New Hampshire ASMFC River Herring Sustainable Fishing Plan

New Hampshire Fish and Game Department
Approved August 4, 2020

Executive Summary

Introduction

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring calls for states to close recreational and commercial river herring fisheries with an exception for systems with a sustainable fishery. The Plan defines a sustainable fishery as one "that demonstrates their alewife or blueback herring stock could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment." States and jurisdictions are required to develop sustainability targets with substantiated data, which "may include, but is not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates."

The unique ecosystem interactions found within a state or jurisdiction allow targets to be "applied state-wide or can be river and species specific." New Hampshire is proposing to use the extensive monitoring data from New Hampshire's largest estuary, the Great Bay Estuary System, to evaluate whether river herring stocks can continue to support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment. River herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest. In addition, New Hampshire Fish and Game (NHFGD) monitors river herring spawning stock returns at fish ladders on four of the seven major rivers in the Estuary and monitors juvenile abundance on an estuary-wide basis via a seine survey. Finally, Great Bay Estuary's unique geographical characteristics lend itself to monitoring the systems resource as a whole rather than on a river-specific basis. The estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River.

Current Regulations

The first law protecting river herring in New Hampshire state waters was enacted in 1967. This law required that any resident wishing to harvest river herring using a seine, net, or weir to obtain a license through the New Hampshire Fish and Game Department. Furthermore, in 1987 regulations prohibiting the taking of river herring on Wednesdays was established to provide a day of escapement for

the fishery. In 2005, prior to adoption of Amendment 2, NHFGD took significant management action to reduce river herring harvest in the state. First, in the Exeter River, allowable harvest days were reduced from six to two days per week and a one fish tote per day possession limit was implemented. This action was taken following seven years of substantial increases in the river herring harvest in this river that accounts for the vast majority of the statewide river herring harvest. Second, a large portion of the Taylor River in the Hampton-Seabrook Estuary System was completely closed to the taking of river herring following long term and persistent declines in the river herring runs in the river. In 2012, the Oyster River was closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond to the mouth of the river at Little Bay. This was in response to diminishing returns of river herring to the Oyster River fishway. These actions resulted in a significant reduction in statewide river herring harvest.

Current Status of Stocks

River herring stocks are managed on a statewide level within New Hampshire state waters. Annual return numbers have been monitored on six of the major coastal rivers, which demonstrate inter-annual variability in return numbers (Table 1). With the exception of return estimates produced in 1979, the number of river herring returning to spawn peaked in the early 1990's at nearly 300,000 fish, but has since gradually declined to levels between 100,000 and 200,000 fish. However, estimates of Z have shown a declining trend during this period (Table A4) and the percentages of repeat spawning fish in the rivers monitored in the Great Bay Estuary have ranged from 32% to 52% for all rivers combined since 2000 (Tables 6 and 7).

Changes in return numbers are most pronounced in the Oyster River where the number of returning fish increased steeply between 1985 and 1992 from less than 5,000 fish per year to more than 150,000 fish, followed by a steady, long term decline to less than 1,000 fish in recent years (Table A1). The declines in recent years may be related to low dissolved oxygen levels that have been measured during the summer months in the impoundment behind the fish ladder.

In the Exeter River, returns of spawning river herring to the fish ladder have been inhibited by the inefficiency of the ladder to pass fish. Significant spawning activity has been observed occurring below the fish ladder and reported harvest below this spawning area has consistently exceeded the ladder counts by large amounts indicating a much larger spawning stock than would be suggested by ladder counts. The Great Dam and associated fish ladder, just above the head-of-tide in the Exeter River, was removed in the fall of 2016.

In the Lamprey and Cocheco rivers, river herring returns have varied greatly without trend during the past two decades; building to a high time series level exceeding 90,000 fish in 2016 (Table A1). Spawning activity has also been

observed occurring in significant numbers below the Lamprey River fish ladder. At present, the number of fish which reach and spawn below both the Lamprey and Exeter fish ladders are not quantified and therefore not included in the annual return values, making return or escapement numbers a minimum estimate.

