement projects on trout populations to ensure the anticipated benefits are achieved, efforts are cost effective and results are used to inform future projects.

<u>Objective 4</u>: Protect high value wild trout habitat.

<u>Strategies</u>:

1. Develop effective strategies to engage and inform riparian landowners regarding the importance of these habitats for aquatic ecosystems to positively influence their stewardship of these lands.

2. Consider purchase or development rights of riparian property. Work with other land acquisition groups as necessary to fund the purchase or development rights of riparian property. Investigate additional funding mechanisms.

Program Goal: *Conserve and enhance the state's wild trout resources at optimal levels supportive of a diversity of recreational opportunities.*

<u>Objective 1</u>: Conserve and/or enhance wild trout populations to provide a diversity of angling opportunities.

<u>Strategies</u>:

1. Continue to monitor wild trout population surveys throughout the state to determine long term trends and inform management strategies.

2. Manage populations consistent with established criteria for wild trout management.

3. Determine the effects of angler harvest on wild trout population levels and/or structure by conducting angler creel surveys.

4. Apply appropriate angler harvest regulations to conserve or enhance trout population levels and/or size structure.

5. Minimize potential impacts of cultured trout on wild populations through the prudent management of cultured trout strains, diseases, stocking densities and species introductions.

Program Goal: *Utilize cultured trout where management of a recreational fishery is justified, but cannot be sustained solely through wild trout management.*

Objective 1: Identify statewide needs for cultured trout.

Strategies:

1. Identify waters where the use of cultured trout is justified to provide recreational fisheries consistent with established guidelines which consider existing sportfish populations, growth and survival potential of stocked trout, contribution of cultured trout to the fishery, angler use and long-term program benefits.

2. Categorize waters into established management categories and stocking priorities and adjust as necessary.

Objective 2: Operate Department fish culture facilities to meet statewide needs for cultured trout.

Strategies:

1. Rear species, numbers and sizes of trout sufficient to meet trout management requests.

2. Develop and evaluate the performance of broodstock sources for genetic strains of trout best suited for Vermont waters and specific management objectives (e.g. growth, survival and return to angler).

3. Utilize triploid (sterile) trout where stocking creates the potential for genetic interactions with wild stocks.

4. Minimize potential impacts of serious fish diseases upon cultured and wild trout stocks through management of a statewide fish health program.

<u>Objective 3</u>: Maximize benefits of stocked trout for Vermont anglers.

<u>Strategies</u>:

1. Review current trout stocking rates for individual waters and make appropriate adjustments following established stocking guidelines.

2. Conduct fish population and angler surveys to evaluate success of cultured trout stocking in meeting individual and statewide program objectives.

3. Stock trout species, strains and sizes at times, under environmental conditions and using distribution techniques which will promote the greatest potential for survival and return to anglers.

4. Evaluate the trout species, strains, and sizes for performance best suited for a variety of waters, environmental limitations (e.g. water quality, predators) and management applications.

5. Do not stock waters which prohibit access to the trout angling public.

Program Goal: *Conserve and/or enhance trout population levels and/or structure through administration of effective harvest regulations.*

<u>Objective 1</u>: Provide basic protection from angler harvest for most trout populations through administration of general statewide regulations.

<u>Strategies</u>:

1. Evaluate both short and long-term trout population and angler surveys throughout the state to identify trends in trout population levels and angler use and catch statistics.

<u>Objective 2</u>: Provide more restrictive angler harvest regulations as warranted to protect specific life stages or concentrations of trout vulnerable to overharvest.

<u>Strategies</u>:

1. Identify waters and apply appropriate regulation options where population concentrations or life stages require additional protection from angler harvest to maintain long-term population levels.

Objective 3: Provide a diversity of quality trout angling opportunities through the appropriate use of harvest regulations.

Strategies:

1. Identify waters and apply appropriate regulation options where biological and fishery characteristics indicate additional harvest regulations will improve the number and or size of trout available to anglers.

2. Evaluate effectiveness of specific regulation changes through trout population and/or angler creel surveys.

Program Goal: *Provide angler access to trout fisheries*

Objective 1: Maintain or improve angler access to streams, rivers, lakes and ponds supporting trout fisheries.

Strategies:

1. Acquire and manage both improved (e.g. boat access areas) and unimproved (e.g. riparian parcels) lands adjacent to trout fisheries to provide angler access. Ensure the trout angling public is aware of these parcels and facilities.

2. Work with private landowners, municipalities and other state, federal and private organizations to provide angler access through their lands. Work with angler organizations and individuals to resolve access conflicts.

3. Encourage respectful angler behavior when using private lands to access trout fisheries.

X. Summary of Laws and Regulations

Title 10, Chapter 41 - Regulation of Stream Flow

This section of the statute dealing with the regulation of stream flow empowers the Department of Environmental Conservation to call to conference any dam owner that regulates natural stream flow and to require the passage of adequate flows to support the stream fishery.

Subchapter 1, Section 1004

Section 1004 makes the Secretary of ANR the state agent with respect to the Federal Energy Regulatory Commission (FERC) dam licensing process and with respect to the Federal Clean Water Act Section 401 administration. Under ***Section 401***, federal agencies cannot issue licenses, license exemptions or permits for activities that may affect water quality until such activities have been certified as meeting state water quality standards. This Section 401 process has proved to be a powerful tool in the review of projects subject to FERC and Corps of Engineers jurisdiction.

Subchapter 2, Alteration of Streams

This permit is required for the movement, excavation or fill of 10 or more cubic yards of material (including natural wood) annually in any perennial stream, or construction or maintenance of a berm in a flood hazard area or river corridor. Examples of regulated activities include streambank stabilization, mineral prospecting, and municipal roadway improvements encroaching on streams, utility crossings under streambeds, municipal or private bridge construction or repair. No person may remove gravel from any watercourse for the primary purpose of construction or sale. Approval is also required for municipal or private stream crossings on perennial streams. Permit review considers the creation of flood hazards; damage to fish life and wildlife; the rights of neighboring landowners; and compliance with VT Water Quality Standards. This subchapter does not apply to dams subject to Chapter 43. While state transportations projects require consultation through **Section 5 of Title 19**, the Stream Alteration General Permit requirements are used as a template for this interaction.

There are also a host of exemptions and non-reporting activities which require compliance with general permit conditions. Exemptions include emergency protective measures with reporting and implementation requirements, removal of up to 50 cubic yards or up to 10 cubic yards in Outstanding Resource Waters annually for riparian landowners with reporting requirements, and Required Agricultural Practices as defined by the Commissioner of Agriculture.

Subchapter 3: Water Withdrawal for Snowmaking

The Snowmaking Rules define the criteria used to determine acceptable conservation flows when the Agency evaluates proposals for new or expanded snowmaking systems. The rules set forth annual water use reporting requirements, and, through a separate guidance document, information to be included in alternatives analyses. Development of a new water intake for snowmaking, or infrastructure changes to an existing snowmaking system that trigger regulatory review under the programs listed below.

Activities related to snowmaking water withdrawals may require permits from any of the following programs: dam safety (10 V.S.A. Chapter 43), stream alterations or flow regulation (10 V.S.A. Chapter 41), Act 250 (10 V.S.A. Chapter 151), or water quality certifications issued under Section 401 of the Federal Clean Water Act.

Title 10, Chapter 43 - Dams

A certificate of public good is required before constructing or modifying any dam impounding more than 500,000 cu. ft. This law is administered by the Department of Environmental Conservation, except for projects involving the generation of hydroelectric energy, where the Public Service Board assumes jurisdiction. In federally licensed hydroelectric projects and government-managed flood control projects, the final authority lies with the Federal Energy Regulatory Commission or the Federal flood control program and the Vermont legislature.

Section 1084 requires the Fish and Wildlife Department to investigate the effect of any proposed project on fish and wildlife habitats and to certify its findings to the Department of Environmental Conservation or the Public Service Board, prior to any hearing.

Section 1086 enumerates the several issue areas that must be explored before a determination of public good is made. Specifically included are recreational values; fish and wildlife; existing uses such as fishing; and the need for minimum stream flows. This section provides the primary legal means for ensuring that the impacts of unlicensed hydroelectric power facilities (i.e., non-FERC jurisdictional) on fish and wildlife resources are minimized.

