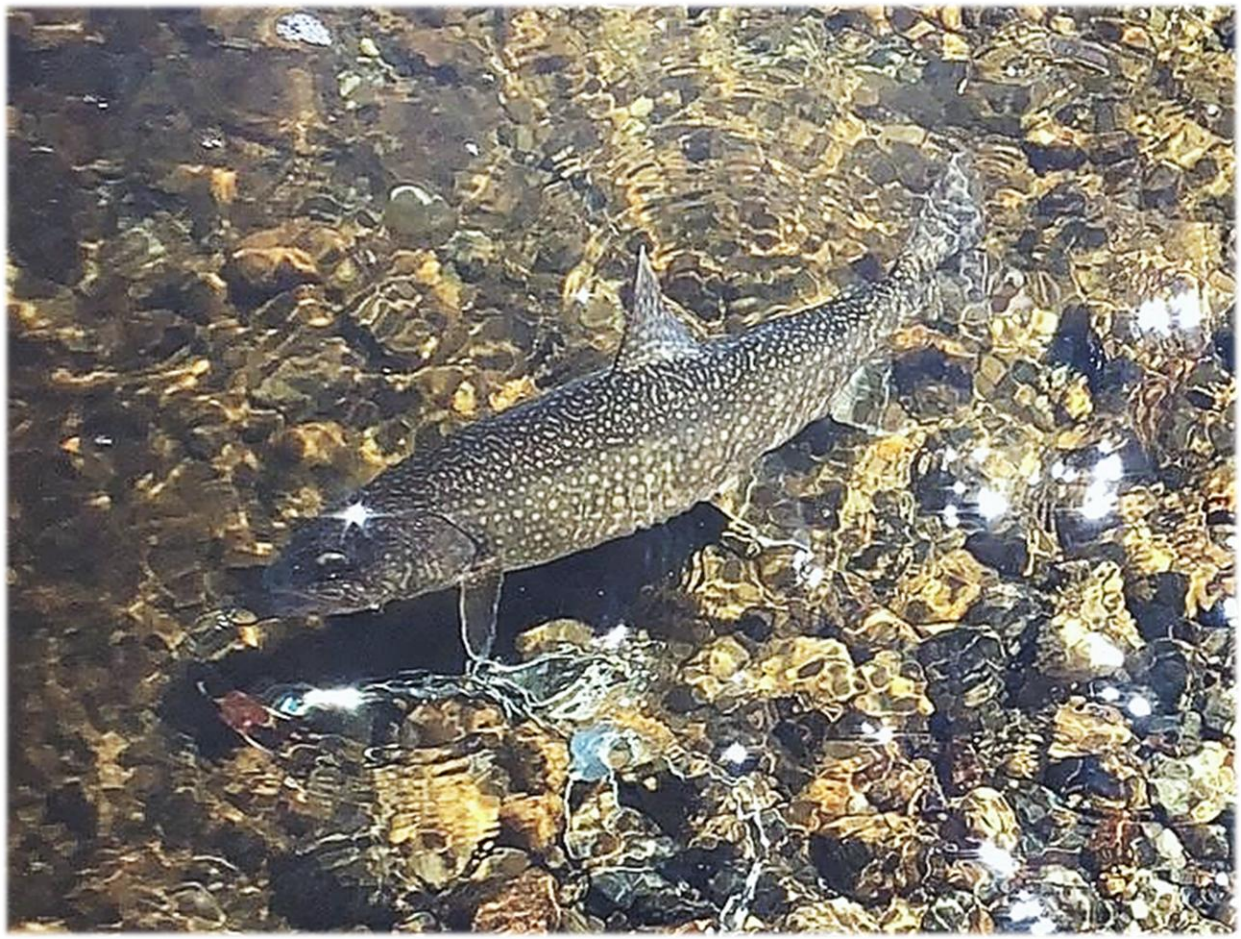
Wachusett Reservoir Creel Survey Report Survey Year 2022



November 2025

Massachusetts Department of Conservation and Recreation
Division of Water Supply Protection
Office of Watershed Management
Wachusett Reservoir Region

Abstract

A roving creel survey of shore anglers was conducted during the 2022 fishing season (April-November) on central Massachusetts' Wachusett Reservoir, a Class A surface water supply serving 2.7 million people. Anglers were counted and interviewed to collect trip specifics and information about fish landed and harvested. A total of 2,007 anglers were surveyed in 2022 on 101 of the possible 244 days in the legal fishing season. Surveys from 2011, 2012, 2017, and 2022 indicate that the Reservoir is used as a recreational angling resource by several thousand anglers annually, with 98% of anglers being Massachusetts residents. Catch per unit effort for all Reservoir fish species was calculated as 0.15 fish per one hour of angling time in 2022, which is the same as 2017, but lower than catch rates documented in 2011 (0.24) and 2012 (0.20). Estimated totals for the complete 2022 angling season include 6,111 fish caught from a total of 12,608 angling trips. Comparison of the current creel survey results to three other creel surveys conducted since 1979 show that the species most frequently caught by anglers have changed, which may reflect changes in the Reservoir's fish community composition over this period. Lake trout and smallmouth bass were the species most frequently caught by anglers and lake trout accounted for 37% of the total harvest across all species. The harvest rate across all species was 22%, while 23% of lake trout and 53% of rainbow trout were harvested. The lake trout estimated yield of 0.17 pounds per acre observed during the 2022 season was lower than the estimated yield in all previous surveys. Fish are an important component of the Reservoir ecosystem and knowledge of fish population dynamics in the Reservoir is important to understanding the Wachusett Reservoir food web and its impacts upon drinking water quality.

Acknowledgements:

This report was prepared by the MA Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management. The principal author is Max Nyquist, Aquatic Biologist. Internal review was provided by Joy Trahan-Liptak, Dan Crocker and Jamie Carr. External review was provided by Jason Stolarski of the MA Division of Fisheries and Wildlife (MassWildlife). Cover based on a photo submitted by a creel agent.

Many thanks are owed to the personnel who made this study possible by performing angler counts and field surveys of anglers, including DWSP Watershed Rangers, MassWildlife staff and DWSP Aquatic Biologists. Also, the collective 99.4% cooperation rate of the anglers is what makes the survey possible.

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Fish Species Documented in Wachusett Reservoir

Common Name	Scientific Name
Banded killifish	*Fundulus diaphanus*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Brown trout	*Salmo trutta*
Chain pickerel	*Esox niger*
Lake trout	*Salvelinus namaycush*
Landlocked salmon	*Salmo salar*
Largemouth bass	*Micropterus salmoides*
Pumpkinseed	*Lepomis gibbosus*
Rainbow smelt	*Osmerus mordax*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Tessellated darter	*Etheostoma olmstedi*
White sucker	*Catostomas commersoni*
White perch	*Morone americana*
Yellow bullhead	*Ameiurus natalis*
Yellow perch	*Perca flavescens*

1. Introduction

The Massachusetts Department of Conservation and Recreation (DCR), Division of Water Supply Protection (DWSP), Office of Watershed Management was established by Chapter 372 of the Acts of 1984. This division of DCR was created to manage and maintain a system of watersheds and reservoirs to provide water to the Massachusetts Water Resources Authority (MWRA), which in turn supplies drinking water to 2.7 million users in metropolitan Boston and central Massachusetts. Water quality sampling and watershed monitoring are an important part of the overall mission of the DWSP Environmental Quality (EQ) Section staff at Wachusett and Quabbin Reservoirs.

The Wachusett Reservoir (Wachusett) is a 4,147-surface acre, 65-billion-gallon man-made drinking water supply reservoir located in central Massachusetts. It was completed in 1906 and is the second largest water body in the state. It is an oligotrophic reservoir with a watershed of 74,800 acres, a mean depth of 48 feet, and a maximum depth of 122 feet. In addition to the watershed, Wachusett Reservoir receives water from the largest body of water in the state, Quabbin Reservoir, via a 25-mile-long aqueduct.

Fish are an important component of the Reservoir ecosystem, and the health of fish populations can have a profound impact on the water quality of the Reservoir. For example, predatory game fish in the Reservoir, including but not limited to lake trout and smallmouth bass, may have important effects on nutrient cycling, interspecific competition, zooplankton, and phytoplankton, which directly impact water quality (Holmlund 1999, Vander Zanden 2002, Vanni 2002). To further understand the relationship between the fish community, the Reservoir food web, and water quality, the DWSP collects information about fish populations in the Reservoir through mark and recapture studies and creel surveys. This report will present and discuss the results of the Wachusett Reservoir Creel Survey. A creel survey is a systematic survey of anglers that is used to estimate the number, type, and size of fish caught by anglers in a specific water body over a specific time period, as well as estimate the level of fishing pressure imposed on a waterbody. In this context, a creel survey of Wachusett Reservoir can serve as a tool to directly assess the following fishery attributes: fishing pressure, catch rate, and harvest.

The Reservoir has historically supported an active recreational fishery, which has produced state record catches of the following species in the catch and keep category: brown trout (1966), smallmouth bass (1991), landlocked salmon (1985), rainbow trout (1999), and white perch (2016) (MassWildlife 2025a). Additionally, it has produced records in the catch and release category: lake trout (2024), landlocked salmon (2024), and white perch (2022). Wachusett also claims a world record catch; the state record 3-pound 8-ounce white perch caught by Val Percuoco on October 16, 2016, certified as the all tackle world record catch for that species (IGFA 2018).

Apart from rainbow trout, all species currently inhabiting the Reservoir are considered naturally reproducing and self-sustaining populations. Rainbow trout have been stocked in Wachusett Reservoir since at least the early 1990s. From 2000 through the present an

average of 2,200 rainbow trout are stocked annually each spring by Massachusetts Department of Fish and Game (DFG), Division of Fish and Wildlife (MassWildlife) staff (Mark Brideau, personal communication). Most recently, 1,800 rainbow trout were stocked in the Spring of 2022 and 1,800 in Spring of 2024 (Caleb Slater 2024, personal communication). In 1999, approximately 2,400 surplus landlocked salmon young-of-year were stocked in the Quinapoxet River, due to natural reproduction problems (MassWildlife 1996, 1997, 2000, 2001). Approximately 2,500 twelve-inch landlocked salmon were stocked by MassWildlife in the fall of 2014 and again in 2015. This was due to excess in the hatchery supply of these fish and none have been stocked since 2015.

The fishing season on Wachusett Reservoir begins on the first Saturday in April (ice conditions permitting) and historically continued until the last day of November. New regulations implemented in 2023, extended the fishing season until December 31. Public boating is not allowed on the Reservoir. Shore fishing is allowed for 29.7 of the 37 miles of Reservoir shoreline; public access is prohibited in the intake zone (Figure 2). Fishing is permitted one hour before sunrise to one hour after sunset and two active lines are permitted per angler.
Angler creel surveys at Wachusett Reservoir were conducted by MassWildlife staff in 1979, 1980, and 1998. No fisheries data was collected in Wachusett Reservoir between 1999 and 2010. Creel surveys led by DWSP staff were conducted in 2011, 2012, 2017, and 2022. To gather more fisheries data, the DWSP and MassWildlife initiated a lake trout tagging study at Wachusett Reservoir in the fall of 2014, which has continued through the present.

The goal of this creel survey was to document angler catch and effort at Wachusett Reservoir during the 2022 fishing season, compare the results to past surveys, and establish a baseline for future comparison. A comprehensive report summarizing the 2011 and 2012 creel seasons is available on the MA DCR website (DCR 2015). That report provides additional historical background, as well as in-depth descriptions of the survey methods, analysis, and equations used to calculate estimated totals.

1.1. Link Between Fish and Water Quality

It is well established that the biological community in a lake or reservoir can impact water chemistry and water quality (Vanni et al. 1997, Vanni 2002, Estes 2011). The fish community in particular – including piscivores, planktivores, and detritivores like bullhead catfish – can have an impact on the rest of the aquatic ecosystem and abiotic factors in a lake or reservoir system (Vander Zanden 2002) (Figure 1). There is evidence to suggest that apex predators in a food web can exhibit “top-down effects," whereby the consumption of lower-level consumers will cascade through lower trophic levels of taxa they do not directly consume, including first level consumers and primary producers (McQueen 1989, Vanni and Layne 1997, Carpenter 2001). There is also evidence for a bottom-up model that describes nutrient recycling via fish excretion as an important source of nutrients that may impact phytoplankton community composition and biomass (McQueen 1989, Vander Zanden 2002). In the case of a reservoir biological community,

the primary consumers often include planktivorous fish and zooplankton, and the primary producers are various forms of phytoplankton. Fish directly consuming or otherwise controlling populations of zooplankton and phytoplankton can ultimately have a direct impact on water clarity. As an example, when predatory walleye and northern pike were stocked in Wisconsin's Lake Mendota a study revealed a shift to large-bodied zooplankton, a decrease in phytoplankton density, and a resultant improvement in water transparency (Lathrop 2002). Changes in the fish community, whether from angling pressure, climate change, or other factors, have the potential to impact water quality. For this reason, it is important to understand the fish community in the Reservoir, including trends in fish populations and potential threats to Reservoir ecology.

It is also important to understand that while the fish community can affect water quality, water quality may also simultaneously impact fish populations, particularly fish with specific habitat requirements. Lake trout require cold water with high dissolved oxygen; increases in water temperature attributed to climate change are shown to negatively impact lake trout by reducing the volume of available cold-water habitat (Dillon 2003, Plumb 2006). Additionally, the negative effects on cold water species associated with higher water temperature may be exacerbated by introductions or increases in populations of fish species that can tolerate warm water and compete with or consume lake trout, such as smallmouth bass (Jackson 2007). This is one of many relationships between water quality and fish populations described in the literature that DWSP is interested in investigating. The Creel Survey is meant to serve as a monitoring program for fish population changes that may reveal themselves through angler catch. The results of this survey can be combined with the results of the DWSP water quality monitoring program, to investigate whether observed changes in water quality may be negatively impacting certain fish species or vice versa. Due to its popularity as a sport fish, much of the focus of this report and of water quality investigations will be on lake trout. The DWSP is interested in protecting this unique Massachusetts fishery because of the recreational and water quality services it provides.