High flows existed in all coastal rivers during April or May in the years 2005–2007, reaching "100-year flood" levels in 2006 and 2007. These high flows prevented river herring from being able to find and ascend fish ladders for significant periods during the spawning run leading to the lowest return numbers through the fish ladders in three decades. During those years, data obtained from the Great Bay Estuary juvenile abundance index seine survey exhibited increases in the geometric mean occurrence of both river herring species (Table 5). This data further suggests that return numbers determined by fish ascending fish ladders are a minimum value and that non-quantified numbers of river herring are successfully spawning below head-of-tide dams.

Sustainability Targets

River herring in New Hampshire are currently managed as a statewide management unit, but two sustainability targets, one fishery-dependent and one fishery-independent, will be established using exploitation rates and numbers of returning river herring per surface acre of available spawning habitat in the Great Bay Estuary. This method was chosen because at least 95% of the river herring harvest in New Hampshire occurs in this estuary and there are currently fish ladders on five of the seven rivers in the Great Bay Estuary, each of which are monitored by the Department annually (Table 3). Historical monitoring of river herring runs within New Hampshire have shown that the numbers of returning river herring to four rivers (Cocheco, Lamprey, Oyster, and Exeter rivers) have accounted for greater than 80% of the returning fish enumerated annually at fish passage structures on New Hampshire coastal rivers (Table 1). The Atlantic States Marine Fisheries Commission Shad and River Herring FMP states that "Definitions of sustainable fisheries and restoration goals can be index-based or model-based" and that "Member states or jurisdictions could potentially develop different sustainability target(s) for river herring based on the unique ecosystem interactions and…Targets can be applied state-wide or can be river and species specific." Therefore, New Hampshire will be using the stocks of river herring returning to the Great Bay Estuary system as an indicator of statewide river herring abundance and refer to them as the 'Great Bay Indicator Stock'. Using an estuary-wide versus river-specific approach is the best suitable method due to the physical/geographical characteristics of the Great Bay Estuary.

The sustainability plan for New Hampshire will include two separate targets, one fishery-dependent and one fishery-independent. The fishery-dependent target will be a harvest level that results in a harvest percentage (exploitation rate) that does not exceed 20% in the 'Great Bay Indicator Stock', providing an 80% escapement level. Specifically, a three-year running average of the total annual river herring harvest from throughout Great Bay Estuary will be compared to a three-year running average of minimum annual counts

of spawning river herring returns documented via fish ladder counts on four rivers (Great Bay Indicator Stock) in Great Bay Estuary plus annual harvest of river herring throughout the estuary system. This is a very conservative target since the harvest from throughout Great Bay Estuary System (including seven rivers, Great Bay, Little Bay, and Portsmouth Harbor) is being compared to river herring return numbers counted at fish ladders on only four of the seven major rivers in Great Bay Estuary which represents some fraction of the total spawning river herring in the estuary each year.

For development of the fishery-independent target, New Hampshire initially used historical studies as a basis for the target used in Maine's River Herring Sustainable Fishery Plan that was previously approved by the Shad and River Herring Board. New Hampshire has never conducted studies to determine ideal densities of fish per acre of available spawning habitat, but the target was established based on studies conducted in the state of Maine during the 1970's and 1980's along with other historical information of annual river herring spawning runs in New Hampshire. Maine studies have indicated that an average return of 235 fish per surface acre and escapement rate of 35 fish per surface acre, allows for adequate harvest, escapement to maintain the run, and available broodstock to increase the run if desired. Using that analysis-based minimum annual escapement of 35 river herring per surface acre, a target value was calculated for the 207 acres of currently accessible spawning habitat in New Hampshire. This escapement level would only provide a minimum of 7,245 river herring returning to the Great Bay Estuary annually. New Hampshire believes that number would be insufficient to maintain current population levels, thus a second approach of calculating half of the mean annual return of river herring in the past 20 years was used to establish a proposed fishery-independent target escapement level of 350 fish per surface acre of available spawning habitat (72,450 fish). This target level is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990.

Proposed Regulation Modification to Support Target

Since recent estimates of exploitation in the Great Bay Indicator Stock have remained below 20% in recent years and total returns are above the 350 fish per acre of available spawning habitat, there are no proposed modifications to existing river herring management plans within New Hampshire state waters and no additional regulations or enforcement measures will be implemented until such a time that the sustainability targets are not met.