Title 10, Chapter 47 - Vermont Water Pollution Control Act

This law administered by the Agency of Natural Resources under auspices of the Federal Water Pollution Control Act (PL 92-500). Within the Water Pollution Control Act (i.e. Clean Water Act) are **sections 1252 and 1258** which, respectively, set up a classification system for state waters and authorize the Agency to manage waters to attain or maintain their classification, including the regulation of discharges to state waters. .

Under **Section 1252**, Water Quality Standards are promulgated by VDEC to establish numeric and narrative standards for the management of waters. The standards also designate all waters as to their fish habitat type - either cold water or warm water. The standards have the force of law and set up an important framework for management of physical water quality, such as dissolved oxygen, temperature, turbidity, and toxics and for protection of other important considerations, such as physical aquatic habitat, hydrology and species propagation.

Section 1259 is often used in the enforcement of illegal activities which create a discharge to state waters as it contains the following broadly defined protection: *"No person shall discharge any waste, substance, or material into waters of the State…"*

Section 1264 provides the authority to regulate stormwater discharges.

Section 404 give the U.S. Army Corps of Engineers the authority to regulate discharges of dredged or fill material into all waters of the U.S. including wetlands. **Section 10 of the Rivers and Harbors Act** requires a Corps of Engineers permit for construction of any structure in or over any navigable water of the U.S. This includes dredging or disposal of dredged material, excavation, channelization or other modification. Depending on the size of the project, federal permitting requirements for Section 404 and the Rivers and Harbors Act may be handled through a single 'General Permit'.

Section 1263a Aquatic Nuisance Control (ANC) Permits
A permit is required for activities used to control nuisance aquatic plants, insects or other aquatic life including lamprey in waters of the State of Vermont. Activities requiring a permit under this program include the use of pesticides and chemicals other than pesticides; the use of Aquashade; the use of biological controls; the installation of bottom barriers to inhibit nuisance plants; the use of powered mechanical devices such as mechanical weed harvesters and hydrorakes; and the use of structural controls. Permits may be issued for up to 5 years for pesticides, Aquashade, copper-based products or chemicals other than pesticides. Permits for bottom barriers, powered mechanical devices, structural controls or biological controls may be issued for up to 10 years.

All of the activities listed above require an ANC permit except:

- The use of copper-based products for the control of algae in ponds one acre or less in size, located entirely on one individual's property, and with an outlet where the flow can be controlled for at least three days after treatment.
- Hand pulling of nuisance plants.
- Activities to control mosquitoes; these activities are regulated by the Agency of Agriculture.
- The use of "pond clarifiers" or products sold under various trade names that according to the labels "reduce sludge, odors, and excess nutrients". However, since use of these products involves putting something into waters of the state, a discharge permit is needed for their use.

10 VSA Chapter 49A - Lake Shoreland Protection Standards

Any project that involves creation of newly cleared area or impervious surface within 250 feet of the mean water level of a lake that is greater than 10 acres in surface area requires either a shoreland registration or permit. Activities that may commonly require a registration or permit include development or redevelopment of a house and clearing of vegetated areas for a lawn, recreation area, or for any other purpose. The mean water level of a lake or pond is defined as the mean summer water level elevation during the period between June 1 and September 15.

The landowner must register: (1) the creation of no more than 100 square feet of impervious surface or cleared area at least 25 feet from mean water level, and (2) the creation of no more than 500 square feet of impervious surface or cleared area at least 100 feet from mean water level. Creation of newly cleared area or impervious surface that does not qualify for registration requires a permit, unless the scope or character of the activity is specifically exempt.

Title 10, Chapters 101 through 123, and Appendix - Fish and Wildlife Conservation

This is where all the laws relating directly to fish and wildlife conservation are found. It also gives the authority to the Fish and Wildlife Board to set seasons, creel limits and size limits. Most of the laws pertaining to fish are found in **Chapter 111** and primarily deal with the "taking of fish."

Three sections provides the Fish and Wildlife Department more specific authority for the protection fish and their habitats:

Chapter 111 Section 4605 (placing fish in waters; fish importation permits) allows for the control of introductions of exotic or undesirable fish species and associated diseases.

Chapter 111 Section 4606 (taking fish by unlawful means) prohibits the use of explosives, toxic substances or the shutting off of water to kill fish.

Chapter 111 Section 4607 (obstructing streams) prohibits the installation of a structure that prevents fish movement, such as a rack, weir or other obstruction, unless an approval has been granted by the Commissioner of Fish and Wildlife.

Title 10, Chapter 151 - Vermont's Land Use and Development Law (Act 250)

Act 250 is Vermont's land use and development law, established in 1970. The law provides a public, quasi-judicial process for reviewing and managing the environmental, social and fiscal consequences of major subdivisions and development in Vermont through the issuance of land use permits. The Governor appoints citizens to the nine District Commissions and the Natural Resources Board. Activities include review of land use permit applications for conformance with the Act's ten environmental criteria, issuance of opinions concerning the applicability of Act 250 to developments and subdivisions, monitoring for compliance with the Act and with land use permit conditions, and public education.

This law provides for broad protection of streams, shorelines, and water quality through criteria that aim to minimize development effects on erosion, public investments, necessary wildlife habitat, and the natural condition of streams and shorelines. Protection of aquatic resources has been primarily through permit conditions for, riparian zone protection, river corridor setbacks, erosion and sediment control, minimum stream flows, and stream crossings which provide unrestricted aquatic passage.

Title 29, Chapter 11 - Management of Lakes and Ponds

This permit is required for any project that involves the placement of material or a structure beyond the mean water level of lakes and ponds which are public waters, or which alters the land underlying such lakes and ponds. Lake encroachment jurisdiction includes encroachments of docks and piers on the boatable tributaries of Lake Champlain and Lake Memphremagog upstream to the first barrier to navigation, and encroachments of docks and piers on the Connecticut River impoundments and upstream to the first barrier to navigation on the boatable tributaries to those impoundments.

Activities that may commonly require a permit include retaining walls or riprap to control shoreland erosion, commercial docks, large docks (including private docks that exceed the private dock size exemption), docks involving concrete, dredging or filling activity, some repairs to existing encroachments, and replacement of existing encroachments.

The public status of a lake or pond is determined by the VT DEC. Public access is not a prerequisite. The mean water level of a lake or pond is defined as the mean summer water level elevation during the period between June 1 and September 15. Several exemptions are provided related to noncommercial docks, small water intake pipes, maintenance and repair of existing infrastructure and duck blinds, rafts and buoys.

XI. Literature Cited

Adams. S.B., C.A. Frissell and B.E. Reiman. 2000. Movements of nonnative brook trout in relation to stream channel slope. Transactions of the American Fisheries Society 129:623-638.

Alexiades, A., B.M. Quay, P. Sullivan and C. Kraft. 2014. Evaluation of the NYSDEC Catch Rate Oriented Trout Stocking Program: Project Report. New York State Department on Environmental Conservation, Albany.

Anderson, D. H. Moggridge, P. Warren, and J. Shucksmith. 2014. The impacts of 'run-of-river' hydropower on the physical and ecological condition of rivers. Water and Environment Journal. DOI:10.1111/wej.12101.

Araki, H. and C. Schmid. 2010. Is hatchery stocking a help or harm? Evidence, limitations and future directions in ecological and genetic surveys. Aquaculture 308:2-11.

Argent, D.G. and W.G. Kimmel. 2013. Potential impacts of climate change on brook trout (Salvelinus fontinalis) populations in streams draining the Laurel Hill in Pennsylvania. Journal of Freshwater Ecology, 2013. http://dx.doi.org/10.1080/02705060.2013.784880

Ashe, W. and D. DeGraaf. 2015. Maine's brook trout stream monitoring project: trends in abundance and size quality of stream-dwelling brook trout, 1990-2014. Maine Department of Inland Fisheries and Management. Fishery Final Report Series No. 15-2, Augusta.

Avery, E.L. 1983. A Bibliography of beaver, trout, wildlife, and forest relationships with special references to beaver and trout. Wisconsin Department of Natural Resources, Technical Bulletin 137, Madison.

Bachman, R.A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113:1-32.

Bachman, R.A. 1991. Brown trout. Pages 208-229 in J. Stolz and J. Schnell, editors. The wildlife series: Trout. Stackpole Books. Harrisburg, Pennsylvania.