Figure 1: Wachusett Reservoir simplified food web

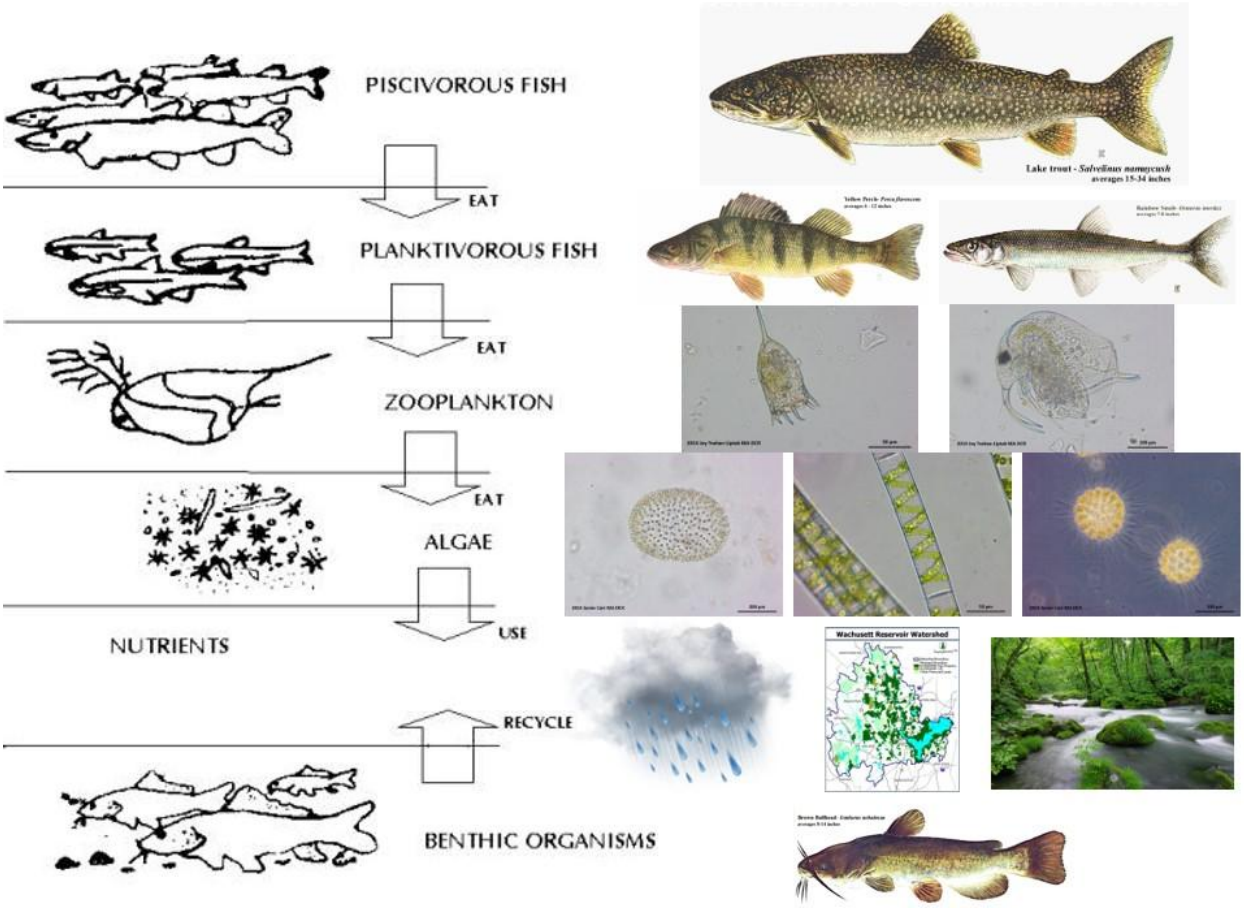
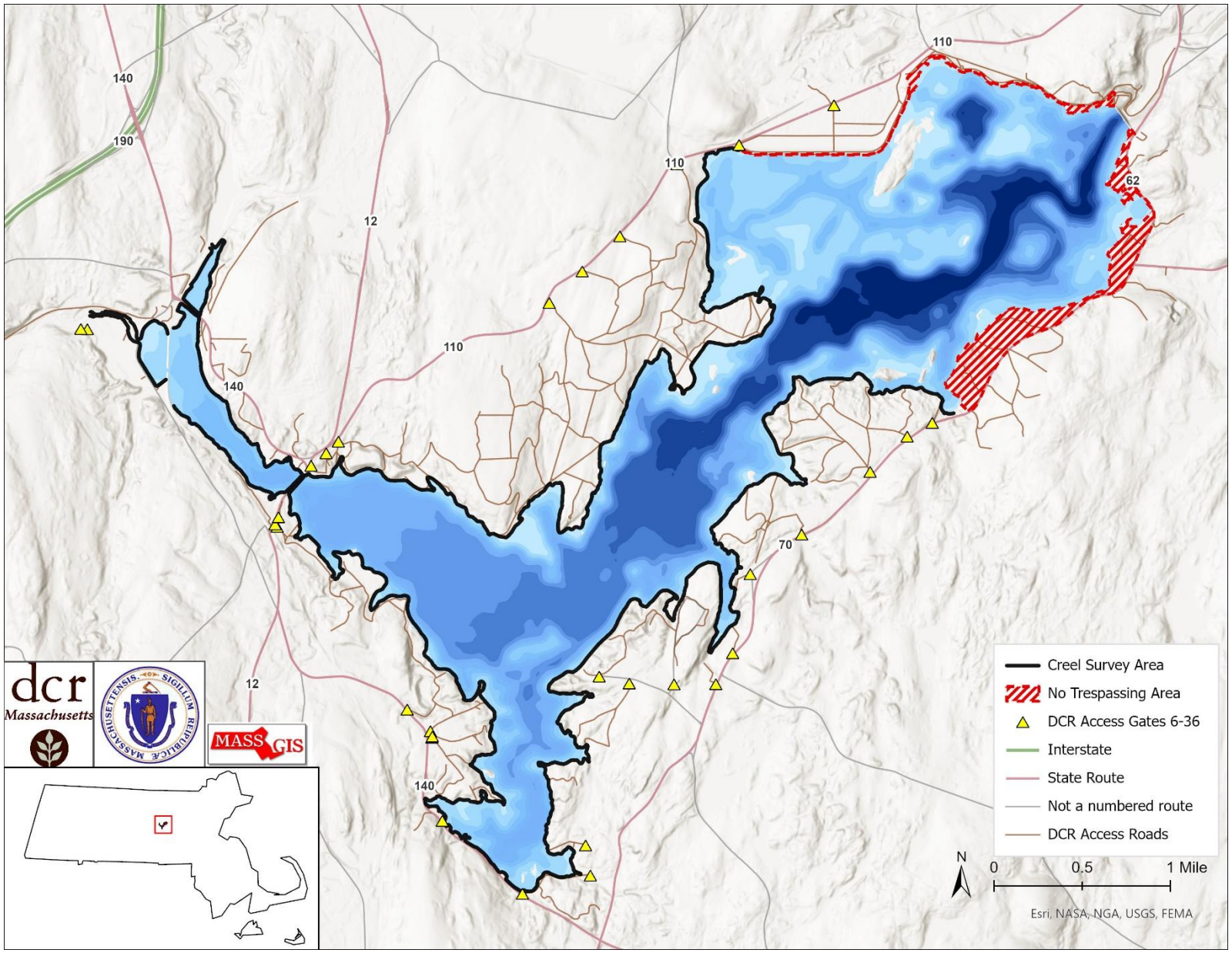


Figure 2: Wachusett Reservoir map



2. Methods

2.1. Sampling Design

A roving creel survey with a progressive count was employed during the 2022 fishing season, which ran from April 2 to November 30. The overall survey procedure for 2022 remained the same as in 2011, 2012, and 2017 (DCR 2015). For the purposes of this report, the Wachusett Reservoir will refer to the main basin of the Reservoir, Thomas basin, and Oakdale basin. The designated no fishing area near the intake and the small upper basins (Quinapoxet and Stillwater basins) north and west of the railroad trestle were not included in the survey area. Reservoir tributaries were also not included as part of the creel survey. Finally, the Lily Ponds inside of DCR gate 28 and all small ponds not directly connected to the Reservoir were also excluded.

Each survey day consisted of two separate loops around the Reservoir: an AM loop and a PM loop. The AM loop was initiated after sunrise and typically concluded before noon. The PM loop was initiated after noon and concluded before sunset. On each assigned loop the creel clerk would make one complete trip around the Reservoir, using a progressive count to determine the number of anglers for that loop. Every visible angler was counted and as many anglers as possible were surveyed while completing one trip around the Reservoir. The total number of anglers counted, surveyed, and specific reasons that anglers were not surveyed were recorded on an electronic form using Survey123 (Appendix B: ArcGIS Survey123 Creel Survey) for each loop. The creel survey form was developed to enable creel clerks to quickly collect basic information from an angler or group of anglers, including time started fishing, tackle used, and home zip code (Appendix A: Wachusett Reservoir Creel Survey Form Explanation of Fields). The species, number, and length of fish caught as reported by the angler were also recorded in the Survey123 form. Creel surveys were performed by DWSP Wachusett Watershed Rangers, DWSP EQ staff, and DFG MassWildlife staff. Trainings were held prior to the 2022 season and all previous seasons to introduce the survey methods and ensure standard data collection. Definitions for each field in the form were provided with an explanation of each field (Appendix A: Wachusett Reservoir Creel Survey Form Explanation of Fields). Starting times and starting locations were not predetermined; due to the variety of personnel conducting the surveys and the various locations from which each group would begin the survey, there was not a consistent bias introduced by starting location. The overall survey procedure for 2011, 2012, 2017, and 2022 were the same, excepting one difference. Starting in 2012, the minimum time required for an angler to be fishing in order to be surveyed was changed to 30 minutes from the 1 hour minimum used in 2011 (Pollock 1997).

Surveys were conducted by vehicle using the DWSP access roads. The network of access roads maintained around the Reservoir makes it possible for personnel to patrol the Reservoir and for creel clerks to efficiently access anglers for interviews. Groups of anglers were often included in a single survey, provided they had begun fishing at the same time and their method of fishing was consistent. Information for a group of anglers fishing together that had multiple start times was recorded with a separate survey for each

angler start time. The allocation of survey days scheduled in April and May of 2022 was similar to the number of survey days for these two months in 2017. The number of survey days in April and May were increased in 2017 and 2022 to match the higher levels of angler effort and catch documented during April and May in the 2011 and 2012 surveys (Table 1, Figure 5). This reallocation decision was made to increase the amount of information collected from Wachusett anglers. The total number of scheduled survey days remained the same between 2012, 2017, and 2022 (Table 1). Once the number of survey days was assigned to each month and day type (weekday vs. weekend), survey days were selected at random. A schedule was then generated for the fishing season that assigned each survey day to a department (i.e. DWSP EQ, DWSP Watershed Ranger, MassWildlife staff, etc.).

Table 1: Number of survey days planned by month

Month	*2011*	*2012*	*2017*	*2022*
April	10	10	23	24
May	13	14	17	18
June	14	13	15	13
July	13	14	14	13
August	13	13	11	10
September	14	13	7	7
October	13	13	7	6
November	14	13	9	12
Total	104	103	103	103

In the months leading up to the 2022 survey, the entirety of the survey agent sheet and creel survey card, which were previously paper forms, were transferred to the ArcGIS Survey123 application. In 2022, agents utilized iPads to collect and submit surveys in the field, essentially eliminating data entry after the survey was completed. The questionnaire and acceptable responses stayed the same as previous survey years to maintain the ability to compare survey responses. Images of the Survey123 application are shown in Appendix B: ArcGIS Survey123 Creel Survey. Definitions for each item on the creel card were provided with an explanation of each field (Appendix A: Wachusett Reservoir Creel Survey Form Explanation of Fields).

Data collected and submitted with the Survey123 version of the survey agent sheets and creel survey card were automatically stored in an ArcGIS Online database. Data were transferred into an existing SQL Server database where data from previous years are also stored. The datasets were combined, cleaned, and analyzed utilizing R/R-Studio (R Core Team, 2019).

2.2. Analysis and Estimations

The methods and formulas for analyzing the creel survey data and generating estimated results followed methods outlined in Estimating Angling Effort and Catch from Michigan

Roving and Access Site Angler Survey Data (Lockwood et al 1999) and are described in detail in the 2011 and 2012 creel report (DCR 2015). Definitions for the survey results that will be discussed in Section 4.0 are provided in Table 2. The formulas used for the survey results are explained in further detail in Appendix C: Explanation of Results and Formulas. In the calculation for estimated yield, the expected weight for the length of a harvested fish was calculated using growth curves, which are developed using data from the lake trout mark and recapture study (Appendix C: Explanation of Results and Formulas, Appendix D: Additional Plots). Currently, growth curves for lake trout and smallmouth bass have been developed. The estimated yield for lake trout and smallmouth bass was calculated by multiplying the expected weight for that length by the estimated total number of fish harvested. Any of the results in Table 2 may be reported per acre; the result is divided by the Reservoir surface area of 4,147 acres.

Table 2: Definitions of results

Result	*Definition*
Survey Loop	The period that creel agents are navigating around the Reservoir, observing anglers, and interviewing anglers. Each survey day has an AM and PM loop.
Anglers Counted	Total number of anglers observed fishing.
Anglers Surveyed	Total number of anglers interviewed.
Angler Trip	The event and period when an angler or group of anglers is actively pursuing fish. Reported as a total, or as an estimated total.
Angler Hours	The amount of time anglers spent fishing. Reported as a total, or as an estimated total.
Estimated	Any result that has undergone a calculation to account for the days in the fishing season when a survey loop was not conducted. This may include Angler Trips, Angler Hours, Fish Caught, or Fish Harvested.
Complete trips	Angler trips where the interview took place after the angler finished fishing for the day.
Incomplete trips	Angler trips where interview took place as angler was still actively fishing.
Expansion factor	A calculated value that is multiplied by survey result totals to estimate the expected totals for the entire fishing season. The resulting estimation is intended to account for the days in the fishing season that did not have a scheduled survey day. More than half the days in the fishing season were not surveyed. Two expansion factors are used in this report: one to estimate angler trips, the other to estimate fish caught and harvested.
Catch Rate	Calculated value based on the total number of fish caught divided by the amount of time spent fishing by anglers.

Result	*Definition*
Fish Caught	The number of fish caught by anglers. Reported as a total, or as an estimated total.
Harvest Rate	The total number of fish harvested divided by the total number of fish caught, typically reported by species.
Annual Harvest Rate	Using all fish caught, a value calculated by dividing the estimated total fish harvested by the total surface area of the Reservoir, reported as fish per acre per year.
Yield	A calculated value used to describe how much fish, by weight, was harvested from the Reservoir throughout the course of a season.

2.3. Survey Limitations

Bias is introduced in any attempt to survey recreational anglers (Ferguson 1984, McCormick 2013). This creel survey was designed to limit obvious sources of bias. The size of Wachusett Reservoir and network of access roads allows a survey agent to travel completely around it, view the fishable shoreline and interview anglers in less time than an average complete angling trip. This lends credibility to the progressive counts; however, time spent stopping to interview anglers means that the progressive counts are biased low and angling effort is likely underestimated (Hoenig et al. 1993). Given the current personnel, logistics, and time constraints, the roving creel survey design with a progressive count is considered the best survey design for Wachusett Reservoir.

The results provided by a creel survey are not unbiased or random and can be skewed by angler attitudes towards undesirable fish and non-target fish (Lockwood, 1999). Anglers can target specific fish habitats, species and sizes. Rainbow smelt and banded killifish are important forage fish in the Reservoir, but they are not typically caught by anglers and thus are not represented in this creel survey. Anglers targeting large lake trout and smallmouth bass expect a lower catch rate as a tradeoff for having a greater chance at a trophy catch. Therefore, catch rate and yield results are influenced by angler attitudes. Catch rates would likely be higher if more anglers focused more effort on catching readily available, albeit smaller, fish. Yield may also be lower if more anglers were targeting and catching smaller fish more frequently.

The DWSP acknowledges the possibility that a portion of the angler reported length data may be skewed due to a propensity for reporting whole even numbers (Figure 7, Figure 8) and the possibility of reporting the legal harvest length at Quabbin Reservoir, 18 inches, when in contact with a state employee. There is currently no harvest length limit at Wachusett Reservoir. However, the DWSP believes the harvest data are accurate and can be used to guide decision-making as more fish population data are collected.

Reallocation of survey effort following the 2011 survey to match angling effort produced obvious benefits (more anglers counted, more anglers surveyed) but results in a lower number of survey days in fall months, typically September and October. In 2017 and 2022, reallocation resulted in only seven survey days scheduled for September and six in October.

3. Results

In 2022, the creel survey was conducted on 101 of the 244 days within the fishing season (April 2 – November 30). The schedule for the season was designed with a total of 103 survey days; surveys were not completed on only two of the scheduled days due to last-minute staff time conflicts, illness, extreme weather, etc. A majority of survey loops were completed by truck, but on occasion loops were completed by boat: 4 survey loops were conducted using the boat in 2022, compared to 6 in 2017, 2 in 2012, and 10 in 2011. Survey agents counted a season total of 3,342 anglers, of which 60% (2,007) were interviewed during the 2022 survey. More anglers were surveyed in 2022 than in 2011, 2012, or 2017, despite observations of fewer anglers than 2017. Loop hours, or the amount of time agents spent surveying, was the highest on record at 564 hours, approximately 15% more survey effort than in 2017 (Table 4).

On an average survey loop (each survey day consisted of one AM loop and one PM loop), the survey agent circumnavigated the Reservoir in two hours and 48 minutes, while counting 17 anglers and surveying 10 anglers. Due to time constraints, survey design, and the potential for creating bias towards a low angler count, agents were not expected to interview all anglers and a rough goal of interviewing half of the anglers was set (Hoenig et al. 1993).

3.1. Angler Attributes

Anglers were asked to provide their home zip code as part of the interview which generated 1,960 valid responses during the 2022 season. It should be noted that attempting to collect all zip codes from groups of anglers was emphasized during training prior to the 2017 and 2022 surveys, as a single zip code often does not represent the entire angling party. This resulted in more records compared to surveys in 2011 and 2012 when a single zip code would often be recorded for a group of anglers. Angler trips for 94% of anglers surveyed in 2022 originated in Massachusetts, with a total of 185 different Massachusetts towns represented (Figure 3, Table 3). Out-of-state angler trips were recorded from 11 other states, including New Hampshire (33), Rhode Island (26), Connecticut (14), Pennsylvania (4), New York (2), California (1), Florida (1), Iowa (1), Maine (1), North Carolina (1), and New Jersey (1). The zip code results demonstrate that Wachusett Reservoir is a regionally important resource for both local and national anglers. Zip code information is known for 98% of the angler population surveyed in 2022, allowing for the town of origin to be assigned to 10,849 of the estimated 12,608 angler trips. As in previous surveys, Worcester was the most frequently reported municipality reported by zip code (Figure 3).