Adaptive Management

The Department annually monitors, evaluates, and quantifies fish passage levels along five major coastal rivers in New Hampshire (Cocheco, Oyster, Lamprey, Winnicut, and Exeter rivers). The harvest of river herring is determined through mandatory reporting of all fish taken by state permitted harvesters and through conduct of the federal Access Point Angler Intercept Survey. Fishery-

independent data from the ladder monitoring and fishery-dependent data from the harvest of river herring will be reviewed annually to ensure that both sustainability targets are met within the Great Bay Indicator Stock. If the fishery-dependent target is not met, then the state will use one or more of the following management measures: 1) Add additional days of prohibited harvest of river herring; 2) Implement or lower a daily harvest limit for state-permitted harvesters; 3) Implement a daily catch limit for recreational anglers. If the fishery-independent target is not met, then the state will implement a prohibition on harvest of river herring to all fisheries operating in state waters. As a requirement of Amendment 2, this plan will be reviewed and updated as necessary or every seven years.

1. Introduction

The purpose of this river herring sustainable fishing plan is to ensure river herring populations in New Hampshire remain stable and fishing opportunities continue to exist.

New Hampshire's coastal rivers once supported abundant runs of river herring. They have been denied access to historical freshwater spawning habitat since the construction of milldams as early as the 1600s but more dramatically during the nineteenth century textile boom in many New Hampshire coastal rivers. Barriers eliminated American shad and Atlantic salmon populations, but river herring only declined in numbers because they utilized the small area of freshwater at the base of dams during spring runoffs for spawning.

Restoration of river herring populations in New Hampshire began with construction of fishways in the late 1950s and continued through the early 1970s by the New Hampshire Fish and Game Department (NHFGD) in the Cocheco, Exeter, Oyster, Lamprey, and Winnicut rivers in the Great Bay Estuary, and the Taylor River in the Hampton-Seabrook estuary. These fishways re-opened acres of freshwater spawning and nursery habitat for American shad, river herring, and other diadromous fish.

<u>'Great Bay Indicator Stock' Management Area:</u>

I. Physical Description:

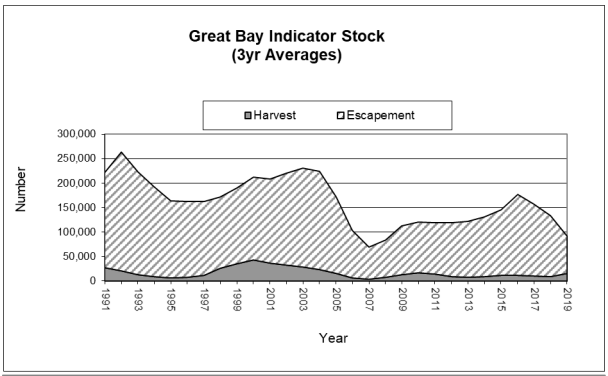
Amendment 2 states that the unique ecosystem interactions found within a state or jurisdiction allow for targets to be "applied state-wide or can be river and species specific." New Hampshire is proposing to use the extensive monitoring data from New Hampshire's largest estuary, the Great Bay Estuary System, to evaluate whether river herring stocks can continue to support a fishery that will not diminish potential future stock reproduction and recruitment.

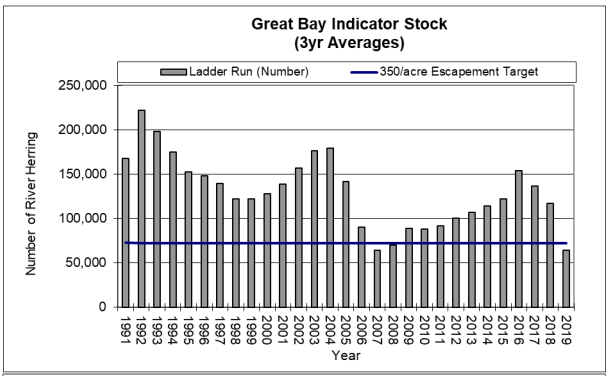
The estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River. NHFGD monitors river herring spawning stock returns at fish ladders on four of the seven major rivers in the Estuary and monitors juvenile abundance on an estuary-wide basis via a seine survey. Analysis of juvenile river herring catch rates from the seine survey do not produce any significant correlations with annual ladder returns, river herring harvest levels, or exploitation rates, likely due to the estuary-wide design and the limited sampling rate in close proximity to river mouths during times of juvenile emigration in the late summer/fall. Fish passage structures on the four monitored rivers allow river herring access to approximately 207 surface acres of available spawning habitat. Great Bay Estuary's unique geographical characteristics lend itself to monitoring the river herring resource as a whole rather than on a river-specific basis.