Baldigo, B.P. and G.B. Lawrence. 2000. Composition of fish communities in relation to stream acidification and habitat in the Neversink River, New York. Transactions of the American Fisheries Society. 129:60-76.

Baird, O. E., and C. C. Krueger. 2003. Behavioral thermoregulation of brook and rainbow trout: Comparison of summer habitat use in an Adirondack river, New York. Transactions of the American Fisheries Society 132:1194-1206.

Baird O.E, C.C. Krueger and D.C. Josephson. 2006. Growth, Movement, and Catch of Brook, Rainbow, and Brown Trout after Stocking into a Large, Marginally Suitable Adirondack River. North American Journal of Fisheries Management 26:180-189.

Barnhart, R.A. 1989. Symposium review: Catch-and-release fishing, a decade of experience. North American Journal of Fisheries Management 9:74-80.

Barnhart, R.A., and R. Engstrom-Heg. 1984. A synopsis of some New York experiences with catch and release management of wild salmonids. Presented at the Third Wild Trout Symposium, Mammoth, Wyoming.

Barnhart, R.A., and T.D. Roelofs, editors. 1977. Catch and release fishing as a management tool. Humboldt State University, Arcarta, California, USA.

Barnhart, R.A., and T.D. Roelofs, editors. 1987. Catch-and-release fishing, a decade of experience. Humboldt State University, Arcata, California, USA.

Bartholomew, A. and J. A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Reviews in Fish Biology and Fisheries 15:129–154.

Bates, K. K. and R. Kirn. 2009. Guidelines for the design of road/stream crossings for passage of aquatic organisms in Vermont. Vermont Fish and Wildlife Department. Montpelier.

Beard, T.D. Jr., and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society 120:711-722.

Beauchamp, D.A. 1990. Seasonal and diel food habits of rainbow trout stocked as juveniles in Lake Washington. Transactions of the American Fisheries Society 119:475-482.

Beckmann, C., P. A. Biro, and J. R. Post. 2006. Asymmetric impact of piscivorous birds on size-structured fish populations. Canadian Journal of Zoology 84:1584-1593.

Behnke, R.J. 2002. Trout and Salmon of North America. The Free Press, New York. 359 pp.

Bennet, S.N. and J.L. Kershner. 2009. Levels of introgression in Westslope cutthroat trout populations nine years after changes in rainbow trout stocking programs in southeastern British Columbia. North American Journal of Fisheries Management 29:1271-1282.

Bernhardt, E.S., M.A. Palmer, J.D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G.M. Kondolf, P. S. Lake, R. Lave, J. L. Meyer, T.K. O'Donnell, L. Pagano, B. Powell, E. Sudduth. 2005. Synthesizing U.S. River Restoration Efforts. Science (308) 636-637.

Beschta, R.L and R.E. Bilby, G.W. Brown, L.B. Holby and T.D. Hofstra. 1986. Stream Temperature and Aquatic Habitat: Fisheries and Forestry Interactions. In E.O. Salo and T.W. Cundy, Streamside Management. Forestry and Fishery Interactions. University of Washington, Seattle.

Bonney, F. 2006. Maine brook trout: biology, conservation, and management. Maine Department of Inland Fisheries and Wildlife, Augusta, ME.

Bonney, F. 2009. Brook trout management plan. Maine Department of Inland Fisheries and Wildlife. Augusta.

Borgeson, D.P. 1966. Trout lake management in A. Calhoun, editor. Inland Fisheries Management, California Fish and Game Department.

Bouwes, N., S. Bennett, J. Wheaton. 2016. Adapting adaptive management for testing the effectiveness of stream restoration: and intensively monitored watershed example. Fisheries 41:84-91.

Brauhn, J.L., and H. Kincaid. 1982. Survival, growth, and catchability of rainbow trout of four strains. North American Journal of Fisheries Management 2:1-10.

Brown, J.J., K.E. Limburg, J.R. Waldman, K. Stephenson, E.P. Glenn, F. Juanes, and A. Jordaan. 2013. Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies. Conservation Letters, 1–7.

Brown, R.S., W.A. Hubert and S.F. Daly. 2011. A primer on winter, ice, and fish: what fisheries biologists should know about winter ice processes and stream-dwelling fish, Fisheries, 36:8-26.

Budy, P., G.P. Thiede , A. Dean , D. Olsen and G. Rowley. 2012. A Comparative and Experimental Evaluation of Performance of Stocked Diploid and Triploid Brook Trout. North American Journal of Fisheries Management 32:1211-1224

Burns, J.W., and A. Calhoun. 1966. Trout stream management in A. Calhoun, editor. Inland Fisheries Management, California Fish and Game Department.

Butler, R.L., and D.P. Borgeson. 1966. "Catchable" trout fisheries in A. Calhoun, editor. Inland Fisheries Management, California Fish and Game Department.

Butryn, R.S., D.L. Parrish, and D.M. Rizzo. 2013. Summer stream temperature metrics for predicting brook trout (Salvelinus fontinalis) distribution in streams. Hydrobiologia, 703:47-57.

Calhoun, A. 1966. The importance of considering the strain of trout stocked in A. Calhoun, editor. Inland Fisheries Management, California Fish and Game Department.

Campton, D. E. and Johnston, J.M. Electrophoretic evidence for a genetic admixture of native and nonnative rainbow trout in the Yakima River, Washington. Transactions of the American Fisheries Society. 1985; 114(6):782-793.

Carline, R.F., and T. Beard, Jr. 1991. Response of wild brown trout to elimination of stocking and to no-harvest regulations. North American Journal of Fisheries Management 11:253-266.

Carline, R.F. and S.P. Klosiewski. 1985. Responses to mitigation structures in two small channelized streams in Ohio. North American Journal of Fisheries Management 5:1-11.

Carmichael, G.J.; Hanson, J.N.; Schmidt, M.E., and Morizot, D. C. Introgression among Apache, cutthroat, rainbow trout in Arizona. Transactions of the American Fisheries Society. 1993; 122(1):121-130.

Carmignani, J.R. and A.H. Roy. 2017. Ecological impacts of winter water level drawdowns on lake littoral zones: a review. Aquatic Sciences 79:803–824.

Chapman, D.W. and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363.

Claussen, J.H. 1980. The effect of the six inch size limit on stream brook trout populations. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report, Montpelier.

Claussen, J.H. 1999. Evaluation of brown trout stocking in District 3 lakes and ponds. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report, Montpelier.

Cone, R.S., and C.C. Krueger. 1988. Comparison of survival, emigration, habitat use, marking mortality, and growth between two strains of brook trout in Adirondack ponds. North American Journal of Fisheries Management 8:497-504.

Connelly, N.A. and B.A. Knuth. 2010. 2010 Vermont angler survey report. HDRU Series No. 10-3. Cornell University Human Dimensions Research Unit. Ithaca.

Cook, M. E, T. J. Goeman, P. J. Radomski, J. A. Younk, and P. C. Jacobson. 2001. Creel limits in Minnesota: a proposal for change. Fisheries 26(5):19-26.

Cooke,S. and Suski, C. 2005. Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? Biodiversity and Conservation 14 1195-1209

Cooke, S.J., C.D. Suski, R. Arlinghaus and A.J. Danylchuk. 2013. Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. Fish and Fisheries, 14:439-457.

Cox, K. 1990. Bourn Pond, Bennington County. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report, Montpelier.

Cox, K. 2006. Batten Kill Trout Management Plan. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report, Montpelier.

Cox, K.M. 2016. Seasonal movements, habitat use and behavior of adult wild brown trout in the Batten Kill. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Cresswell, R.C. 1981. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters--a review. Journal of Fish Biology 18,429-442.

Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53 (Suppl. 1):267-282.

Currens, K.P, A.R.Hemmingsen, R.A.French, D.V. Buchanan, C.Schreck and H.W.Li. 1997. Introgression susceptibility to disease in a wild population of rainbow trout. North American Journal of Fisheries Management, 17:1065-1078.

Cunjak, R.A. and G. Power. 1986. Winter habitat utilization by stream resident brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta). Canadian Journal of Fisheries and Aquatic Sciences 43:1970-1981.

Curry, R.A. and D.L.G. Noakes. 1995. Groundwater and the selection of spawning sites by brook trout (Salvelinus fontinalis). Canadian Journal of Fisheries and Aquatic Sciences 52:1733-1740.