Table 3: Percentage of angler visitation by state

State	2022	2011-2022
MA	94%	96%
No Response	2%	2%
NH	2%	1%
CT	<1%	<1%
RI	<1%	<1%
FL	<1%	<1%
NC	<1%	<1%
ND	NA	<1%
MI	NA	<1%
NY	<1%	<1%
PA	<1%	<1%
TX	NA	<1%
IL	NA	<1%
ME	<1%	<1%
VT	NA	<1%
CA	<1%	<1%
GA	NA	<1%
IA	<1%	<1%
NJ	<1%	<1%

For all three survey years most angler trips originated from Worcester, which accounted for 22% of all angling trips with an estimated 11,447 trips (Figure 4). The next 35% of responses across all survey years come from towns with at least 1,000 estimated trips, and includes Clinton (4,511), Leominster (2,993), Fitchburg (2,290), Shrewsbury (1,967), West Boylston (1,891), Sterling (1,398), Holden (1,337), Marlborough (1,136), and Millbury (1,033). Since the zip code is not known for all anglers, these numbers likely underestimate the totals by municipality.

Across all three survey seasons, 98% of anglers reported home zip codes in Massachusetts. A total of 227 different Massachusetts towns and cities are represented from the 2011, 2012, 2017 and 2022 surveys, combined (Figure 4).

During the 2022 angling season, 60% (1,197) of anglers surveyed were unique anglers, indicating they had not been surveyed during the current fishing season, while the remaining 40% had been previously surveyed that season. It is estimated that 7,519 unique anglers utilized Wachusett Reservoir as a recreational fishery during the 2022 fishing season (making a total of 12,608 estimated trips) (Table 4). This is fewer anglers than the estimated 9,206 unique anglers in 2017 (14,180 trips), 8,326 unique anglers in 2012 (12,580 trips) and the 11,116 anglers that visited in 2011 (15,957 trips) (Table 4).

Figure 3: Estimated number of angler trips by town of origin

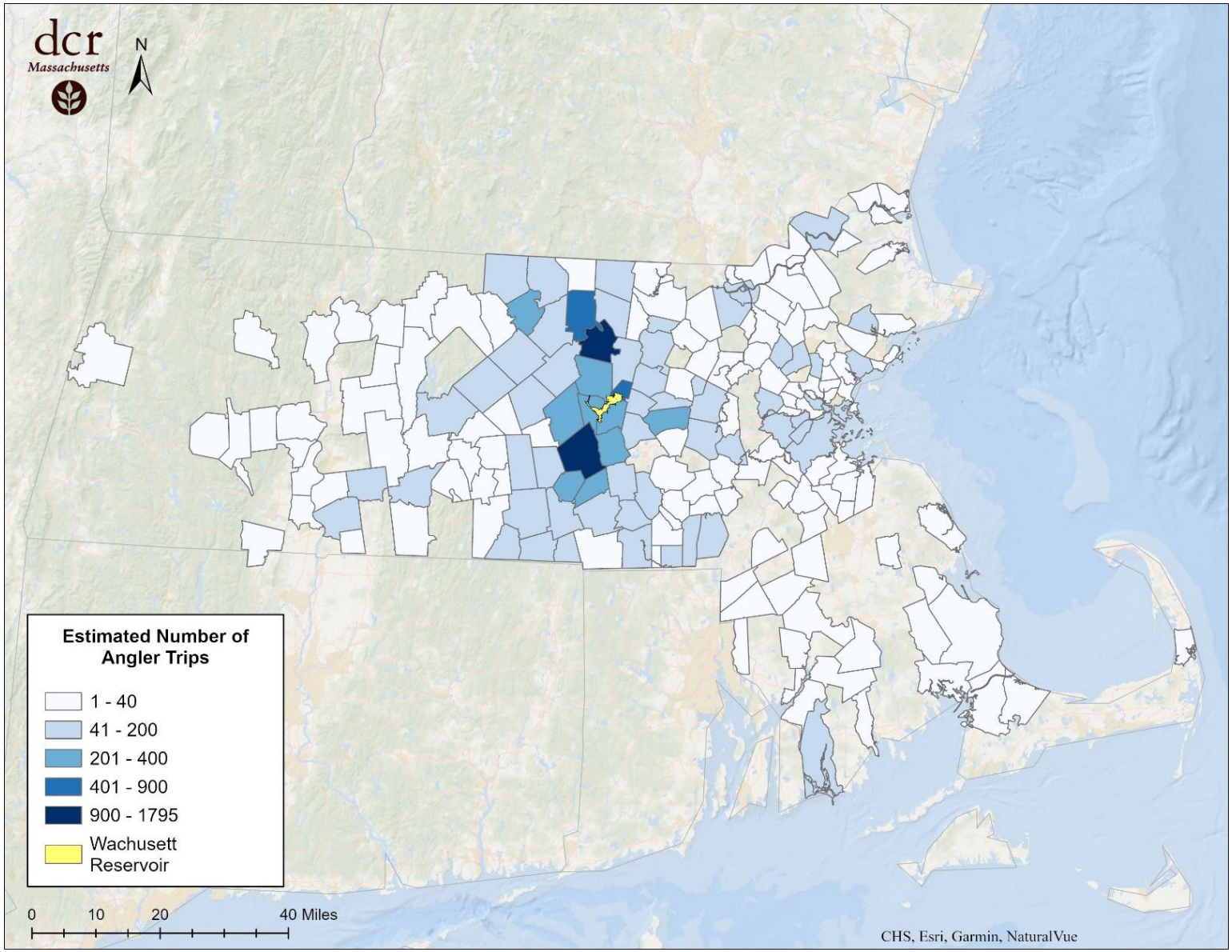
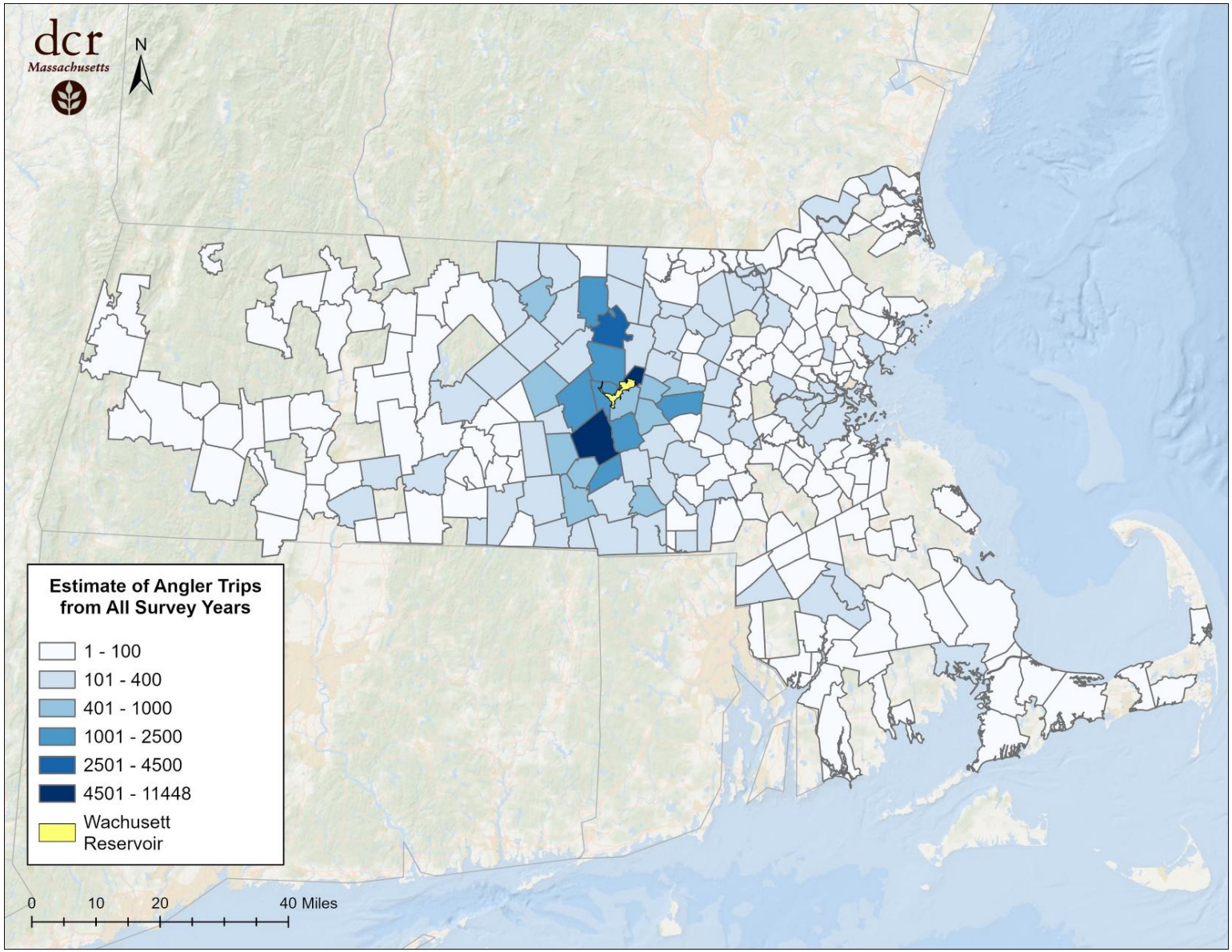


Figure 4: Total estimated number of angler trips by town of origin for all survey years



3.2. Estimated Angler Effort

During the 2022 angling season, creel surveys and subsequent expansions revealed that an estimated 12,608 angling trips took place, encompassing 40,450 hours of total angling time (Table 4). Angling pressure for 2022 is therefore estimated at 9.75 hours per surface acre. Mean angling trip lengths calculated from complete trip surveys show that the average angling trip during 2022 lasted 3.4 hours. These results are similar to previous surveys; however, the estimated total angling trips and angling hours fell below estimated values for previous surveys (Table 4). The mean completed trip time for 2022 fell between the 2011 and 2012 results and was equivalent to the 2017 results.

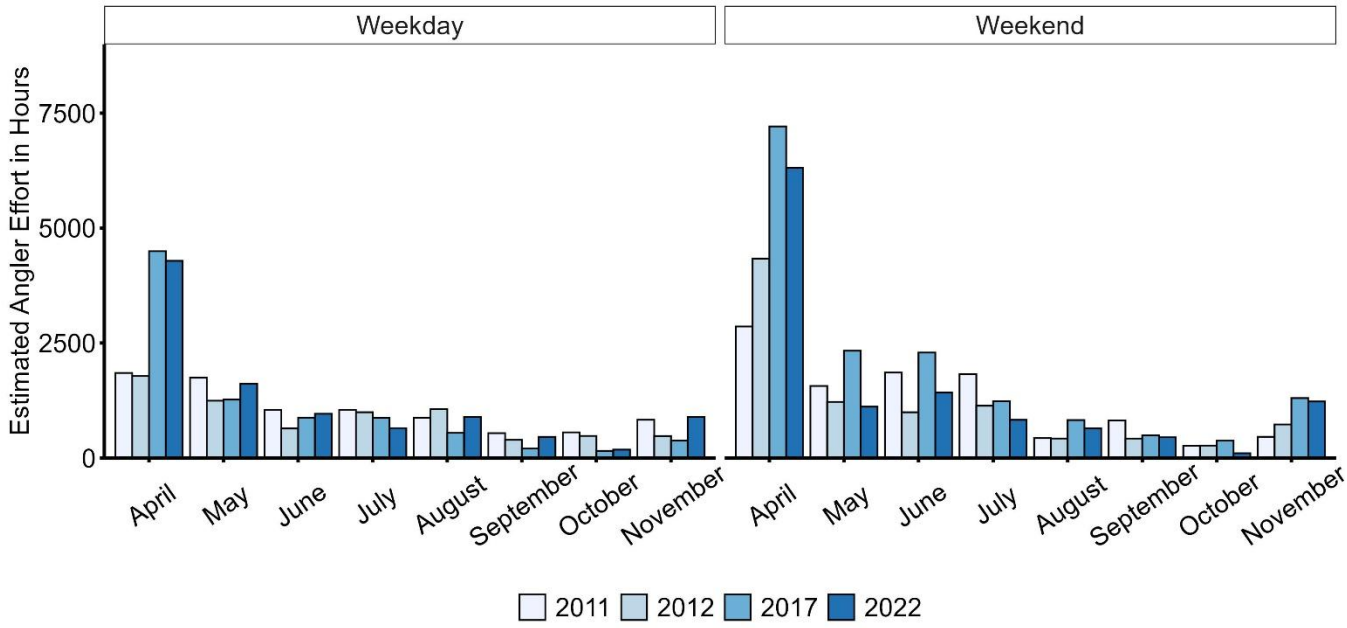
Table 4: Summary of estimated creel survey totals by year.

Statistics marked with an asterisk are estimations made using an expansion factor.

Value	*2011*	*2012*	*2017*	*2022*
Number of Anglers Counted	2,555	2,454	3,463	3,342
Number of Anglers Surveyed	1,223	1,328	1,873	2,007
*Total Estimated Angler Hours**	45,406	40,266	44,731	40,450
*Estimated Angler Trips**	15,957	12,580	14,180	12,608
Days with Completed Survey Loop	98	98	97	101
Survey Loops Completed	178	189	183	201
Days In Fishing Season	243	238	244	243
Completed Angler Trips	241	211	270	200
Mean Complete Trip (Hours)	3.1	3.5	3.4	3.4
Angler Hours Per Acre	11	10	11	10

As in previous years, 2022 monthly angler effort was highest in April and May (Figure 5). In general, effort tapered off as the season progressed, with the minimum effort occurring in October. However, weekend and weekday effort increased somewhat in November when water temperatures decreased before the close of the season, but total effort in November did not exceed that of April or May (Figure 5). In November, the last month of the fishing season at the Reservoir, weekend angling effort was estimated to be 457 hours/day in 2011, 726 hours/day in 2012, 1,299 hours/day in 2017, and 1,226 hours/day in 2022 (Figure 5).