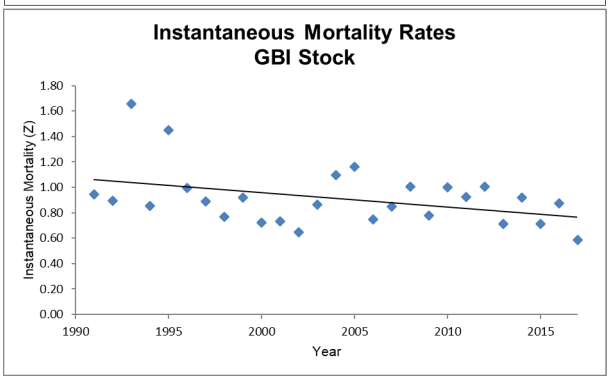
II. Description of fishery:

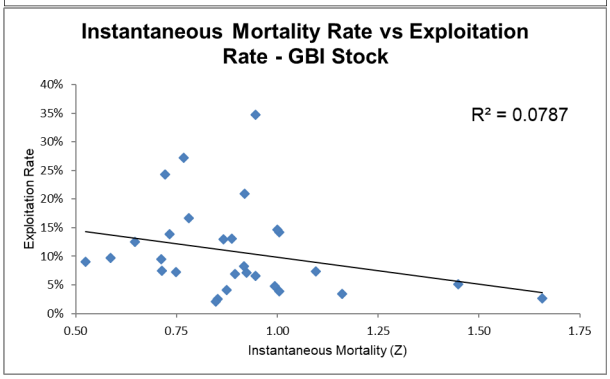
River herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest. The primary harvest of river herring in New Hampshire is for personal use as bait by anglers and lobster harvesters. The intensity of fishing effort and resulting harvest varies greatly between individual rivers, although the methods for harvest are almost primarily cast nets, dip nets, and gill nets in all locations. The annual river herring harvest numbers from the Great Bay Indicator Stock have ranged from approximately 3,200 fish to 43,600 fish (Table 3).

The exploitation rate is currently 17%, which is below the fishery-dependent target of 20% (Table 4) and the run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1). In addition, both the three-year repeat spawning percentage of 44% (59% R-0, 19% R-1, 18% R-2, 4% R-3, 0% R-4; Tables 6 and 7) and the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4). Table A7 and the figure below shows is a significant correlation between mortality rates and exploitation rates. The trend of the data indicates that as the instantaneous mortality rate increases, the exploitation rate decreases.









New Hampshire's coastal area contains two major estuaries with the Great Bay Estuary System being the largest. The Great Bay Estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River (Figure 1).

The following is a description of each river in the estuary, a description of the river herring fishery, and other factors related to river herring management.

Cocheco River

III. Physical Description of River, Watershed, and Impoundment:

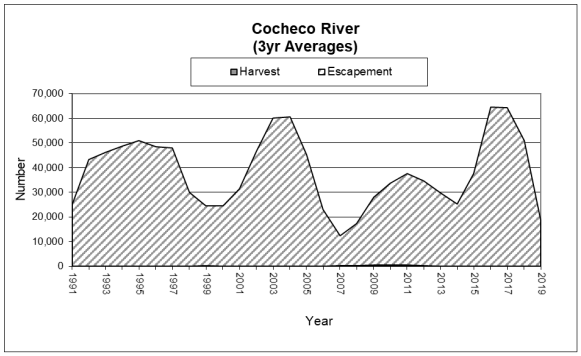
The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River (Figure 1). The Piscataqua River flows approximately 15 km to the sea. The Cocheco River drains a watershed of 479 square km. The lowermost dam (4.6m high, built on a natural ledge for a total height of 8-10 m) on the Cocheco River is within the City of Dover, at rkm 6.1. This dam impounds an area of 20 acres. A Denil fish ladder, which provides access for anadromous fish to approximately 49 acres of potential spawning habitat, was constructed at the dam between 1969 and 1970 by NHFGD. The dam owner maintains a downstream migration structure which was replaced for increased efficiency in 2010 and modified again in 2017. The downstream passage system is a PVC tube emptying in a plunge pool below the dam, which successfully passes emigrating diadromous species when operating efficiently. The next barrier is a set of natural falls located at rkm 10.6. It has never been studied to determine if river herring can ascend this natural falls and continue migrating upriver a distance of 1.3 km to the Watson Dam in Dover, NH, during normal flow conditions. However, there is no fish ladder at this dam and no fish have been observed during occasional observations, but a downstream migration pipe is provided by the hydroelectric facility to accommodate emigration of enhancement stocking in upper river reaches.