Davis, L.A., T.Wagner and M.L. Bartron. 2015. Spatial and temporal movement dynamics of brook *Salvelinus fontinalis* and brown trout *Salmo trutta.* Environ Biol Fish 98:2049–2065

Detar, J., D. Kristine, T. Wagner and T. Greene. 2014. Evaluation of catch-and-release regulations on brook trout in Pennsylvania streams. North American Journal of Fisheries Management, 34:49-56.

DeWeber, J.T. and T. Wagner. 2014. A regional neural network ensemble for predicting mean daily river water temperature. Journal of Hydrology 517 (2014) 187-200.

Diana, J.S., J.P. Hudson and R.D. Clark. 2004. Movement patterns of large brown trout in the mainstream AuSable River, Michigan. Transactions of the American Fisheries Society 133:34-44.

Dillon, J.C., D.J. Schill, and D.M. Teuscher. 2000. Relative return to creel of triploid and diploid rainbow trout stocked in eighteen Idaho streams. Fisheries. 2000; 20(1):1-9.

Dillman, C.B. and J.B. Koppelman. 2006. Genetic diversity among hatchery stocks and established populations of rainbow trout in Missouri. Transactions of the American Fisheries Society 135:341-347.

EBTJV (Eastern Brook Trout Joint Venture). Eastern Brook Trout: Status and Threats. http://easternbrooktrout.org/

Eby, L.A., W.J. Roach, L.B. Crowder and J.A. Stanford. 2006. Effects of stocking-up freshwater food webs. TRENDS in Ecology and Evolution Vol.21 No.10.

Edwards, C.J., B.L. Griswold, R.A. Tubb, E.C. Weber and L.C. Woods. 1984. Mitigating effects of artificial riffle and pools on the fauna of a channelized warmwater stream. North American Journal of Fisheries Management 4:194-203.

Engstrom-Heg, R. 1979. Salmonid stocking criteria for New York's fisheries program. Bureau of Fisheries, Division of Fish and Wildlife, New York State Department of Environmental Conservation, Albany.

Engstrom-Heg, R. 1981. A philosophy of trout stream management in New York. Fisheries, Vol. 6, No. 3.

Engstrom-Heg, R. 1990. Guidelines for stocking trout streams in New York State. Bureau of Fisheries, Division of Fish and Wildlife, New York State Department of Environmental Conservation, Albany.

Engstrom-Heg, R., and P.J. Hulbert. 1982. Evaluation of trout regulations in streams, 1977-1980. New York State Department of Environmental Conservation, Federal Aid in Fish Restoration Project FA-5-R, Final Report, Albany.

Eschmeyer, R.W. 1938. Experimental management of a group of small Michigan lakes. Transactions of the American Fisheries Society 120-129.

Everhart, W.H., and W.D. Youngs. 1981. Principles of fishery science, 2nd edition. Comstock Publishing Associates, a division of Cornell University Press, Ithaca and London.

Fausch, K.D., 1991. Competition. Pages 82-83 in J. Stolz and J. Schnell, editors. The wildlife series: Trout. Stackpole Books. Harrisburg, Pennsylvania.

Fausch, K.D., B.E. Rieman, J.B. Dunham, M.K. Young, and D.P. Peterson. 2009. Invasion versus isolation: trade-offs in managing native salmonids with barriers to upstream movements. Conservation Biology 23:859-870.

Fay, C.W., and G.B. Pardue. 1986. Harvest, survival, growth, and movement of five strains of hatchery-reared rainbow trout in Virginia streams. North American Journal of Fisheries Management 6:569-579.

Feld, C. K., S. Birk, D. C. Bradley, D. Hering, J. Kail, A. Marzin, A. Melcher, D. Nemitz, M. L. Pedersen, F. Pletterbauer, D. Pont, P. F. M. Verdonschot, and N. Friberg. 2011. From Natural to Degraded Rivers and Back Again. Advances in Ecological Research 44:119–209.

Flick, W.A. 1991. Brook trout. Pages 196-207 in J. Stolz and J. Schnell, editors. The wildlife series: Trout. Stackpole Books. Harrisburg, Pennsylvania.

Fox, C.A., F.J. Magilligan, C.S. Sneddon. 2016. ‘‘You kill the dam, you are killing a part of me”: Dam removal and the environmental politics of river restoration. Geoforum 70:93-104.

Galbreath, P. F., N.D.Adams,. S.Z. Guffey, C.J. Moore, and J.L. West. 2001. Persistence of native southern Appalachian brook trout populations in the Pigeon River system, North Carolina. North American Journal of Fisheries Management. 21(4):927-934.

Gard, R. and D.W. Seegrist. 1972. Abundance and harvest of trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101(3):463-477.

Gerardi, L. and J. Kratzer. 2011. Brook trout pond evaluations. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Giebeau, P., B.M. Connors, and W.J. Palen. 2017. Run-of-river hydropower and salmonids: potential effects and perspective on future research. Canadian Journal of Fisheries and Aquatic Sciences 74:1135-1149.

Gillespie, N. and 17 authors. 2014. Flood effects on road–stream crossing infrastructure: economic and ecological benefits of stream simulation designs. Fisheries, 39:(2) 62-76.

Gjedrem, T. 1976. Possibilities for genetic improvements in salmonids. Journal of the Fisheries Research Board of Canada 33:1094-1099.

Goede, R.W. 1986. Management considerations in stocking of diseased or carrier fish. Pages 349-355 in R.H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, Maryland.

Good. S. 2007. Viral hemorrhagic septicemia and baitfish use and movement in Vermont. Vermont Fish and Wildlife Department. Montpelier

Gowan, C. and K.D. Fausch. 1996. Mobile brook trout in two high-elevation streams: re-evaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Sciences 53:1370-1381.

Grizzle, J.M. 1981. Effects of hypolimnetic discharge on fish health below a reservoir. Transactions of the American Fisheries Society 110:29-43.

Groen, C.L. and J.C. Schmulbach. 1978. The sport fishery of the unchannelized and channelized Missouri River. Transactions of the American Fisheries Society 107:412-418.

Habera, J. and S. Moore. 2005. Managing southern Appalachian brook trout: a position paper. Fisheries 30(7):10-17.

Habera, J.W., and R.J. Strange. 1993. Wild trout resources and management in the Southern Appalachian Mountains. Fisheries 18(1):6-13.

Hall, J.D., and N.J. Knight. 1981. Natural variation in abundance of salmonid populations in streams and its implications for design of impact studies, a review. Department of Fisheries and Wildlife, Oregon State University, Corvallis.

Ham, K.D. and T.N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 26(4):15-23.

Hansen, M.M.; Nielsen, E.E.; Bekkevold, D. and Mensberg, K.D. 2001. Admixture analysis and stocking impact assessment in brown trout (Salmo trutta), estimated with incomplete baseline data. Can. J. Fish. Aquat. Sci. 58(9):1853-1860.

Hanson, H.C. 1962. Dictionary of ecology. Philosophical Library Inc., The Catholic University of America, Washington D.C.

Harbicht, A.B., M. Alshamlih, C.C. Wilson and D.J. Fraser. 2014. Anthropogenic and habitat correlates of hybridization between hatchery and wild brook trout. Canadian Journal of Fisheries and Aquatic Sciences. 71:688-697.

Hartzler, J.R. 1988. Catchable trout fisheries: the need for assessment. Fisheries 13(2):2-8.

Hazzard, A.S., and D.S. Shetter. 1939. Results from experimental plantings of legal-sized brook trout (Salvelinus fontinalis) and rainbow trout (Salmo irideus). Transactions of the American Fisheries Society 68:196-210.

Heidinger, R.C. 1999. Stocking for sport fisheries enhancement. Pages 309-333 *in* C.C. Kohler and W.A. Hubert, eds. Inland fisheries management in North America. American Fisheries Society, Bethesda, MD.

Henderson, Richard; Kershner, Jeffrey L., and Toline, C. Anna. Timing and location of spawning by nonnative wild rainbow trout and native cutthroat trout in the South Fork Snake River, Idaho, with implications for hybridization. Fisheries. 2000; 20(3):584-596.

Hensler, M.E. 1987. A field evaluation of four strains of Salmo introduced into seven Montana waters. Master of Science thesis. Montana State University, Bozeman.