Figure 5: Estimated angling effort by month

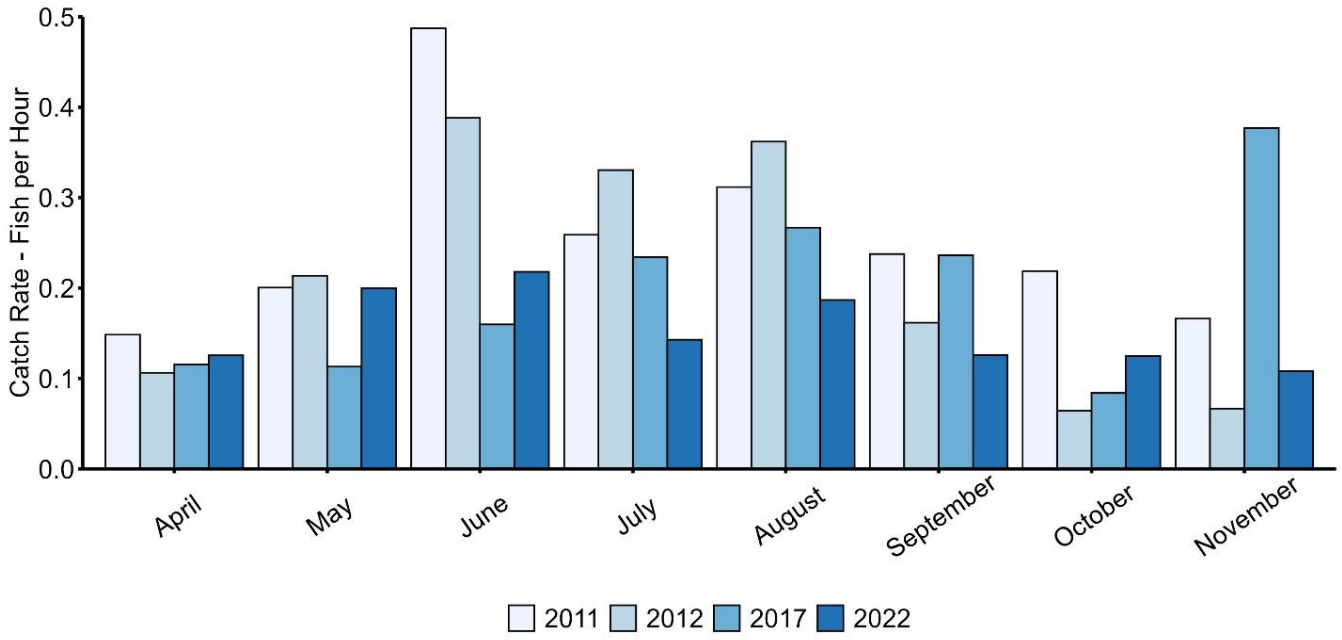


3.3. Catch Per Unit Effort

Catch per unit effort by anglers is a standard measure of angling success which represents the number of fish caught by anglers per a standard unit of time. Catch rate is reported here as catch of all species combined per angling hour. During the 2022 angling season, creel surveys show an overall catch rate of 0.15 fish per hour (Table 10). This overall rate was equal to the 0.15 rate reported in 2017, and lower than the rate of 0.24 observed in 2011 and 0.20 in 2012. Expressed another way, on average it took an angler 4.1 hours to catch one fish in 2011, 5.1 hours in 2012, 6.4 hours in 2017, and 6.8 hours in 2022 (Table 10, Table 4). The highest catch rate for a given month in 2022 was 0.22 fish per hour in June, only slightly higher than 0.20 recorded in May and 0.19 in August (Figure 6). April catch rates in 2022 appeared similar to those in previous survey years. The increased catch rate observed in November of 2017 was not observed again in 2022; instead, catch rates were similar to those observed in 2011 and 2012. In terms of angling success by trip, 40% of angler trips during the 2022 season resulted in at least one fish being caught. This is equal to the percentage of successful trips in 2017 (40%), but a lower percentage of successful angler trips compared to 2011 (55%) and 2012 (47%).

Figure 6: Wachusett Reservoir catch rates.

The unit for this measurement is the number of fish caught per hour.



3.4. Size Distribution of lake trout and smallmouth bass

An analysis of lake trout length distribution in Wachusett Reservoir as reported by anglers shows that the most frequently reported lake trout length was 18 inches for 2011, 2012, and 2017, and 20 inches for 2022 (Figure 7). The proportion of lake trout lengths reported as 20 inches or greater was 45% in 2022; lower than the 47% observed in 2017, but higher than the 26% in 2011 and 42% in 2012. It appears that odd lengths of lake trout are under-reported across all survey years, with lengths of 18 and 20 inches likely being over-reported.

Figure 7: Length distribution of lake trout caught in Wachusett Reservoir 2011-2022 (n=1385).

Reporting total fish caught, not total fish estimated.

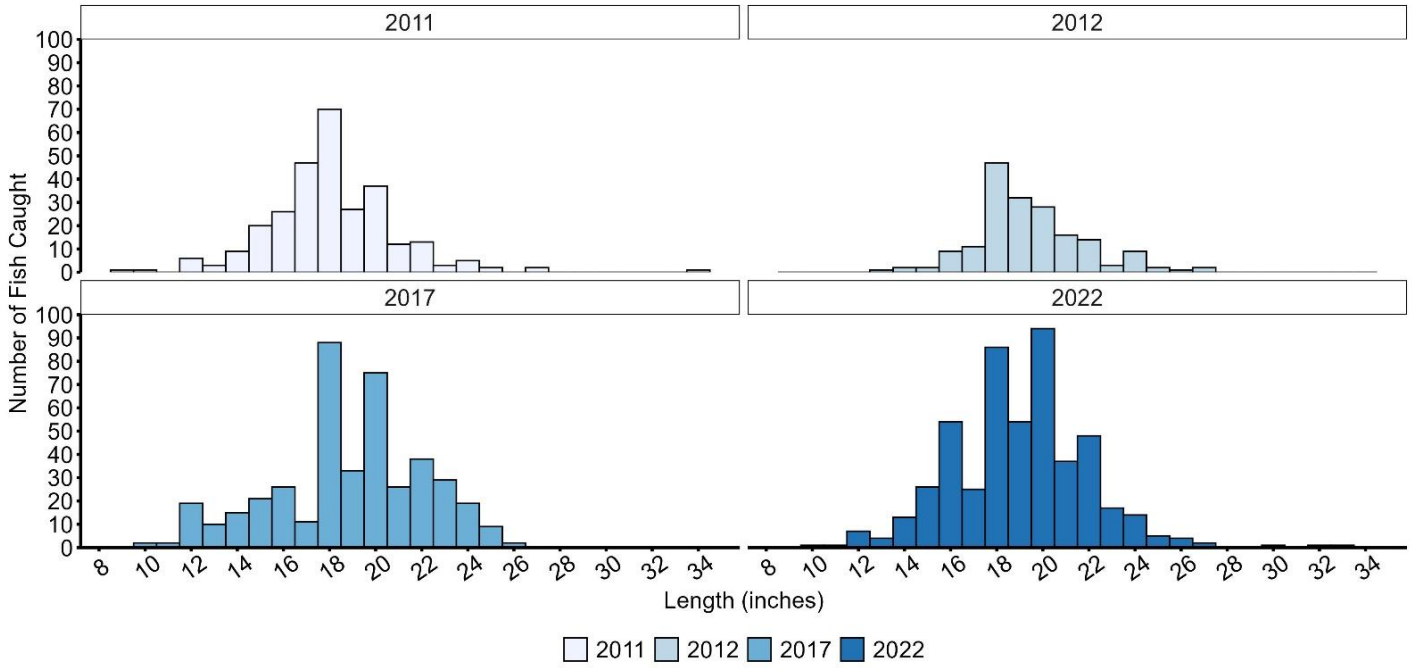
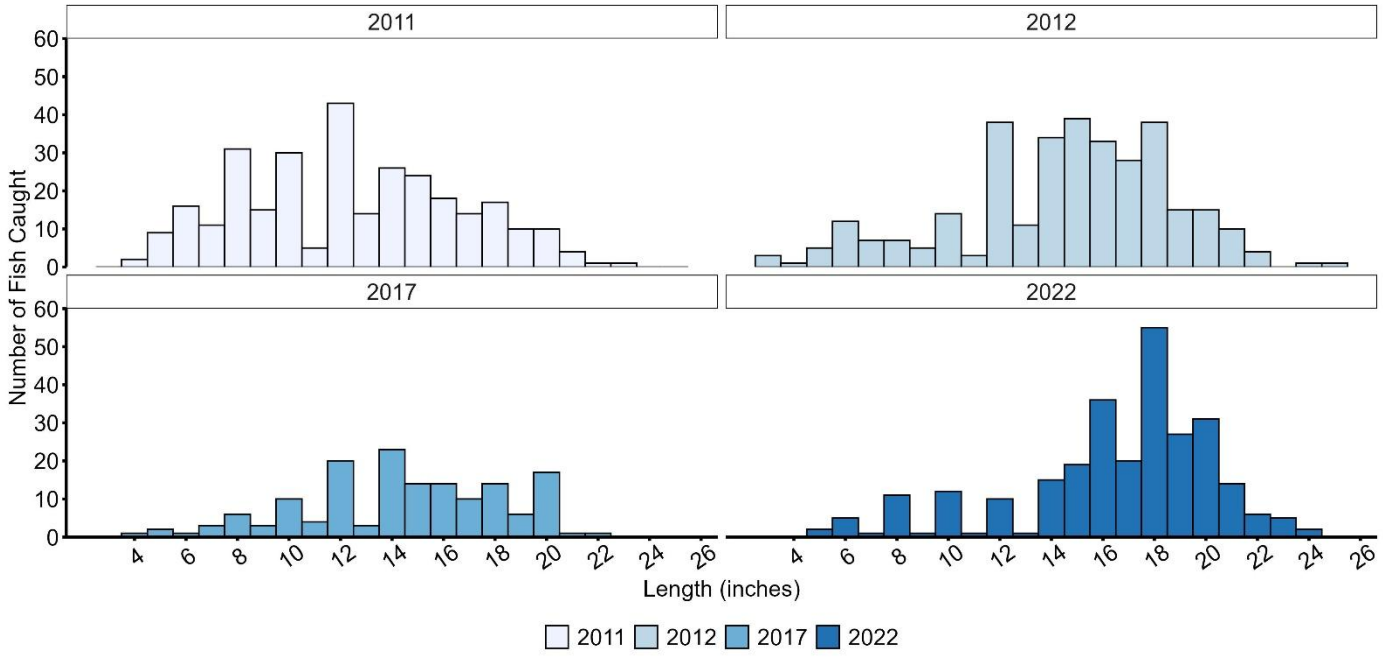


Figure 8: Length distribution of smallmouth bass caught in Wachusett Reservoir 2011-2022 (n=1054).

Reporting total fish caught, not total fish estimated.



Analysis of smallmouth bass size distribution in Wachusett Reservoir as reported by anglers shows that the most frequently occurring length was 18 inches in 2022, 14 inches in 2017, and 12 inches in the previous two surveys (Figure 8). The proportion of smallmouth bass caught reported with lengths 16 inches or greater was 71% in 2022; drastically higher than the 45% in 2012, the 41% in 2017, and the 25% in 2011. As with lake trout, odd number lengths of shorter smallmouth bass are consistently under-reported by anglers, who more consistently report even number lengths for small fish. The total number of smallmouth bass caught during the 2022 season was slightly higher than in 2017, but still far less than during the 2012 and 2011 survey years. Most smallmouth bass were caught in May and June, which was also observed in 2012 and 2011 (Figure 9).

3.5. Estimated Total Catch and Harvest

During the 2022 angling season, creel surveys and extrapolations show an estimated total catch of 6,111 fish (Table 5**,** Table 6). Lake trout were the most frequently caught species in 2022, followed by smallmouth bass (Table 6, Figure 10). Collectively, these two species of game fish accounted for more than half of the total catch (64%). Lake trout accounted for 34% of the total catch in 2022, a higher proportion than observed in 2011 (26%) or 2012 (20%), but lower than observed in 2017 (39%) (Figure 13). The total estimated catch of smallmouth bass in 2022 was higher compared to 2017 but was still lower than 2011 and 2012. Yellow perch estimated catch decreased to levels similar to 2012 (Table 6, Figure 10). The total catch of stocked rainbow trout was the third most frequently caught species in 2022 and the highest recorded among all survey years (Figure 13, Figure 10).

Table 5: Annual harvest rate, estimated fish caught, and estimated fish harvested

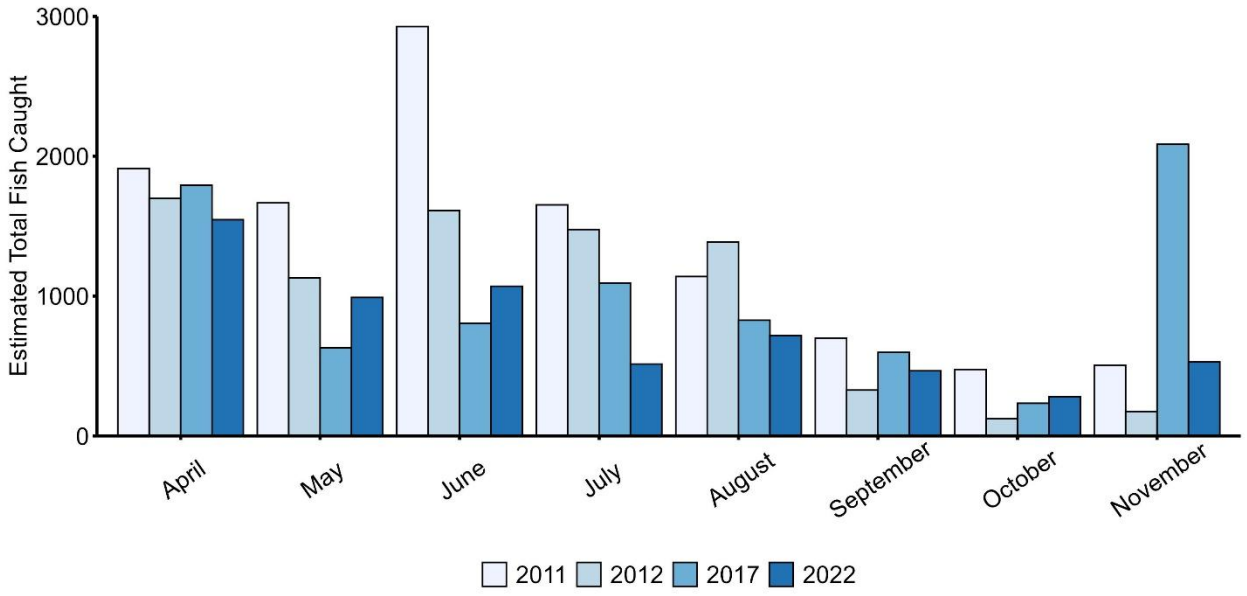
Year	*Estimated Fish Caught*	*Estimated Fish Harvested*	*Annual Harvest Rate*
2011	10,976	3,101	0.30
2012	7,926	1,937	0.26
2017	8,064	2,745	0.34
2022	6,111	1,292	0.22

Table 6: Estimated total fish caught during 2022 fishing season by month.

Results are whole fish; rounding may result in different totals by column or row. Trout includes brown trout and eastern brook trout.

Month	*Black crappie*	*Trout*	*Chain pickerel*	*Landlocked salmon*	*Largemouth bass*	*Lake trout*	*Rock bass*	*Rainbow trout*	*Smallmouth bass*	*White perch*	*Yellow perch*	*Bullhead*	*Sunfish*
April	24	6	18	57	6	1066	3	39	302	21	3	0	0
May	7	14	42	28	49	267	14	63	470	0	7	7	21
June	17	0	8	8	92	75	50	159	393	0	176	8	84
July	0	0	0	0	92	79	0	66	211	0	13	0	53
August	0	0	0	32	53	53	42	158	127	21	0	0	232
September	0	0	0	0	27	151	0	109	178	0	0	0	0
October	0	0	0	0	31	62	0	93	93	0	0	0	0
November	0	0	15	5	15	347	0	59	78	0	5	0	5
Total	48	20	83	130	365	2100	109	746	1852	42	204	15	395

Figure 9: Estimated total fish caught by month



The total estimated harvest by anglers for the 2022 season was 1,292 fish (Table 7). Lake trout were the most frequently harvested species and accounted for more than a third of the total harvest (37%). The overall harvest rate for all species was lower in 2022 than in all previous years, with 22% of all fish kept as compared to 25% in 2012, 28% in 2011, and 34% in 2017. This

is likely due to the decrease in total lake trout harvested during 2022 (Figure 10, Figure 12). The harvest rate for lake trout in 2022 was 23%, the lowest on record (Figure 11). Smallmouth bass on the other hand experienced an increase in harvest rate, similar to 2012, as 12% were harvested during the 2022 season, 14% were harvested in 2012, and only 8% and 9% were harvested in 2017 and 2011, respectively (Figure 11). Rainbow trout maintained a relatively high harvest rate of 53% in 2022, which compares to similar rates of 70% in 2011 65% in 2017, and 62% in 2012.

Table 7: Estimated total fish harvested during 2022 fishing season

Results are reported as whole fish; rounding may result in slightly different totals by column or row. Species with no harvest not shown. Trout includes brown trout and eastern brook trout.