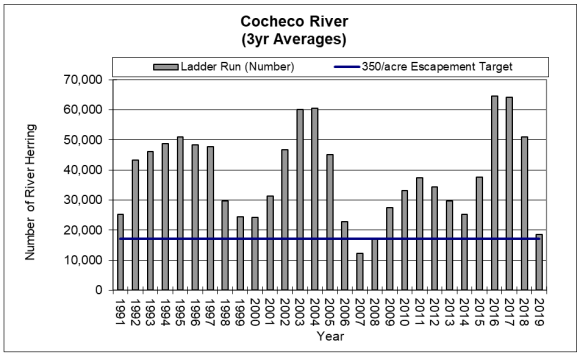
IV. Description of fishery:

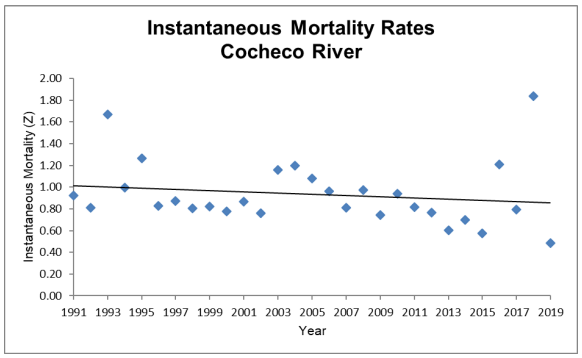
The river herring fishery in the Cocheco River is very sporadic with very few fish harvested over the course of the last several years (Tables 3 and A2). Total annual in-river harvest has ranged from zero fish to approximately 600 fish (Table 4). Harvesters typically fish with cast nets, dip nets, or gill nets. The Cocheco River is closed to fishing from the fish ladder at the lowermost dam to the Washington Street Bridge, approximately 200 m downstream. Most of the river herring harvest occurs from the downstream side of the Washington Street Bridge to approximately 0.50 km downstream. In addition, there is a popular striped bass fishery that occurs along this stretch of river where recreational anglers "snag" river herring to be used as live bait.

The run is currently above the fishery-independent target of 350 fish per acre (Figure below and Table A1); has a three year repeat spawning percentage of 49% (48% R-0, 19% R-1, 28% R-2, 4% R-3, 1% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are steady or slightly declining (Figure Below and Table A4), and there is

no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







V. Ladder Efficiency, Spawning Area, and Water Quality:

Currently there are no concerns with the upstream passage efficiency of the existing fish ladder or the water quality throughout the spawning and emigration season in the Cocheco River. No spawning activity has been observed below the dam in recent years.

Lamprey River

I. Physical Description of River, Watershed, and Impoundment:

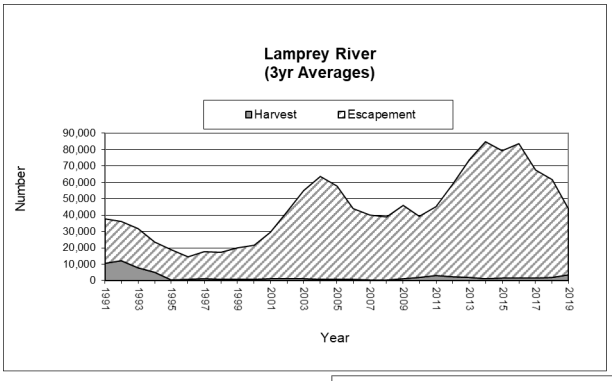
The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay Estuary just north of the mouth of the Exeter River (Figure 1). The mouth of the Lamprey River in Great Bay is approximately 27 km inland from the Atlantic coast. The Lamprey River watershed drains an area of 549 square km. It is the largest watershed that empties directly into The Great Bay. The Macallen Dam, located at rkm 3.8 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. A Denil fish ladder constructed between 1969 and 1970 for anadromous fish by NHFGD allows access to 120 acres of potential spawning habitat. The 3.4 m high Wiswall Dam is located 4.8 km upstream of the Macallen Dam and has a Denil fish ladder that was completed in January of 2012. The fish ladder at