High, B. and K.A. Meyer. 2009. Survival and dispersal of hatchery triploid rainbow trout in an Idaho river. North American Journal of Fisheries Management 29:1797-1805.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48:945-957.

Hudy, M. and C.R. Berry, Jr. 1983. Performance of three strains of rainbow trout in a Utah reservoir. North American Journal of Fisheries Management 3:136-141.

Hudy, M., T.M. Thieling, N. Gillespie and E.P. Smith. 2008. Distribution, Status, and Land Use Characteristics of Subwatersheds within the Native Range of Brook Trout in the Eastern United States. North American Journal of Fisheries Management 28:1069–1085.

Humston, R., K.A. Bezold , N.D. Adkins, R.J. Elsey, J. Huss, B.A. Meekins. 2012. Consequences of stocking headwater impoundments on native populations of brook trout in tributaries. North American Journal of Fisheries Management 32:100-108

Hunt, R.L. 1966. Production and angler harvest of wild brook trout in Lawrence Creek, Wisconsin. Wisconsin Conservation Department Technical Bulletin No. 35.

Hunt, R.L. 1970. A compendium of research on angling regulations for brook trout conducted at Lawrence Creek, Wisconsin. Department of Natural Resources Research Report No. 54, Madison.

Hunt, R.L. 1975. Angling regulations in relation to wild trout management. Proceedings of the Wild Trout Management Symposium at Yellowstone National Park, September 25-26, 1974. Trout Unlimited.

Hunt, R.L. 1977. An unsuccessful use of catch-and-release regulations for a wild brook trout fishery. Pages 125-136 in R.A. Barnhart and T.D. Roelofs, editors. Catch and release fishing as a management tool. Humboldt State University, Arcata, California.

Hunt, R.L. 1981. A successful application of catch and release regulations on a Wisconsin trout stream. Wisconsin Department of Natural Resources Technical Bulletin 119, Madison.

Hunt, R.L. 1987. Characteristics of three catch-and-release fisheries and six normal-regulation fisheries for brown trout in Wisconsin. Catch-and-release fishing a decade of experience--a national sport fishing Symposium. Humboldt State University, Arcata, California.

Hunt, R.L. 1991. Evaluation of a catch and release fishery for brown trout regulated by an unprotected slot length. Department of Natural Resources Technical Bulletin No. 173, Madison, Wisconsin.

Hunter, C.J. 1991. Better trout management -- a guide to stream restoration and management. Island Press, Washington, D.C. 320pp.

Hyman, A.A., S.L. McMullin and V. DiCenzo. 2016. Dispelling assumptions about stocked-trout fisheries and angler satisfaction. North American Journal of Fisheries Management, 36:1395-1404.

Hyvärinen P, Vehanen T. Effect of brown trout body size on post-stocking survival and pike predation. Ecology of Freshwater Fish 2004: 13: 77–84.

Isermann, D.A. and C.P. Paukert. 2010. Regulating harvest. Pages 185-212 *in* Inland Fisheries Management in North America (3rd edition). W.A. Hubert and M.C. Quist (ed). American Fisheries Society, Bethesda, MD.

Johnson, D.M., R.J. Behnke, D .A. Harpman, R.G. Walsh. 1995 . Economic benefits and costs of stocking catchable rainbow trout a synthesis of economic analysis in Colorado . North American Journal of Fisheries Management 15:26-32.

Kaczmarek, H. Mazaeva O. A., Kozyreva E.A., Babicheva V. A., Tyszkowski S., Rybchenko A.A., Brykała D., Bartczak, A., Slowiński, M. 2016. Impact of large water level fluctuations on geomorphological processes and their interactions in the shore zone of a dam reservoir. Journal of Great Lakes Research 42: 926-941

Kanno, Y. B.H. Letcher, J.A. Coombs, K.H. Nislow and AR. Whiteley. 2013. Linking movement and reproductive history of brook trout to assess habitat connectivity in a heterogeneous stream network. Freshwater Biology 1-13.

Kanno, Y., M.A. Kulp and S.E. Moore. 2016. Recovery of Native Brook Trout Populations Following the Eradication of Nonnative Rainbow Trout in Southern Appalachian Mountains Streams. North American Journal of Fisheries Management 36:1325–1335.

Kanno, Y, M.A. Kulp, S.E. Moore, and G.D. Grossman. 2017. Native brook trout and invasive rainbow trout respond differently to seasonal weather variation: spawning timing matters. Freshwater Biology 62:868-879.

Kelly, B., K.E. Smokorowski and M. Power. 2017. Downstream effects of hydroelectric dam operation on thermal habitat use by Brook Trout (Salvelinus fontinalis) and Slimy Sculpin (Cottus cognatus) Ecololgy of Freshwater Fish.;26:552–562.

Kelly, W.H. 1965. A stocking formula for heavily fished trout streams. New York Fish and Game Journal 12(2):170-179.

Kirn, R. 1987. Waterbury Reservoir. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report, Montpelier.

Kirn, R. 1993. Brown trout strain evaluation. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report. Montpelier.

Kirn, R. 1995. Winooski River creel survey. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report. Montpelier.

Kirn, R. 1996. Brook trout strain evaluation. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Job Performance Report. Montpelier.

Kirn, R. 1997. A Ten-year evaluation of the effects of ski area development on wild brook trout populations in Vermont streams. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project FW-17, Job Performance Report. Montpelier.

Kirn, R. 1998a. Dog River trout evaluations. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 1998b. The potential use of specialized fishing regulations for improving wild trout stream fisheries in Vermont. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 1999. Evaluation of the use of cultured trout in Vermont. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2000a. The potential use of specialized fishing regulations for improving wild trout stream fisheries in Vermont. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2000b. Dog River trout evaluations - 2000. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2001. Winooski River trout evaluations. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2003. White River trout evaluations - 2001. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2003b. Genetic Considerations for the Management of Wild and Cultured Stocks of Brook, Brown and Rainbow Trout in Vermont. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier

Kirn, R. 2011. An evaluation of the use of triploid trout in Vermont – 2010 – Final Report. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2012. Impacts to stream habitat and wild trout populations in Vermont following tropical storm Irene. Vermont Fish and Wildlife Department. Federal Aid in Fish Restoration, F36-R-14. Montpelier.

Kirn, R. 2016a. Dog River Wild Trout Evaluations 2000-2015. Vermont Fish and Wildlife Department. Federal Aid in Fish Restoration, F-36-R-18. Montpelier.

Kirn, R. 2016b. Effects of the Mollys Falls hydroelectric project operations on stream temperature and wild trout populations within Mollys Brook and the Winooski River. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kirn, R. 2017a. Evaluation of wild brook trout populations in Vermont streams. Vermont Fish and Wildlife Department. Federal Aid in Fish Restoration, Project F-36. Montpelier.

Kirn, R. 2017b. Evaluation of Fisheries and Water Quality Impacts Associated with the Wrightsville Reservoir Hydroelectric Project Operations. Vermont Fish and Wildlife Department. Federal Aid in Fish Restoration, Project FW-17. Montpelier.

Kirn, R. and J. McMenemy.1988. Literature Review of Salmonid Movements in Streams. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12. Montpelier.

Kocovsky, P.M. and R.F. Carline. 2005. Stream pH as an abiotic gradient influencing distributions of trout in Pennsylvania streams. Transactions of the American Fisheries Society. 134:1299-1312.

Kozfkay, J.R., J.C. Dillon and D.J. Schill. 2006. Routine use of sterile fish in salmonid sport fisheries: Are we there yet? Fisheries. 31(8):392-401.

Kratzer, J. 2013. Passumpsic River creel survey. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kratzer, J. 2014. Woody habitat additions to the East Branch Nulhegan River. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kratzer, J. 2016a. Angler effort survey on Northeast Kingdom rivers (aka NEK500). Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kratzer, J. 2016b. Strategic Wood Additions in the Nulhegan River Watershed. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kratzer, J. 2016c. Angler effort on small trout ponds in District V. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Kratzer, J. and D.R. Warren. 2013. Factors limiting brook trout biomass in northeastern Vermont streams. North American Journal of Fisheries Management 33:130–139.