Month	*Black crappie*	*Trout*	*Chain pickerel*	*Landlocked salmon*	*Largemouth bass*	*Lake trout*	*Rock bass*	*Rainbow trout*	*Smallmouth bass*	*White perch*	*Yellow perch*	*Bullhead*	*Sunfish*
April	15	3	1	25	0	248	0	21	39	7	0	0	0
May	4	14	3	12	1	62	0	34	60	0	0	4	1
June	11	0	1	4	2	17	0	85	50	0	7	4	5
July	0	0	0	0	2	18	0	35	27	0	1	0	1
August	0	0	0	14	1	12	0	85	16	7	0	0	13
September	0	0	0	0	1	35	0	59	23	0	0	0	0
October	0	0	0	0	1	14	0	50	12	0	0	0	0
November	0	0	1	2	0	81	0	31	10	0	0	0	0
Total	30	17	6	57	8	487	0	400	237	14	8	8	20

Lake trout were the most frequently harvested fish each survey year, with an estimated 1,110 harvested in 2011, 830 in 2012, 1,217 in 2017, and 487 in 2022 (Figure 12). Rainbow trout were the second most harvested fish in 2022 and had the highest levels of harvest compared to all survey years; rainbow trout are stocked in the Reservoir annually and considered a put-and-take resource. Anglers in 2022 indicated that they intended to consume the fish that they harvested 100% of the time, the first time the consumption responses have been this high across all survey years.

Figure 10: Estimated fish caught by year and species.

Other category includes black crappie, brown bullhead, brook trout, brown trout, chain pickerel, and white sucker.

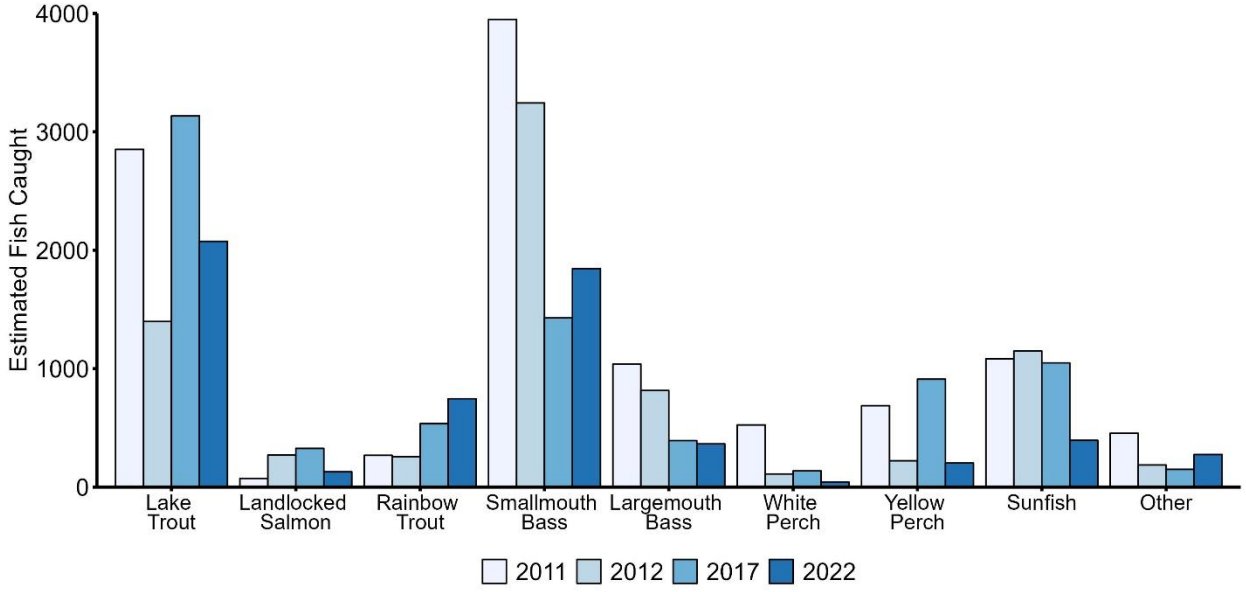


Figure 11: Estimated harvest rate by species and year.

Black crappie, brown bullhead, brook trout, brown trout, chain pickerel, and white sucker excluded from this plot.

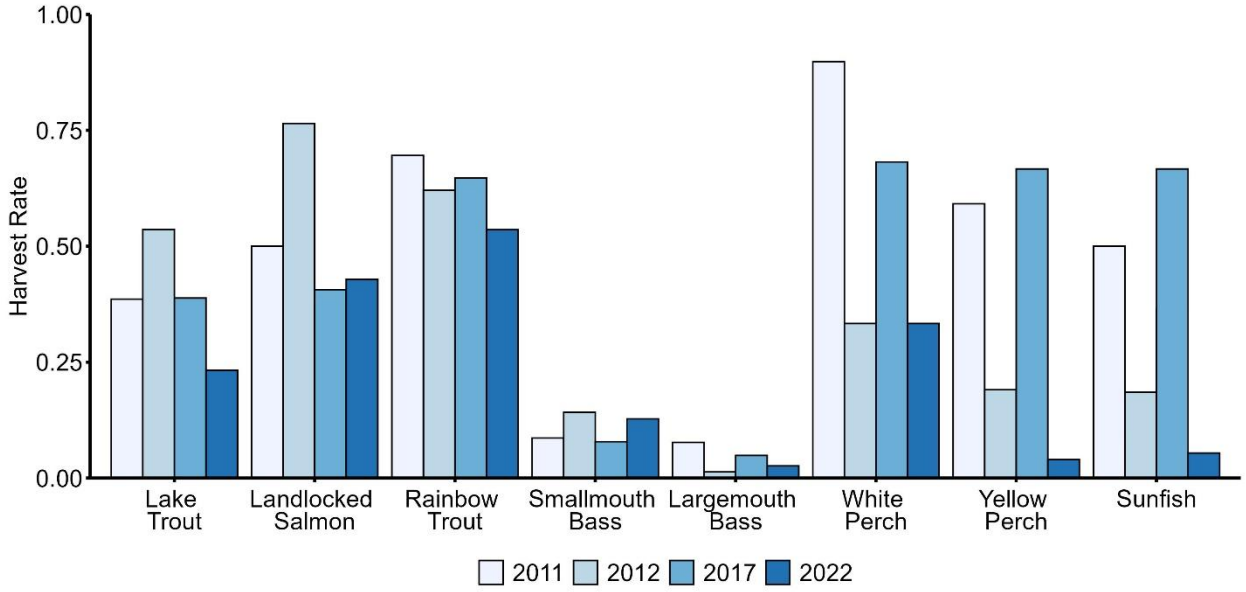
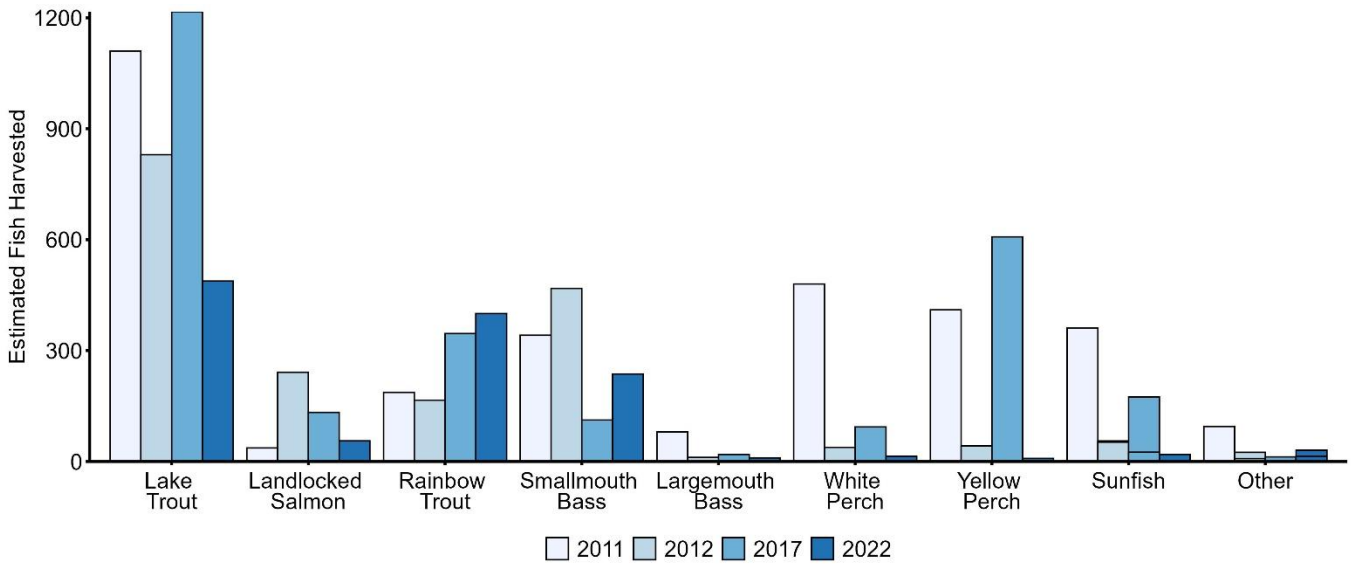


Figure 12: Estimated number of fish harvested by species and year.

Other category includes black crappie, brown bullhead, brook trout, brown trout, chain pickerel, and white sucker.



3.6. Harvest Rates and Yield

In 2022, the Wachusett Reservoir estimated harvest rate for all species was 0.22 fish per acre (Table 5). This rate is the lowest harvest rate recorded among all survey years; previous harvest rates are 0.34 fish per acre in 2017, 0.30 in 2011, and 0.26 in 2012.

The estimated yield and the estimated yield per acre are weight estimates of fish taken from the Reservoir each survey year, which provide a general estimate of the amount of biomass being removed from the Reservoir. The full description on how these values were calculated can be found in the 2011-2012 Wachusett Reservoir Creel Survey Report (DCR 2015). The estimated yield per acre was calculated for the two most frequently caught species, lake trout and smallmouth bass. With respect to lake trout, the average length of fish harvested, the estimated yield, and the estimated yield per acre were the lowest on record in 2022 compared to all three previous creel survey seasons (Table 8). The average length of harvested lake trout was 17.8 inches in 2022, 19.5 in 2017, 18.8 inches in 2011 and 18.8 inches in 2012. The lake trout estimated yield in pounds was only 723 in 2022; down from 2,419 in 2017 1,968 in 2011 and 1,476 in 2012 (Table 8). The estimated yield per acre for lake trout was 0.17 pounds per acre in 2022; this value again is the lowest on record, compared to 0.58 pounds per acre in 2017, 0.47 in 2011 and 0.36 reported in 2012.

Table 8: Lake trout yield

Year	Mean Length Released (in)	Mean Length Kept (in)	Harvest Rate	Expected Weight Kept in Pounds	Annual Yield in Pounds	Pounds per Acre
2011	*17.77*	*18.81*	*0.39*	*1.77*	*1967.89*	*0.47*
2012	*19.49*	*18.83*	*0.54*	*1.78*	*1475.80*	*0.36*
2017	*18.13*	*19.47*	*0.39*	*1.99*	*2418.92*	*0.58*
2022	*19.55*	*17.81*	*0.23*	*1.48*	*722.82*	*0.17*

Table 9: Smallmouth bass yield

Year	Mean Length Released	Mean Length Kept	Harvest Rate	Expected Weight Kept in Pounds	Annual Yield in Pounds	Pounds per Acre
2011	13.46	16.13	0.09	2.05	700.52	0.17
2012	14.75	18.05	0.14	3.07	1437.71	0.35
2017	14.95	16.09	0.08	2.04	228.11	0.06
2022	15.89	16.90	0.13	2.42	573.65	0.14

Smallmouth bass follow different yearly patterns for the average length of fish harvested, the estimated yield of fish harvested, and the estimated yield per acre. The average length of smallmouth bass harvested was 16.9 inches in 2022, 18.0 inches in 2012, 16.1 inches in 2011, and 16.1 inches in 2017. The estimated yield in pounds was 573 in 2022, which is the second lowest yield on record compared to 1,438 pounds in the 2012 harvest, 701 pounds in 2011, and only 228 pounds in 2017 (Table 8). The estimated yield per acre for smallmouth bass in 2022 was 0.14 pounds per acre, compared to 0.34 in 2012, 0.16 in 2011, and 0.05 in 2017.

It should not be assumed that the fishery will support the same harvest rate of lake trout in the future as it does at present or has in the past. The current harvest regulation for Wachusett lake trout is three fish of any size per day (321 CMR 4.01). In the case of Wachusett Reservoir, the shoreline access and restricted no fishing zone play a role in limiting angler exploitation of lake trout simply by limiting access to the fish. However, this may not be enough to prevent the yield from surpassing a sustainable level. Lake trout regulations will be discussed later in this report.

3.7. Comparison to Historical Creel Surveys

The first survey effort for Wachusett Reservoir began in 1979 and was repeated in 1980. These surveys concentrated on interviews of anglers fishing at the Reservoir throughout the fishing season and used a similar approach to recent surveys. Summary tables with the expanded

results of each creel survey are available in the MassWildlife archives (MassWildlife 1979 and 1980) and are presented in Table 10. Another creel survey conducted in 1998 documented a similar number of angling trips to the survey 18 years prior but indicated more angling hours. Detailed methods for the survey design are available (MassWildlife 1998) and an expanded summary table of estimated results was calculated; however, there is no description of survey results, documentation for the number of anglers surveyed, or the methods used to analyze the data.

Table 10: Historical angler surveys at Wachusett Reservoir.

Dashes indicate missing data.

Survey Year	*Anglers Surveyed*	*Avg. Trip Length (hours)*	*Angling Trips*	*Angling Hours*	*Catch/Hour*	*Catch/Angler*
1979	1,761	2.1	22,029	53,989	0.41	1.00
1980	1,974	2.3	26,770	63,534	0.56	1.33
1998	-	-	26,907	83,144	-	-
2011	1,223	3.1	15,957	45,406	0.24	0.76
2012	1,328	3.5	12,580	40,266	0.20	0.60
2017	1,873	3.4	14,180	44,730	0.15	0.50
2022	2,007	3.4	12,608	40,450	0.15	0.51

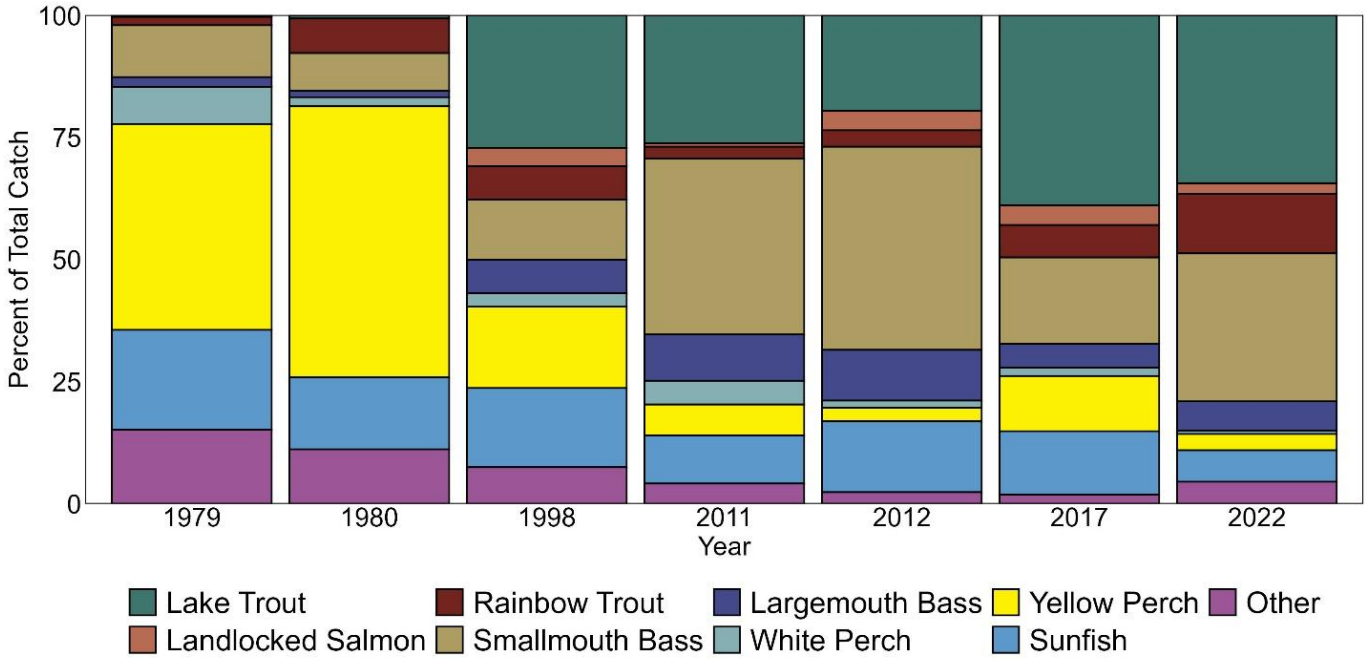
As the result of limited documentation and differences in survey design, it is difficult to directly compare the results of creel surveys conducted sporadically over the past 45 years. In general terms, it appears that there may be fewer annual angling trips now than in the past, and anglers are fishing for longer when they do fish (Table 10). Higher catch rates reported in the 1979/1980 creel surveys are most likely related to the types of fish that were most frequently caught. Yellow perch and sunfish comprised most of the catch in older surveys, as opposed to larger game fish such as smallmouth bass and lake trout recorded in recent creel surveys where, (Figure 13).