Krimmer, A.N., A.J. Paul, A. Hontela, and J.B. Rasmussen. 2011. Behavioural and physiological responses of brook trout Salvelinus fontinalis to midwinter flow reduction in a small ice-free mountain stream. Journal of Fish Biology 79:707-725.

Krueger, C.C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48(Supp. 1):66-77.

Krueger, C.C., and B.W. Menzel. 1979. Effects of stocking on genetics of wild brook trout populations. Transactions of the American Fisheries Society 108:277-287

Kulp, M.A. and S.E. Moore. 2005. A case history in fishing regulations in Great Smoky Mountains National Park: 1934-2004. North American Journal of Fisheries Management, 25:510-524.

Lachane, S., and P. Magnan. 1990. Performance of domestic, hybrid, and wild strains of brook trout, Salvelinus fontinalis, after stocking: the impact of intra- and interspecific competition. Canadian Journal of Fisheries and Aquatic Sciences 47(12):2278-2284.

Lackey, R.T., and L.A. Nielsen, editors. 1980. Fisheries management. Blackwell Scientific Publications, Boston, Massachusetts.

Ladago, B. 2014. Peacham Pond Winter Creel Surveys 1991-2014. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36-R-16, Job Performance Report. Montpelier.

Ladago, B. 2015. Winooski River quality trout reach creel survey. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Ladago, B. 2016. Winooski River trout evaluations. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Larson, G.L., and S.E. Moore. 1985. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian Mountains. Transactions of the American Fisheries Society 114:195-203.

Lau, J.K, T.E. Lauer and M.L. Weinman. 2006. Impacts of channelization on stream habitats and associated fish assemblages in east central Indiana. The American Midland Naturalist 156:319-330.

Leary, R.F.; Gould, W.R., and Sage, G.K. 1996. Success of basibranchial teeth in indicating pure populations of rainbow trout and failure to indicate pure populations of westslope cutthroat trout. North American Journal of Fisheries Management. 16(1):210-213.

Lennon, R.E., R.A. Schnick, and R.M. Burress. 1970. Reclamation of ponds, lakes, and streams with fish toxicants: a review. FAO Fisheries Technical Paper 100, FIRI/T100, United States Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Lessard, J.L. and D.B. Hayes. 2003. Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. River Research and Applications 19(7):721-732.

Letcher, B.H., Nislow, K.H., Coombs, J.A., O'Donnell, M.J., and Dubreuil, T.L. 2007. Population response to habitat fragmentation in a stream-dwelling brook trout population. PLoS ONE, 2(11): e1139. doi:10.1371/journal.pone. 0001139. PMID:18188404.

Levine, J. 2013. An economic analysis of improved road-stream crossings. 2013. The Nature Conservancy. Adirondack Chapter.

Loomis, J.B. and P. Fix. 1997. An econometric approach to estimating the short run and long run costs of propagating hatchery trout in Colorado. Department of Agricultural and Resource Economics, Colorado State University, Fort Collins.

Losee, J.P. and L. Phillips. 2017. Bigger is better: optimizing trout stocking in western Washington lakes. North American Journal of Fisheries Management 37:489–496.

Louhi, P., T. Vehanen, A. Huusko, A.Mäki-Petäys and T. Muotka. Long-term monitoring reveals the success of salmonid habitat restoration. Canadian Journal of Fisheries and Aquatic Sciences 73: 1733–1741.

Lytle, D.A., and N.L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution. 19:94-100.

Macdonald, J. S., Morrison, J., & Patterson, D. A. (2012). The efficacy of reservoir flow regulation for cooling migration temperature for sockeye salmon in the Nechako River watershed of British Columbia. North American Journal of Fisheries Management, 32, 415–427.

MacKenzie, C. 1990. Evaluation of a "no-kill, artificial lures only" regulation implemented on the New Haven River, Addison County. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-12, Final Report, Montpelier.

MacKenzie, C. 2017. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

MacMartin, J.M. 1962. Statewide stream survey by watersheds. Vermont Fish and Game Department, Federal Aid to Fisheries Project F-2-R, Final Report, Montpelier.

MAF&G (Massachusetts Department of Fish and Game Division of Ecological Restoration). 2015. Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts. Westboro, MA.

Marsden, J.E., Chipman, B.D., Nashett, L.J., Anderson, J.K., Bouffard, W., Durfey, L.E., Gersmehl, J.E., Schoch, W.F., Staats, N.R., Zerrenner, A., 2003. Sea lamprey control in Lake Champlain. Journal of Great Lakes Research. 29 (Supplement 1), 655–676.

Marsh, G.P. 1857. Report, made under authority of the legislature of Vermont, on the artificial propagation of fish. Free Press Print, Burlington, Vermont.

Matkowski, S. M. D. 1989. Differential susceptibility of three species of stocked trout to bird predation. North American Journal of Fisheries Management 9:184-187.

Maxted, J.R., C.H. McReady and M.R. Scarsbrook. 2005. Effects of small ponds on stream water quality and macroinvertebrate communities. New Zealand Journal of Marine and Freshwater Research. Vol. 39: 1069–1084.

McAfee, W.R. 1966. Rainbow trout in A. Calhoun, editor. Inland Fisheries Management, California Fish and Game Department.

McCracken, G.F.; Parker, C.R., and Guffey, S. Z. 1993. Genetic differentiation and hybridization between stocked hatchery and native brook trout in Great Smoky Mountains National Park. Transactions of the American Fisheries Society. 122(4):533-542.

McFadden, J.T. 1961. A population study of the brook trout, Salvelinus fontinalis. Wildlife Monograph No. 7.

McKenna Jr., J.E., M.T. Slattery and K.M. Clifford. 2013. Broad-Scale Patterns of Brook Trout Responses to Introduced Brown Trout in New York. North American Journal of Fisheries Management 33:1221–1235.

McMahon, T. E. and D. H. Bennett. 1996. Walleye and northern pike: boost or bane to northwest fisheries? Fisheries 21(8):6–13.

MDNR (Michigan Department of Natural Resources). 2015. Criteria for selection of trout streams with gear restriction regulations. MDNR, Fisheries Order 213.15, Lansing. Available: http://www. michigan.gov/documents/dnr/FO-213.15_Trout_Streams_with_Gear_Restriction_ Regulations_503045_7.pdf (October 2015).

Meka, J.M. 2004. The Influence of Hook Type, Angler Experience, and Fish Size on Injury Rates and the Duration of Capture in an Alaskan Catch-and-Release Rainbow Trout Fishery. North American Journal of Fisheries Management, 24:4.

Merrell, K. E.A. Howe, and S. Warren. 2009. Examining shorelines, littorally. LakeLine 29(1):10-15. http://www.anr.state.vt.us/dec/waterq/lakes/docs/lp_Exam-Shorelines-Littorally-Spring-2009.pdf

Meyer, K.A., B. High and F.S. Elle. 2017. Effects of stocking catchable-sized hatchery rainbow trout on wild rainbow trout abundance, survival, growth, and recruitment. Transactions of the American Fisheries Society 141:224–237, 2012

Miller, A. and R. Kirn. 2017. Standard Operating Practices for Stocking Cultured Trout and Salmon. Vermont Fish and Wildlife Department. Montpelier.

Modde, T., A.F. Wasowicz and D.K. Hepworth. 1996. Cormorant and grebe predation on rainbow trout stocked in a southern Utah reservoir. North American Journal of Fisheries Management 16:388-394.

Moffitt, C., A.H. Haukenes and C.J. Williams. 2004. Evaluating and understanding fish health risks and their consequences in propagated and free-ranging fish populations. American Fisheries Society Symposium 44:529-537.

Mongillo, P.E. 1984. A summary of salmonid hooking mortality. Washington Department of Game, Fish Management Division.

Moore H.E. and I.D. Rutherfurd. 2017. Lack of maintenance is a major challenge for stream restoration projects. River Res Applic. 1–13. https://doi.org/10.1002/rra.3188

Moring, J.R. 1982. An efficient hatchery strain of rainbow trout for stocking Oregon streams. North American Journal of Fisheries Management 2:209-215.

Needham, P.R. 1959. New horizons in stocking hatchery trout. Page 395-407. In Proceedings of the twenty-fourth North American wildlife conference.

Negus, M. 1995. Bioenergetics modeling as a salmonine management tool applied to Minnesota waters of Lake Superior. North American Journal of Fisheries Management 15:60-78.