Fortunately, raw data of the actual fish caught by anglers is available for each of the historical creel surveys. Thus, the proportion of each species caught is comparable across the different surveys and provides some interesting insights into changes in the fish species caught by anglers over the past 40 years. For example, yellow perch accounted for 50% of the total catch in the 1979/1980 time period, declined to 17% in 1998 and declined further to remain below 12% in all survey years since 2011 (Figure 13). The proportion of sunfish, white perch, largemouth bass, and rainbow trout caught has remained relatively stable over all survey years; the total catch for each of these species typically does not exceed 10%. Smallmouth bass accounted for only 9% of the total catch in 1979/1980, increased to 12% in 1998 and has accounted for over 30% of the total catch in all survey years since, except 2017 (17%).

One of the goals of the 1979 and 1980 creel surveys was to determine how many lake trout were caught at Wachusett Reservoir. Presumably, there were reports of angler catches of this species as it was becoming newly established in the Reservoir that Masswildlife wished to investigate. Results showed that fewer than 20 lake trout were caught by anglers surveyed in the entire two-year period. Since that time, this species has become the primary cold-water fish species in the Reservoir and one of the most frequently reported species caught by anglers, accounting for over 20% of total catch in every survey since 1998 (Figure 13). These results indicate that changes to the Reservoir fish community have occurred over the past 35 years.

Creel surveys are not a random sample of the fish population because the fish caught by anglers are only those of a catchable size. Using lake trout as an example, the smallest lake trout caught during the 2022 season was 9 inches long. A lake trout of this length is at least one year old, which means all age classes below one year are excluded from the survey. Additionally, creel surveys are not a random sample of the fish community as anglers consider certain species desirable or more easily caught depending on specific conditions and subsequently target those species, increasing the odds of catching them. An example of this phenomenon is the shift in the predominant species caught throughout the year; smallmouth bass are typically caught in a higher proportion in May and June, when the April lake trout catch has declined until water temperatures decrease again in November.

Figure 13: Percentage of total creel catch by species



4. Discussion

4.1. Survey Results

Wachusett Reservoir is used primarily by anglers from Worcester County, Massachusetts; however, anglers from outside Worcester County and non-Massachusetts residents frequent the Reservoir. Despite relatively low catch rates, anglers are drawn to the fishery for the chance to catch a trophy fish in an undeveloped setting. The Reservoir fishery is used primarily for recreation, as more than three quarters of the fish caught are released. Those fish that are harvested are typically consumed by the angler.

As demonstrated in previous surveys, anglers continued to be cooperative and many were genuinely interested in the creel survey and its results. Remarkably, only 29 surveys (0.6%) could not be completed this season due to a lack of angler cooperation. This is the highest number of uncooperative responses ever recorded. That said, the quality and scale of these angler creel surveys remains extremely high and is possible due to the participation and 99.4% cooperation of anglers across all survey years. Compliance with angling laws and watershed regulations by anglers at the Reservoir also remains very high, as 98.7% of anglers encountered in the course of the survey followed applicable regulations. The Wachusett Reservoir Watershed Rangers patrol the Reservoir frequently and have regular contact with anglers; this facilitates execution of the creel survey and factors into compliance with regulations.

Overall, the creel survey process and effort from survey agents in 2022 was consistent with previous years. Angling effort in 2022 appeared to fall within a similar range, as the total estimated angler trips and angler hours for the 2022 season fall below the values from 2017, but between the lowest values recorded in 2012 and the highest recorded in 2011. Wachusett

Reservoir is exclusively a shoreline fishery due to regulations; as a result, angler effort and angler catch rates are likely susceptible to the influence of seasonal weather conditions and water temperatures from year to year. In some instances, effort may also be linked to an angler's ability or willingness to hike to fishing locations far from the road. The first and last months of the fishing season are the months where weather conditions, i.e. air temperature and seasonal variation in precipitation and wind, may have a particularly strong influence on the Reservoir water temperature. Water temperature is a strong influence on the presence of coldwater fish species in the shallow, near-shore areas of the Reservoir. With this seasonal weather variation and corresponding variable timing of water temperatures suitable for coldwater fish species, it is expected that catch rates can be highly variable at both the start and the end of the fishing season. In addition, certain weather conditions, such as wind, rain, snow, and generally cooler temperatures, may have a strong effect on reducing angler effort. Catch rates and angler effort may also be influenced by the difficulty associated with fishing a reservoir that does not allow boating and excludes portions of the shoreline due to security concerns, and by the target species and specimen size preferences of Wachusett Reservoir anglers. In 2011, ice out was very near to the opening day of fishing in April after an extended freeze 76 days in duration, while in 2012 the Reservoir never fully froze. Consequently, the average water temperature for the month of April was 6.1° C in 2011, far colder than the average of 7.8° C in April of 2012. Winter leading into the 2017 season featured a brief period of ice over in February lasting only 13 days; the average water temperature in April was 7.0° C. In 2022, the Reservoir froze for a total of 21 days, from January 27 to February 17 and the average temperature in April was 5.1° C (DCR 2022). This seasonal variation in weather and water temperatures influences the availability of cold-water species to shore anglers. If the most desirable species, such as lake trout and landlocked salmon, are less available to shore anglers during warmer months, then both the catch rate and the angler effort could be negatively influenced; these are compounding factors that would lead to lower total catch and yield. Presumably, anglers alter their behavior by fishing more frequently and staying for a longer period when they have experienced angling success themselves, or when they have heard positive reports from other anglers via word-of-mouth or posts on popular social media sites. The reverse effect is also presumably true. This is important to consider within the context of the 2022 season as increased angling effort and the increased catch of lake trout were concentrated in April and November: 67% of lake trout caught for the season were caught in those two months. While it is possible the updated survey schedule may have increased reporting of lake trout catch and harvest, the estimated catch rates for all species remained relatively similar in 2011, 2012, 2017, and 2022.

Anglers were asked to identify their "target species" and survey agents were instructed to select one response. Despite this, many anglers reported fishing for more than one species. Additionally, certain fishing methods are suitable to target multiple species of fish; therefore, a detailed analysis of angler effort by target species or fishing method is not presented. It can be generally stated that some combination of lake trout and/or smallmouth bass are the target species for approximately 80% of anglers. Landlocked salmon are indicated as a desired species

by 14% of anglers (counting responses of “landlocked salmon” as well as “lake trout and landlocked salmon”) while rainbow trout were targeted by a maximum of 10% of anglers (counting responses of “rainbow trout” as well as “trout”). Interestingly, landlocked salmon and rainbow trout often have a very high harvest rate, so anglers fishing for them may utilize specific methods and be subsistence anglers. Rainbow trout are often seen as a non-native put-and-take resource by anglers, landlocked salmon are often targeted for their table quality. Anecdotal evidence suggests that many anglers return lake trout in the hopes that the lake trout continues to grow, possibly to a trophy size.

The overall annual harvest rate in 2022 was 0.22 fish per acre, while the 2017 result of 0.34 fish per acre is higher compared to harvest rates documented in the past two surveys, which ranged from 0.26 to 0.30 fish per acre (Table 5). These rates are the effect of the relatively low overall catch rate combined with the fact that most fish caught by anglers are released. The total harvest is also limited by the fact that anglers are only able to access the fishery from the shoreline and are unable to fish a significant area around the intake and dam. These regulations provide refuge from angling pressure and thus play a role in the presence of large game fish and state record catches. Although the overall impact of angling on the fish community of Wachusett Reservoir is likely low, popular species, such as lake trout, landlocked salmon, and smallmouth bass may be disproportionally affected.

4.2. Species Interactions

The current fisheries data for Wachusett Reservoir is not conducive to describing species interactions; however, data collected from the creel survey can be used in combination with the literature on the subject to make inferences on the interactions that occur in the Reservoir ecosystem.

Focusing on lake trout, these fish are negatively affected by high species richness, especially in combination with high levels of angler harvest (Thill, 2014). Research shows that smallmouth bass (Selinger 2006, Kerr 2000, Lepak 2006, Weidel 2007), yellow perch, and rock bass (Kerr 2000, Ontario 2007) negatively impact lake trout abundance and population status. It is interesting to note the inverse relationship between lake trout and smallmouth bass abundance in the three most recent creel surveys (Figure 13). A reduction in the availability of forage fish following bass introductions has been shown to have adverse impacts on native top predators, including lake trout, which in some cases rely on littoral prey fish (Vander Zanden 2004, Lepak 2006). Lake trout condition can be negatively affected by introduced competitors, especially bass, and may result in a diet shift from forage fish to zooplankton and other pelagic invertebrates (Thill 2014, Lepak 2006, Hammers 2018). It has been further suggested that populations within lakes lacking pelagic forage fish are most vulnerable to the impacts of bass introductions, as bass can outcompete other species in littoral feeding areas (Vander Zanden 2004, Weidel et al. 2007). In some cases, where pelagic fish such as rainbow smelt are present, lake trout condition is buffered from the negative impacts of bass (Selinger 2006, Kerr 2000). This may be the case in Wachusett Reservoir; however, the population status of rainbow smelt is currently unknown. Kerr

(2000) highlights that the disadvantages associated with rainbow smelt as the primary forage fish include their extreme population fluctuations and a “pronounced post-spawn mortality.” There is evidence to support the idea that in the absence of forage fish such as alewives and smelt, lake trout will feed on smaller invertebrates as a primary food source until they are large enough, and thus less gape-limited, to consume yellow perch (Hammers 2018, Vander Zanden 2004).

The interaction between juvenile yellow perch and rainbow smelt in Wachusett Reservoir is not well understood, but the two species are known competitors for eggs and other juvenile fish (Kerr 2000). Historic reports on rainbow smelt suggest numbers are declining (Quabbin Reservoir and Wachusett Reservoir 2018), while there is evidence of a large year class of yellow perch in 2017 (Section 6.0). Juvenile yellow perch predation on zooplankton may overlap with rainbow smelt, but rainbow smelt may have a competitive advantage (Hrabik et al. 2001, Kerr 2000). However, if rainbow smelt have a poor year class, it is possible that yellow perch could increase in density. No data is available for rainbow smelt in Wachusett Reservoir at this time; however, it is possible that a cycle of yellow perch becoming the predominant forage fish in the Reservoir again is beginning. A decrease in alewives and smelt was observed in Keuka Lake, New York, and it was not until recently that scientists found the first evidence that lake trout were feeding on yellow perch; however, yellow perch were only found in the stomachs of lake trout greater than 350 mm (Hammers 2018). Considering that yellow perch are more often concentrated in the littoral zones of lakes, and bass species are better adapted to littoral zones than lake trout, it is possible that the rise of yellow perch as the primary forage fish will negatively affect lake trout population size and condition if they are seasonally unavailable to lake trout.

4.3. Lake trout Life History and Yield

Lake trout are a slow growing member of the char family that typically inhabits very cold, highly oxygenated water found within deep, oligotrophic water bodies (Thill 2014, Gunn and Pitblado 2001, cited by Stolarski 2019). They are less tolerant to increases in water temperature compared to the warm water fish species found in Wachusett Reservoir and are susceptible to high competition and species richness (Thill 2014). Wachusett Reservoir is at the southernmost extent of the lake trout range and has a naturally reproducing population. Lake trout are the most popular cold-water game fish in Wachusett Reservoir, based on the results of the target species responses of the survey and the catch and harvest data. There is currently limited population density, growth rate, and condition data for the lake trout population in Wachusett Reservoir; however, an ongoing mark and recapture study at Wachusett Reservoir and a recent paper about the lake trout population in nearby Quabbin Reservoir investigates the age at maturity, growth rates, and condition (Stolarski 2019). Quabbin Reservoir data will be referenced in portions of this discussion, as Wachusett and Quabbin Reservoir are regionally comparable.

Lake trout in Quabbin Reservoir reach sexual maturity at approximately 4-6 years and breed in October and November, when water temperatures in the epilimnion drop between 11° C and 17° C (Thill 2014, Stolarski 2019). Comparably, lake trout at Wachusett Reservoir have been captured during the mark and recapture study in water temperatures between 8-15° C. Otoliths have been extracted from incidental lake trout mortalities that occurred during sampling at

Wachusett Reservoir, but thus far, results of otolith inspection have been difficult to interpret, as annual cycles of growth appeared extremely inconsistent (Stolarski 2018, personal communication). DWSP staff will continue to collect otoliths from incidental lake trout mortalities and will investigate possible reasons for the unclear annual growth patterns. Otoliths of lake trout from Quabbin Reservoir were aged successfully and revealed that lake trout tend to mature between 4-6 years old and that the length at ages 4-6 ranges from 350 to 500 mm (Stolarski 2019).

The study at Quabbin Reservoir demonstrated that variability in the forage base of the Reservoir, which historically has been dominated by rainbow smelt, may affect the age at which lake trout reach a total length of 457 mm (18 inches), which is the minimum length for legal harvest at Quabbin Reservoir (Stolarski 2019, MassWildlife 2023). A similar study spanning 1997-2016 in Keuka Lake, New York demonstrated that lake trout did not reach 18 inches until ages 5-7 and that growth rate and condition have declined as the forage base has changed (Hammers 2018). High rates of male capture may be attributed to differences in spawning behavior, a greater number of male lake trout in the population, and females spawning at later ages and on multi-year cycles (Hartel 2002, Stolarski 2019). Wachusett Reservoir lake trout likely fall within a comparable age range at first maturity to Keuka Lake, Quabbin Reservoir, and other regional lakes.

The current Quabbin Reservoir minimum harvest regulations for lake trout are two fish at least 18 inches, or 457 mm, which falls within the aforementioned size range at which lake trout most likely first reach sexual maturity. There is currently no minimum length limit for lake trout harvest at Wachusett Reservoir, and up to three fish can be harvested per angler per day. The lack of minimum size for legal harvest and resulting overlap with the age and size at first maturity may make Wachusett Reservoir lake trout more susceptible to overharvest or overexploitation under the current regulation, if small fish that have not yet spawned or are only just reaching maturity are harvested. The current results of the creel survey do not indicate that this is happening however, as the harvest rate in 2022 was the lowest on record, and the mean length of harvested lake trout was 17.9 inches. Additionally, the mean length of harvested lake trout across all other survey years was greater than 18 inches.

These results are somewhat promising for Wachusett Reservoir, as studies show that many lake trout fisheries can only support very low harvest rates and that this species is highly vulnerable to overexploitation by anglers (Burr 1991, Burr, 2006, Thill 2014, Shuter 1998, Johnson 2001). The low harvest rate and the estimated yield of 0.17 pounds per acre documented in the 2022 creel survey is lower than all other estimated yields recorded in previous surveys, including the 0.65, 0.50, and 0.42 pounds per acre documented in 2017, 2011, and 2012 respectively (Table 8).

The harvest rate and the yield in pounds per acre calculated based on the results of the 2022 survey are below the recommended harvest rates and maximum sustainable yield values described in the literature. Maximum sustainable yield (MSY) is the threshold at which naturally

reproducing populations can be harvested without long-term degradation (Burr 1992, Lenker 2016). 2022 harvest levels exceed neither the 0.45 pounds per acre per year 'annual harvest rate' suggested as an upper limit for heavily fished, naturally reproducing, non-stocked lake trout populations in Maine nor the 0.45 pounds per acre 'exploitation limit' for Canadian and Laurentian Great Lake populations described by Healey in 1978 (Johnson 2001). Annual harvest rate and exploitation limit are the terms used in these sources and are considered equivalent to estimated yield per acre. The Maine management plan suggests even lower annual harvest rates of 0.25 pounds per acre, depending on the lake trout population age structure and growth rate; however, more information about the Wachusett lake trout population age structure and growth rate is needed to make management decisions. The Maine management plan and the management guidelines from the Ontario Ministry of Natural Resources, recommend estimated yield per acre of 1.0 pounds per acre and higher only in populations supplemented by stocking (Johnson 2001, Ontario 2007). Wachusett Reservoir is not currently stocked and has never been directly stocked with lake trout. Based on these studies, the DWSP suggests maintaining the estimated yield per acre for Wachusett Reservoir lake trout at or below 0.5 pounds per acre per year until more data are collected to develop a Wachusett Reservoir lake trout maximum sustainable yield value.