Nehring, R.B. 1987. Stream fisheries investigations. Colorado Division of Wildlife, Federal Aid in Fish and Wildlife Restoration, Project F-51-R, Job Final Report, Fort Collins.

Nehring R.B., Walker PG. 1996. Whirling disease in the wild: the new reality for the Intermountain West. Fisheries. 21(6):28–30.

Nelson, W.C. 1987. Survival and growth of fingerling trout planted in high lakes of Colorado. Colorado Division of Wildlife Technical Publication No. 36, Fort Collins.

Noble, R.L. and T.W. Jones. 1999. Managing fisheries with regulations. Pages 455-477 *in* C.C. Kohler and W.A. Hubert (ed) Inland Fisheries Management in North America (2nd edition). American Fisheries Society, Bethesda, MD.

Novak, R., J.G. Kennen, R.W. Abele, C.F. Baschon, D.M. Carlisle, L. Dlugolecki, D.M. Eignor, J.E. Flotemersch, P.Ford, J. Fowler, R. Galer, L.P. Gordon, S.E. Hansen, B. Herbold, T. E. Johnson, J.M. Johnston, C.P. Konrad, B. Leamond, and P.W. Seelbach. 2016. Final EPA-USGS Technical Report: Protecting Aquatic Life from Effects of Hydrologic Alteration. EPA Report 822–R–16–007 USGS Scientific Investigations Report 2016–5164, 156 p. http://www.epa.gov/wqc/aquatic-life-ambient-water-quality-criteria

Nuhfer, A.J, T.G. Zorn, and T.C. Willis. 2017. Effects of reduced summer flows on the brook trout population and temperatures of a groundwater-influenced stream. Ecology of Freshwater Fish. 26:108-119.

Odum, E.P. 1953. Fundamentals of ecology. Press of W.B. Saunders Company, Philadelphia.

O'Shaughnessy, E., M. Landi, S.R. Januchowski-Hartley and M. Diebel (2016) Conservation leverage: ecological design culverts also return fiscal benefits, Fisheries, 41:12, 750-757.

Paul, A.J., J.R. Post and J.D. Stelfox. 2003. Can anglers influence the abundance of nonnative brook trout in a stream from the Canadian Rocky Mountains? North American Journal of Fisheries Management 23:109–119.

Pearsons, T.N. 2008. Misconception, reality and uncertainty about ecological interactions and risks between hatchery and wild salmonids. Fisheries 33:278-290.

Pegg, M.A. and J.H. Chick. 2010. Habitat improvement in altered systems. Pages 295-324 *in* Inland Fisheries Management in North America (3rd edition). W.A. Hubert and M.C. Quist (ed). American Fisheries Society, Bethesda, MD.

Pelletier, C., Hanson, K.C., and Cooke, S.J. 2007. Do catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices. Environ Manage 39 760-733

Perry, F.J. 1964. Progress report of the Vermont Fish & Game Dept.: from colonization and depredation to conservation and education. Montpelier.

Peterson, D.P. and K.D. Fausch. 2003. Upstream movement by nonnative brook trout (Salvelinus fontinalis) promotes invasion of native cutthroat trout (Oncorhynchus clarki) habitat. Canadian Journal of Fisheries and Aquatic Sciences 60: 1502-1516.

Peterson, R.H., P.G. Daye, G.L. Lacroix and E.T. Garside. 1982. Reproduction in fish experiencing acid and metal stress. Pages 177-196 *in* Acid Rain and Fisheries. Northeastern Division of the American Fisheries Society. Bethesda, MD.

Petrosky, C.E., and T.C. Bjornn. 1988. Response of wild rainbow (Salmo gairdneri) and cutthroat trout (S. clarki) to stocked rainbow trout in fertile and infertile streams. Canadian Journal of Fisheries and Aquatic Sciences 45:2087-2105.

Philipp, David P.; Epifanio, John M., and Jennings, Martin J. Point/Counterpoint: Conservation genetics and current stocking practices - are they compatible? Fisheries. 1993; 18(12):14-16.

Platts, W.S., and R.L. Nelson. 1988. Fluctuations in trout populations and their implications for land-use evaluation. North American Journal of Fisheries Management 8:333-345.

Ploskey, G.R., 1986. Effects of water-level changes on reservoir ecosystems, with implications for fisheries management. Pages 86-97 in G.E.Hall and M.J. Van Den Avyle, editors Reservoir Fisheries Management, Strategies for the 80's. American Fisheries Society, Bethesda.

Poole, G.C. and C. H. Berman, 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. Environmental Management 27(6):787-802.

Radomski, P.J., G.C. Grant, P.C. Jacobson, and M.E Cook. 2001. Visions for recreational fishing regulations. Fisheries 26(5):7-18.

Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Fish and Wildlife Service FWS/OBS-82/10.24.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish and Wildlife Service Biological Report 82 (10.124).

Raleigh, R.F., T. Hickman, R.D. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow trout. U.S. Fish and Wildlife Service FWS/OBS-82/10.60.

Reinitz, G.L. Electrophoretic distinction of rainbow trout (Salmo gairdneri), west-slope cutthroat trout (S. clarki) and their hybrids. J. Fish. Res. Board Can. 1977; 34(8):1236-1239.

Richardson, F., and R.H. Hamre, editors. 1984. Proceedings of the wild trout III symposium at Yellowstone National Park, September 24-25, 1984.

Roni, P., Hanson, K., and Beechie, T. 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28: 856–890.

Ross, R.M. and J.H. Johnson. 1999. Effect of Altered Salmonid Stocking Methods on Cormorant Predation in Eastern Lake Ontario. New York State Department of Environmental Conservation Special Report. Albany.

Ryder, R.A., S.R. Kerr, K.H. Loftus, and H.A. Regier. 1974. The morphoedaphic index, a fish yield estimator--review and evaluation. Journal of the Fisheries Research Board of Canada 31:663-688.

Sass, G.G., A.L. Rypel and J.D. Stafford. 2017. Inland fisheries habitat management: lessons learned from wildlife ecology and a proposal for change. Fisheries 42: 197-205.

Sánchez-Hernández, J., S.L. Law, F. Cobo and M.S. Allen. 2016. Influence of a Minimum-Length Limit Regulation on Wild Brown Trout: an Example of Recruitment and Growth Overfishing. North American Journal of Fisheries Management 36:1024–1035.

Scarola, J.F. 1987. Freshwater fishes of New Hampshire. New Hampshire Fish and Game Department.

Schiff, R., E. Fitzgerald, J. MacBroom, M. Kline, and S. Jaquith, 2014. Vermont Standard River Management Principles and Practices (Vermont SRMPP): Guidance for Managing Vermont's Rivers Based on Channel and Floodplain Function. Prepared by Milone & MacBroom, Inc. and Fitzgerald Environmental Associates, LLC for and in collaboration with Vermont Rivers Program, Montpelier, Vermont.

Schill, D.J. 1996. Hooking mortality of bait-caught rainbow trout in an Idaho stream and a hatchery: implications for special-regulation management. North American Journal of Fisheries Management. 16:348-356.

Schill, D.J. and R.L. Scarpella. 1997. Barbed hook restrictions in catch and release trout fisheries: a social issue. North American Journal of Fisheries Management,17: 873-881.

Shetter, D.S. 1950. Results from plantings of marked fingerling brook trout (Salvelinus f. fontinalis Mitchill) in Hunt Creek, Montmorency County, Michigan. Transactions of the American Fisheries Society 79:77-93.

Simenstad, C. and D.L. Bottom. 2010. Guiding ecological principles for habitat improvement. Pages 318-320 *in* Inland Fisheries Management in North America (3rd edition). W.A. Hubert and M.C. Quist (ed). American Fisheries Society, Bethesda, MD.

Skaala, Oystein; Jorstad, Knut E., and Borgstrom, Reidar. Genetic impact on two wild brown trout (Salmo trutta) populations after release of non-indigenous hatchery spawners. Can. J. Fish. Aquat. Sci. 1996; 53(9):2027-2035.

Smith, R.H. 1991. Rainbow trout. Pages 304-323 in J. Stolz and J. Schnell, editors. The wildlife series: Trout. Stackpole Books. Harrisburg, Pennsylvania.

Staley, J. 1966. Brown trout. Pages 233-241 in A. Calhoun, editor. Inland Fisheries Management. California Fish and Game Department.

Stewart, J.D. 1966. A Test Program: Ice fishing for salmon, trout and bass. Vermont Fish and Wildlife Department. Montpelier.

Stewart, J.E. 1991. Introductions as factors in diseases of fish and aquatic invertebrates. Canadian Journal of Fisheries and Aquatic Sciences 48 (Suppl. 1):110-117.

Stone, M.D. 1995. Fish stocking programs in Wyoming: a balanced approach. American Fisheries Society Symposium 15:47-51.

Stuber, R.J., C. Sealing, and E.P. Bergersen. 1985. Rainbow trout returns from fingerling plantings in Dillon Reservoir, Colorado, 1975-1979. North American Journal of Fisheries Management 5:471-474.

Surber, E.W. 1940. Lost: 10,839 fingerling trout! an appraisal of the results of planting fingerling trout in St. Mary River, Virginia. The Progressive Fish-Culturist Memorandum I-131 No.49.

Sweeney, Bernard W. and J. Denis Newbold, 2014. Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. Journal of the American Water Resources Association. (JAWRA) 50(3): 560-584. DOI: 10.1111/jawr.12203US

Taylor, M.T. and K.R. White. 1992. A meta-analysis of hooking mortality of nonanadromous trout. North American Journal of Fisheries Management 12:760-767.

Teuscher, D.M. D.J. Schill , D.J. Megargle and J.C. Dillon. 2003. Relative Survival and Growth of Triploid and Diploid Rainbow Trout in Two Idaho Reservoirs, North American Journal of Fisheries Management, 23:983-988

Thibault, I. and J. Dodson 2013.Impacts of Exotic Rainbow Trout on Habitat Use by Native Juvenile Salmonid Species at an Early Invasive Stage. Transactions of the American Fisheries Society 142:1141–1150.

Tyrus, H.M. and B.D. Winter. 1992. Hydropower Development. Fisheries 17:30-32.

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2014. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

Varley, J.U. 1975. The Yellowstone fishery in Proceedings of the wild trout management symposium at Yellowstone National Park. Trout Unlimited, Inc.

VDEC (Vermont Department of Environmental Conservation). 2011. Introduction to river channel evolution. Montpelier, VT. http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_introduction_to_channel_evolution.pdf

VDEC (Vermont Department of Environmental Conservation). 2017. River gravel excavation: historical perspective and current practices. Vermont Agency of Natural Resources. June16, 2017. http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_gravel_perspective_practices.pdf

Verry, E.S., J.W. Hornbeck, and C.A. Dolloff (eds). 2000. Riparian management in forests of the continental Eastern United States. Lewis Publishers, Boca Raton, FL. 402p.

VFGD (Vermont Fish and Game Department) 1973. Vermont's first fisheries annual. Bulletin 73-1. Montpelier.

VFWD (Vermont Fish and Wildlife Department). 2010. Vermont stream crossing handbook. Montpelier.

VFWD (Vermont Fish and Wildlife Department). 2015. Vermont's Wildlife Action Plan. Montpelier.

VFWD (Vermont Fish and Wildlife Department). 2016. Vermont stream crossing handbook. http://www.vtfishandwildlife.com/common/pages/DisplayFile.aspx?itemId=111508

Vincent, E.R. 1987. Effects of stocking catchable-size hatchery rainbow trout on two wild trout species in the Madison River and O'Dell Creek, Montana. North American Journal of Fisheries Management 7:91-105.

Vincent E.R. 1996. Whirling disease and wild trout: the Montana experience. Fisheries. 21(6):32–33.

VTANR (Vermont Agency of Natural Resources) 2005. Riparian buffers and corridors technical papers. Vermont Agency of Natural Resources. Montpelier, VT.

VTANR (Vermont Agency of Natural Resources) 2015. Riparian management guidelines for Agency of Natural Resources lands. Vermont Agency of Natural Resources. Montpelier, VT.

VTANR (Vermont Agency of Natural Resources). 2016. 2016 Water quality integrated assessment report, Clean Water Act Section 305(b) report. Department of Environmental Conservation, Montpelier.

Wagner, T., J.T. Deweber, J. Detar, and. J.A. Sweka. 2013. Landscape-scale evaluation of asymmetric interactions between Brown Trout and Brook Trout using two-species occupancy models. Transactions of the American Fisheries Society. 142:353-361.

Waples, Robin S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Can. J. Fish. Aquat. Sci. 48(Suppl. 1)(1):124-133.

Waters, T., 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society: Bethesda, MD, 251 pp.

Waters, T.F. 1983. Replacement of brook trout by brown trout over 15 years in a Minnesota stream: production and abundance. Transactions of the American Fisheries Society 112:137-146.

Walters, J.P., T.D. Fresques and S.D. Bryan. 1997. Comparison of creel returns from rainbow trout stocked at two sizes. North American Journal of Fisheries Management, 17:474-476.

Webster, D.A. and G. Eriksdottir. 1976. Upwelling water as a factor influencing choice of spawning sites by brook trout (Salvelinus fontinalis). Transactions of the American Fisheries Society 105:416- 421.

Wenger S.J., D.J. Isaak, C.H. Luceb, H.M. Neville, K.D. Fausch, J.B. Dunham, D.C. Dauwalter, M. K. Young, M.M. Elsner, B.E. Rieman, A.F. Hamlet and J.E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. PNAS www.pnas.org/cgi/doi/10.1073/pnas.1103097108

Wells, J. 1987. Catch-and-release fishing, the Montana experience in Catch-and-release fishing a decade of experience--a national sport fishing symposium. Humboldt State University, Arcata, California.

Whal, D.H., R.A. Stein and D.R. DeVries. 1995. An ecological framework for evaluating success and effects of stocked fishes. American Fisheries Society Symposium 15:176-189.

White, R.J., J.R. Karr and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. American Fisheries Society Symposium 15:527-547.

Whiteley, A.R., Coombs, J.A., Hudy, M., Robinson, Z., Colton, A.R., Nislow, K.H. and B.H. Letcher. 2013. Fragmentation and patch size shape genetic structure of brook trout populations. Can. J. Fish. Aquat. Sci. 70(5): 678–688. doi:10. 1139/cjfas-2012-0493.

Wildi W. 2010. Environmental Hazards of Dams and Reservoirs. Natural Environmental Science. 88:187-197

Wiley, R.W., R.A. Whaley, J.B. Satake, and M. Fowden. 1993. Assessment of stocking hatchery trout: a Wyoming perspective. North American Journal of Fisheries Management 13:160-170.

Wiley, R.W. 1995. A common sense protocol for the use of hatchery-reared trout. American Fisheries Society Symposium 15:465-471.

Will, L. 2014. Black River quality trout management reach creel survey analysis. Vermont Fish and Wildlife Department, Federal Aid in Fish Restoration, Project F-36, Job Performance Report. Montpelier.

Williams, R. N.; Shiozawa, D. K.; Carter, J. E., and Leary, R. F. 1996. Genetic detection of putative hybridization between native and introduced rainbow trout populations of the upper Snake River. Transactions of the American Fisheries Society. 125(3):387-401.

Williams, R.N., R.F. Leary and K.P. Currens. 1997. Localized genetic effects of a long-term hatchery stocking program on resident rainbow trout in the Metolius River, Oregon. North American Journal of Fisheries Management 17:1079-1093

Witzel, L.D., and H.R. MacCrimmon. 1983. Redd-site selection by brook trout and brown trout in southwestern Ontario streams. Transactions of the American Fisheries Society 112:760-771.

Wright, S. 1992. Guidelines for selecting regulations to manage open-access fisheries for natural populations of anadromous and resident trout in stream habitats. North American Journal of Fisheries Management 12:517-527.

Wydoski, R.S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management *in* a national symposium on catch and release fishing. Humbolt State University, Arcata, California.

Young, P.S., J.J. Cech, and L.C. Thompson. 2011. Hydropower-related pulsed-flow impacts on stream fishes: a brief review, conceptual model, knowledge gaps, and research needs. Reviews in Fish Biology and Fisheries. 21:713–731.

Yule, D.L., R.A. Whaley, P.H. Mavrakis, D.D. Miller and S.A. Flickinger. 2000. Use of strain, season of stocking, and size at stocking to improve fisheries for rainbow trout in reservoirs with walleyes.