According to a series of reports written by MassWildlife spanning 1994-2001, the Wachusett Reservoir lake trout daily creel limit was increased in April 1996 and the minimum size limit was eliminated, which likely resulted in the current Wachusett Reservoir regulations: a creel limit of three fish and no minimum size (MassWildlife 1996, MassWildlife 2023). The stated goal of this regulatory change was to prevent overpopulation; however, the data used to make this change are unclear in the available reports. Biologists at this time likely observed small or lean lake trout; therefore, the fishing regulations were changed to increase the harvest to reduce the population size and increase individual fish size. It is unclear whether these proposed regulations had the desired impact of preventing overpopulation because gillnetting was not conducted between 2000 and 2014.

5. Recommendations

Creel surveys are currently the most efficient method used by DWSP to obtain fisheries and angler visitation data at Wachusett Reservoir. Data collection methods may be adjusted and expanded to increase efficiency and data gathered; however, all surveys should be designed such that data continues to be comparable to previous years. Future creel surveys should continue to use the results of angler effort data collected in this survey to more closely align creel agent survey effort and angling effort.

Repeating the creel survey at regular intervals is useful to observe change over time. Investigations of change over time are more difficult when large data gaps are created, including the gap between the 2011-2022 surveys and the surveys collected prior to 2011. Maintaining a regular interval of five years is recommended. The survey process was streamlined by utilizing new applications available to the DWSP, such as ESRI's Survey123 application. This reduced a large portion of the data entry process and allowed for more frequent review of survey results.

The ability to track survey submissions in real time allowed the primary researcher to provide feedback to creel agents in a timely manner. As new tools and applications are produced by ESRI, it is recommended that DWSP continue to test these products for new insights into survey methods and data visualization.

Continued study is necessary to learn more about the current population status, life history, and sustainable yield of lake trout and smallmouth bass in Wachusett Reservoir. Additional creel surveys and research are needed to explore and establish an appropriate maximum sustainable yield for this naturally reproducing lake trout fishery. At the same time, DWSP and MassWildlife should investigate methods for encouraging harvest of these species, in case there is evidence for an overabundance of either species. Research will include the lake trout mark and recapture study, but studies involving lake trout otoliths, stomach contents, condition, and electrofishing warm-water species will also be pursued as time and funding allow.

In the meantime, a conservative approach is to maintain a harvest rate and estimated total yield that does not exceed 0.5 pounds of lake trout per acre per year as suggested in the Maine and Ontario proposed management targets. Current estimations from the 2022 data show that anglers did not exceed the estimated total yield or harvest rate ceilings suggested in regionally similar fisheries. Therefore, there is no recommendation for regulation change at this time.

The information collected from the creel survey and the lake trout mark and recapture study can be used to monitor lake trout estimated yield over time. If the estimated yield of the Wachusett Reservoir lake trout population varies from the maximum sustainable yield described in the literature, or if there is a notable decline in the catch rate of lake trout, DWSP is able to make recommendations on the current freshwater fishing regulations to ensure that they contribute to maintaining a sustainable lake trout population in Wachusett Reservoir. Further investigations into the primary forage species at Wachusett Reservoir should also be considered, with the goal of associating the forage base effect on lake trout condition and growth rates, similar to Stolarski 2019. The age and length at maturity and the condition factor for Wachusett Reservoir lake trout are used to set the minimum harvest size limit and should be monitored to protect the breeding population and safeguard future recruitment.

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Appendix A: Wachusett Reservoir Creel Survey Form Explanation of Fields

Time started fishing:_____ AM/PM The time the angler or party started fishing.

Interview Time:_____ AM/PM The time the creel survey interview is conducted. The interview time needs to be at least 30 minutes after the time started fishing for the survey to be valid. If the fishing time is less than 30 minutes, do not fill out the survey. You could come back to that fisherman at a later time. If you are coming back to an angler you surveyed earlier in the day who is still fishing, you can update the interview time, update any new fish caught since the last survey, and leave the rest of the survey the same.

Fishing trip completed? Y /N It is important to get completed fishing trips in order to get an estimate of the average length of time that trips last to make total fishing time estimates at the end of the year. You can survey anglers who are walking out, or arriving at their vehicles after a fishing trip. These surveys will be helpful to capture completed fishing trips.

 # anglers in party:___ This can allow multiple anglers to be included in one survey. However, if anglers started fishing at different times, or are using different fishing methods, a separate survey needs to be completed for that angler.

 # lines in water:___ This would be the total number of lines in the water for the angler or party the survey covers. It is legal for each angler to have up to two lines in the water at one time.

Primary Fishing Type: Baitfish/Bait /Lures /Flies/ Bait and Lures Baitfish includes live or dead fish. Bait includes worms, nightcrawlers, dough, corn, in general anything natural that can be put on a bare hook to catch fish. A lure is something artificial, usually made of wood, plastic, or metal. A rubber or plastic worm is considered a lure. Flies should represent people fly fishing with a fly rod and fly line using an artificial “fly”, however if they are doing something odd and have a fly rod and are using bait then it should be counted as “bait”. If they use two different types of fishing during one trip, ask for the one they spent the most time using. Bait and lures can be circled if their method of fishing is two methods at once- i.e. a shiner cast out to sit while casting with a lure on a second rod.

Target species (choose one):_____ This is the primary fish species that that person is trying to catch on that fishing trip. If they use two different types of fishing to target different species, ask for the one they spent the most time using. If there is confusion about what fish name the angler uses please use the freshwater fish of MA pamphlet to point to a picture or agree upon an accepted name for that species. Please try to be as specific, i.e. record “Largemouth bass” and not “bass.”

Surveyed before in 2012? Y /N

Home zip code? _____ The home zip code for each angler surveyed, including one for each angler in a group.

Prevent aquatic hitchhikers Don't dump bait buckets Just a reminder to the survey agent to remind or educate anglers about preventing the spread of aquatic invasive species.

Date: _____

Day of the week: MO TU WE TH FR SA SU

Location: _____ Please describe the general location where the survey took place or the person has fished, as appropriate. Sample descriptions might include: "Greenhalge Point", "Rainbow Cove", "RR trestle in Oakdale Basin", "Old Stone Church", "near Gate 17 in South Basin", or " shore east of Gates Cove". Anyone fishing the Lilly ponds is not considered to be fishing the reservoir and should not be surveyed.

Survey #: 124 This will be a unique number for each survey automatically filled in for each survey when it is printed out.

Survey agent: _____ The person who is completing the creel survey.

Please list the fish species you have caught today, their length, and whether kept or released: The goal of this question/chart is to record information to represent each fish caught by the angler or anglers on the day of the survey and the approximate length in inches of each fish. "Caught" means they brought the fish in to shore and released it. If there is confusion about what fish name the angler uses please use the freshwater fish of MA pamphlet to point to a picture or agree upon an accepted name for that species. If the angler says " I've caught 4 smallies that were 7-10 inches, I let them all go" Then write down smallmouth bass for lines 1-4, and tell him "Ok, I'm going to write down one 7 inch fish, one 8 inch, one 9 inch, and one 10 inch fish. Does that sound about right?" Also, if an angler gives length estimates for fish that are kept and are easily visible, use your own size estimate as opposed to the angler size estimate if there is a disparity. If the best you can get is something general like "catfish" then that is what will have to be recorded.

	Fish Species	Length (inches)	
1			Kept / Released
2			Kept / Released
3			Kept / Released
4			Kept / Released

If fish were kept, do you plan to eat the fish that you kept? Y /N

Survey Notes: This section is for any additional notes the creel survey agent may have that make that survey unique, or adds additional information that may be useful.

Other survey issues:

Language Barrier: If the survey is attempted but cannot be completed due to a language barrier, then note information such as the number of anglers and lines and complete as much of the survey as possible. Make a note in the survey notes section that some/all fields could not be completed due to a language barrier.

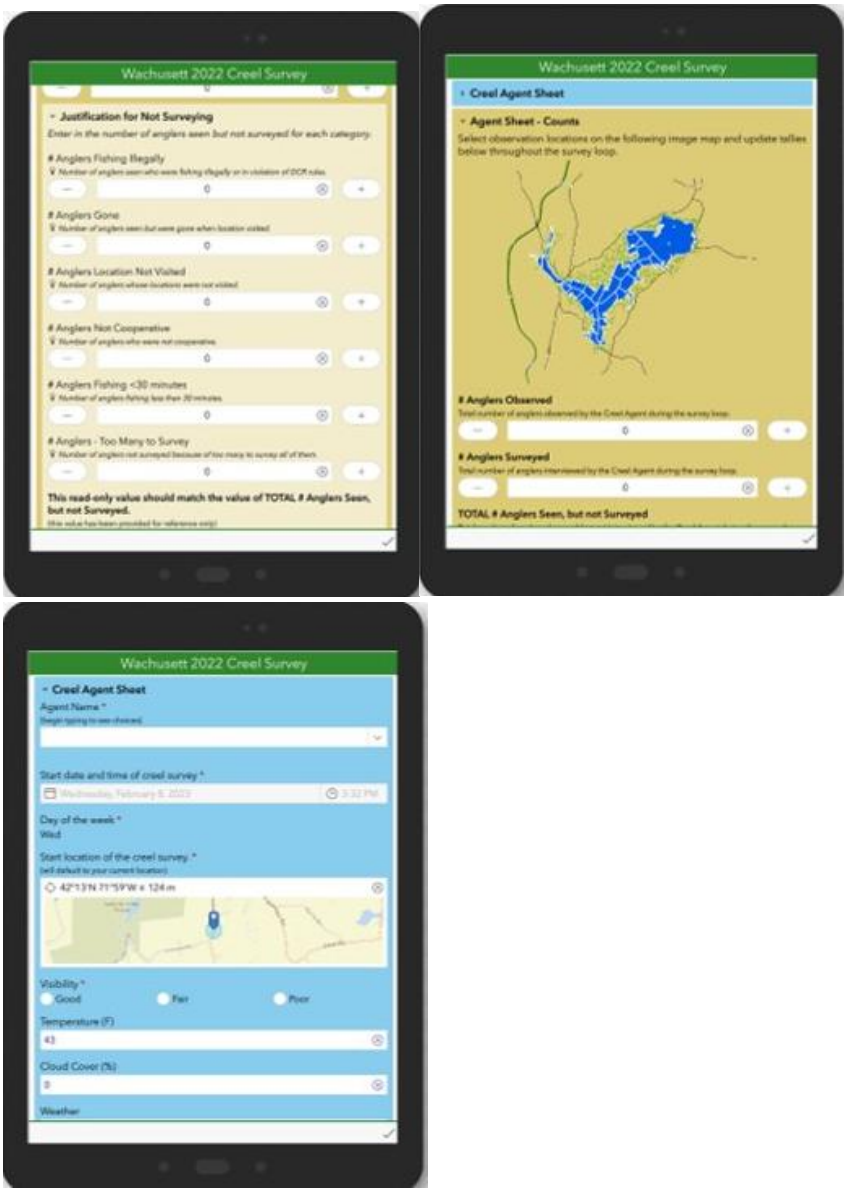
Appendix B: ArcGIS Survey123 Creel Survey

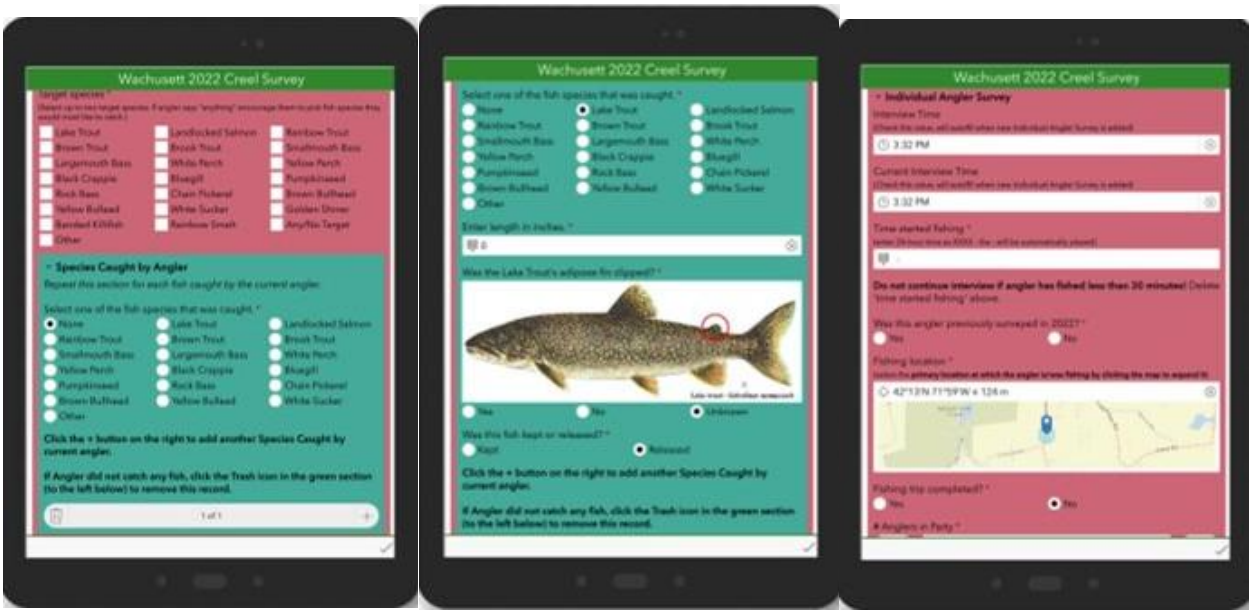
The survey is comprised of four parts including creel agent sheet, agent sheet, individual angler survey, and species caught.

The creel agent sheet consists of basic information including name, survey direction and survey start time. The next portion of the survey is the agent sheet, consisting of a place to tally observed anglers, interview anglers and the number of anglers not interviewed in addition to the reasons an angler is not interviewed such as fishing illegally or fishing for less than thirty minutes.

The individual angler survey asks what time the angler started fishing, zip code, target species, and fishing gear information. Additional information includes species caught, approximate length in inches, and whether fish were harvested. Anglers that caught a lake trout were also asked if the fish was missing an adipose fin.

Figure 14: ArcGIS Survey123 user interface




Wachusett 2022 Creel Survey
Wachusett 2022 Creel Survey
Wachusett 2022 Creel Survey

Appendix C: Explanation of Results and Formulas

Result	Definition
Survey Loop	The period of time that Creel Agents are actively navigating around the reservoir, observing anglers, and interviewing anglers. Each scheduled survey day has an AM and PM loop.
Anglers Counted	Total number of anglers observed fishing on a survey day.
Anglers Surveyed	Total number of anglers interviewed on a survey day.
Angler Trip	The event and period when an angler or group of anglers is actively pursuing fish. Reported as a total, or as an estimated total.
Angler Hours	The amount of time anglers spent fishing. Reported as a total, or as an estimated total.
Estimated	Any result that has undergone a calculation to account for the days in the fishing season when a survey loop was not conducted. This may include Angler Trips, Angler Hours, Fish Caught, or Fish Harvested.
Angler Effort: Estimated Angler Trips	Total Estimated Angler Hours divided by the Mean Completed Trip Length in hours.
Angler Effort: Total Estimated Angler Hours	The calculation is made based on day type, either weekend or weekday, and actual totals of time spent fishing reported by anglers. The ratio of the number of days in a month by the number of survey days (both by day type) is multiplied by the Sum Daily Estimated Angler hours.
Complete trips	Angler trips where the interview took place after the angler was finished fishing for the day.
Incomplete trips	Angler trips where interview took place as angler was still actively fishing.

Result	Definition
Expansion factor	A calculated value that is multiplied by survey result totals to estimate the expected totals for the entire fishing season. The resulting estimation is intended to account for the days in the fishing season that did not have a scheduled survey day. More than half the days in the fishing season were not surveyed. Two expansion factors are used in this report: one to estimate angler trips, the other to estimate fish caught and harvested. Angler Trips expansion factor is used to estimate the number of angler trips by each zip code.
Angler Trips Expansion Factor Formula	Estimated Angler Trips divided by Total Anglers Interviewed.
Catch Rate	Calculated value based on the total number of fish caught divided by the amount of time spent fishing by anglers. In this report, this value used data from both complete trips and incomplete trips. The catch rates from complete trips and incomplete trips are calculated differently, but are combined to report a catch rate for the month or the entire fishing season.
Catch Rate Formula	The mean of ratios of incomplete survey catch rates (the initial catch rate of incomplete surveys divided by the incomple trip anglers interviewed) by month, multiplied by the ratio of completed trip survey hours and reported angler hours multiplied by the ratio of means of completed trip catch rates (completed trips total fish caught divided by the sum of completed trip angler survey hours), added to the sum of incomplete trip angler survey hours and actual angler hours.

Result	Definition
Catch Rate Expansion Factor Formula	Estimated total catch divided by reported total catch. Applied to monthly totals of fish caught to estimate fish caught based on the species.
Estimated Total Fish Caught	The total number of fish caught as reported by anglers multiplied by an expansion factor.
Annual Harvest Rate	Using all fish caught, a value calculated by dividing the estimated total fish harvested by the total surface area of the reservoir, reported as fish per acre per year.
Estimated yield	A calculated value describing how much fish, by weight, was harvested from the reservoir throughout the course of a season. Uses growth curves for lake trout and smallmouth bass to estimate weight of harvested fish.
Estimated yield per acre	Estimated yield divided by the acreage of the reservoir (4,147).
Daily Estimated Angler Hours Formula	The number of fishable hours multiplited by anglers counted. Fishable hours are equivalent to the number of daylight hours in a day.
Mean Completed Trip Length (hours)	The average duration of completed fishing trips. Completed trip data were collected by agents when an angler was finished fishing for the day and knows the start and stop time of the fishing trip.
Sum Daily Estimated Angler Hours	The summation, by either weekend or weekeday, of Daily Estimated Angler Hours.

Appendix D: Additional Plots

The estimated yield reported in section 4.6 was recalculated for the 2011 and 2012 survey years based on results of fish sampling in the reservoir conducted during 2014-2022. This is an improvement over previous estimates because no length or weight information were available for smallmouth bass and only a limited number of Lake trout measurements were available at the time of the 2015 report.

Figure 15: Wachusett Reservoir lake trout length and weight.

These data are the results of the Wachusett Reservoir lake trout tagging program which began in 2014. Points are individual fish.

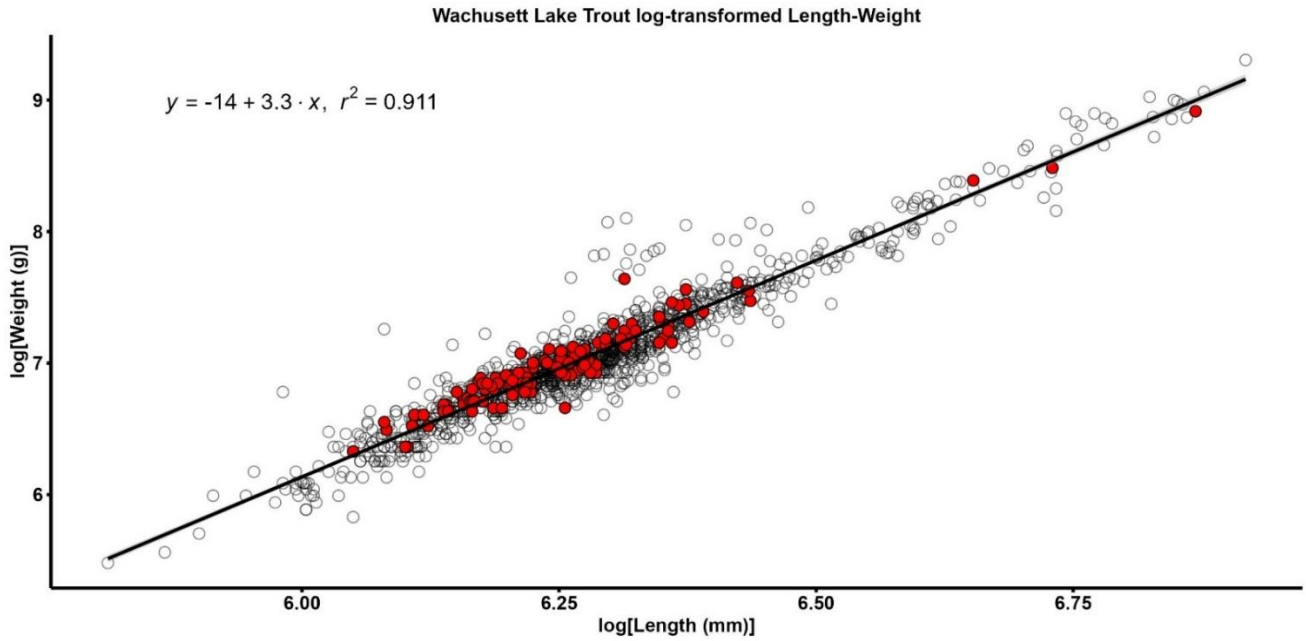


Table 11: Annual lake trout mark and recapture results

Year	*Caught*	*Tagged*	*Caught Mean Weight (g)*	*Caught Mean Length (mm)*	*Not Tagged*
2014	110	102	2,067	582	8
2015	161	147	1,427	547	14
2016	67	60	1,312	553	7
2017	83	76	1,016	515	7
2018	71	65	1,402	541	6
2019	162	150	1,422	538	12
2020	114	NA	1,367	540	114
2021	134	127	1,172	535	7
2022	119	105	1,282	533	4
2023	125	116	1,057	515	9
2024	120	115	1,198	522	5
Total	1,266	1063	1,332	538	193

Figure 16: Proportion of total lake trout caught by sex

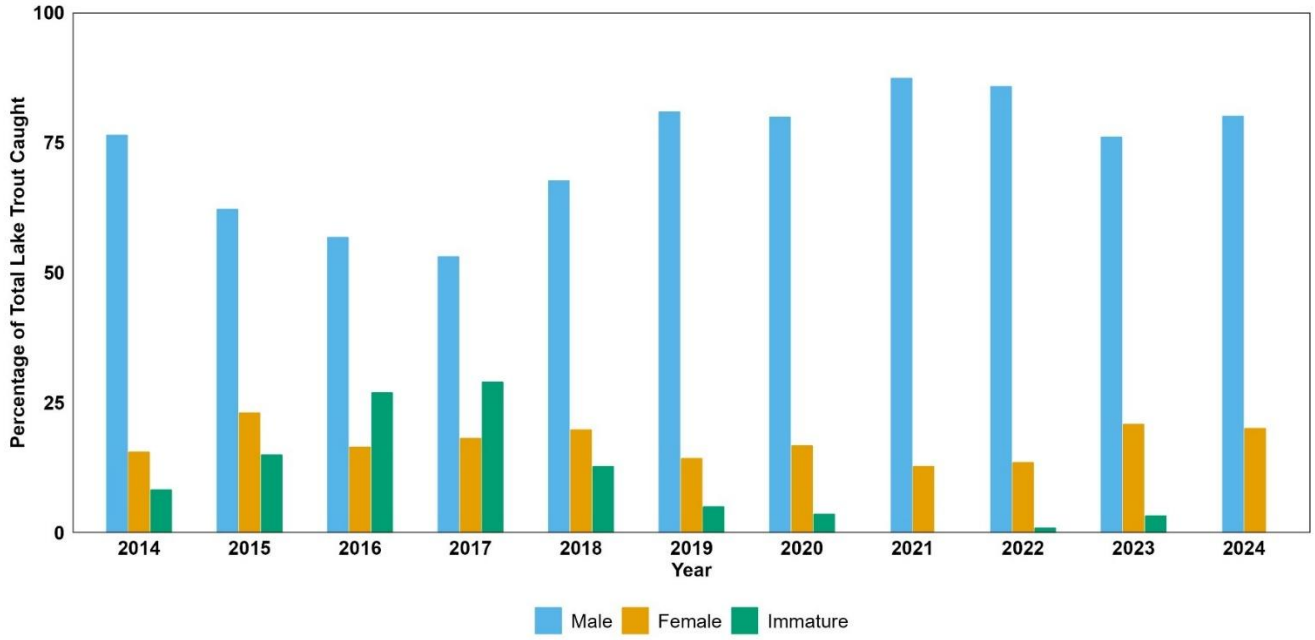
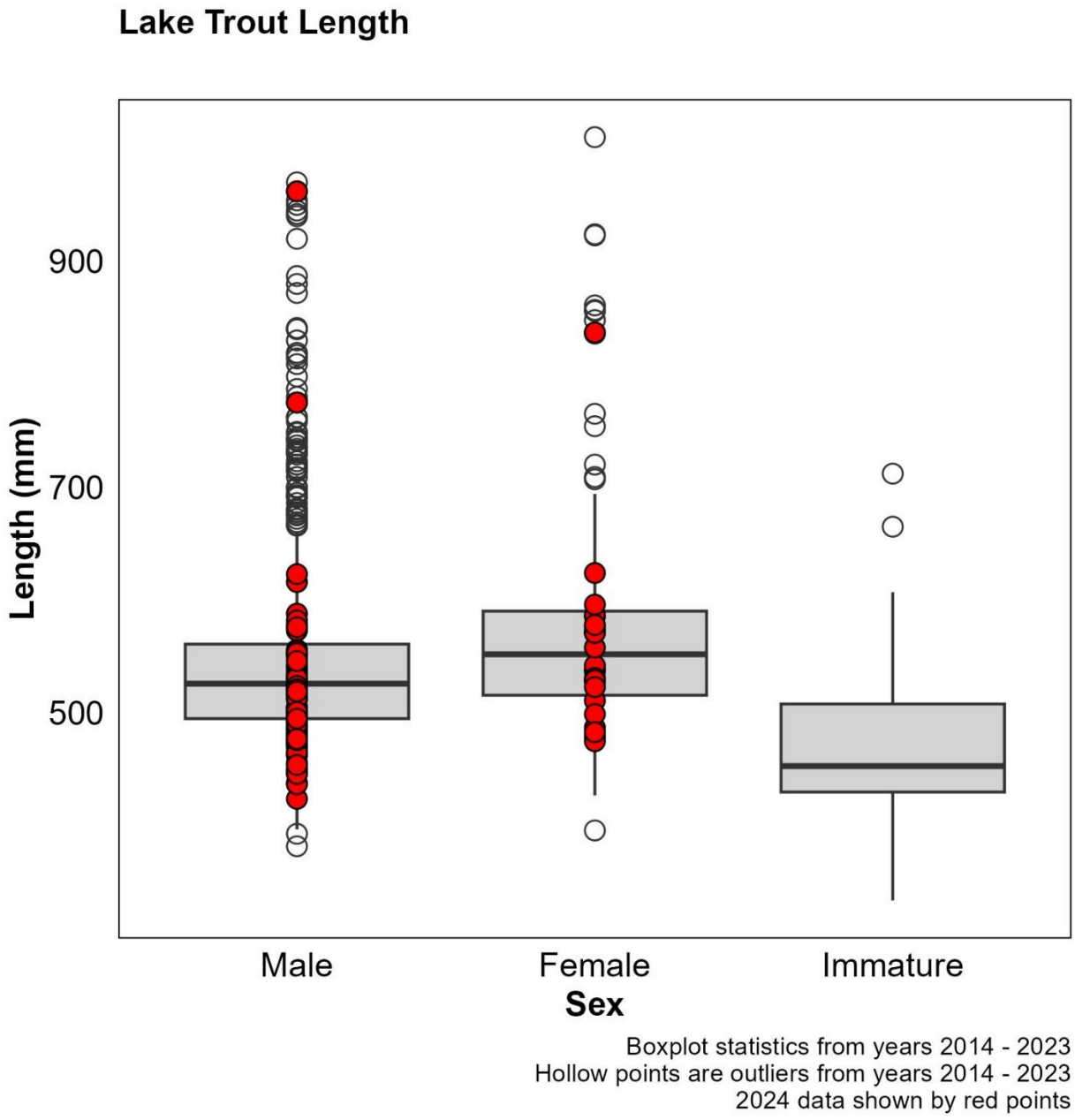
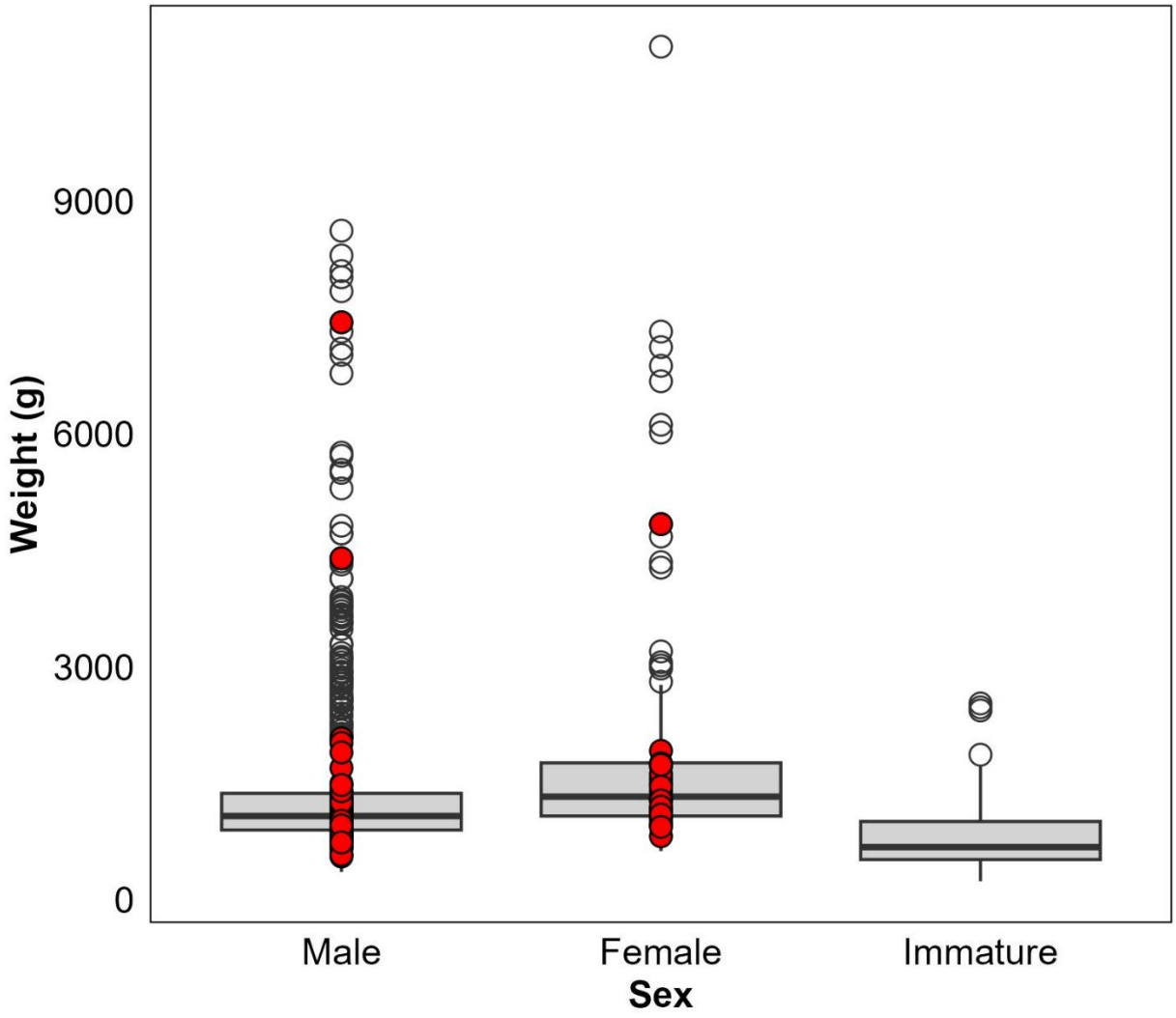


Figure 17: Wachusett lake trout length and weight distributions



Lake Trout Weight



Boxplot statistics from years 2014 - 2023
Hollow points are outliers from years 2014 - 2023
2024 data shown by red points