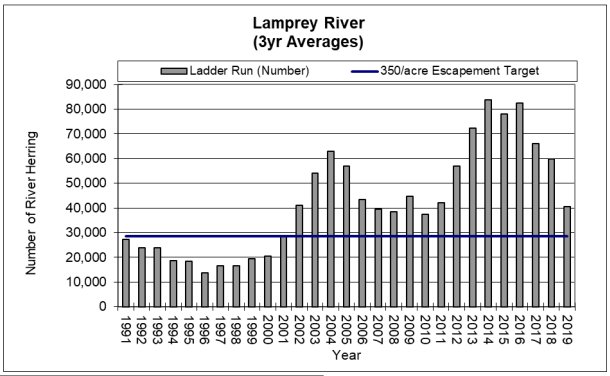
Wiswall Dam is owned and operated by the Town of Durham, NH, with technical advice and monitoring provided by NHFGD. This fishway provides access to another 5.8 km of river habitat up to the next barrier to fish passage, a partially breached dam at Wadleigh Falls in Lee, NH. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults emigrate with limited mortality.

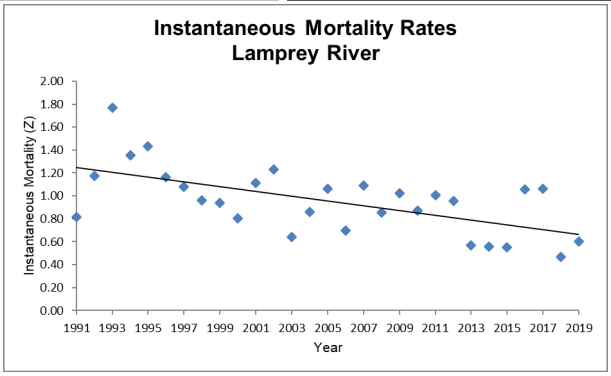
II. Description of fishery:

River herring fishing activity is very sporadic and harvest at the Lamprey River in recent years has been very low, usually less than 2,000 fish per year (Table 3). Landings are reported using a variety of methods including: cast net, gill net, dip net, and weir. Primarily the harvest occurs between approximately 70–500 m downstream of Macallen Dam. It is worth noting that each spring there is a very popular striped bass fishery that occurs within 350 m downstream of Macallen Dam and those anglers "snag" river herring to use as live bait.

The run is currently above the fishery-independent target of 350 fish per acre (Figure below and Table 1), has a three year repeat spawning percentage of 60% (39% R-0, 21% R-1, 29% R-2, 9% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The run of river herring through the fishway each year tends to be mostly alewives. However, each spring towards the end of the annual migration a large number of blueback herring congregate just below the Macallen Dam. A small number of these blueback herring ascend the fishway, but the vast majority spawn below the dam. The area they spawn in is approximately 0.40 acre in size. Above the Macallen Dam, there is a variety of spawning habitat available for both alewives and blueback herring with no observed water quality issues, so it is unclear why most bluebacks spawn below the fishway/dam.

Oyster River

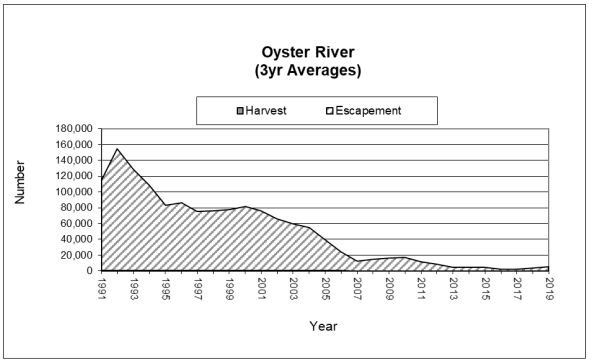
I. Physical Description of River, Watershed, and Impoundment:

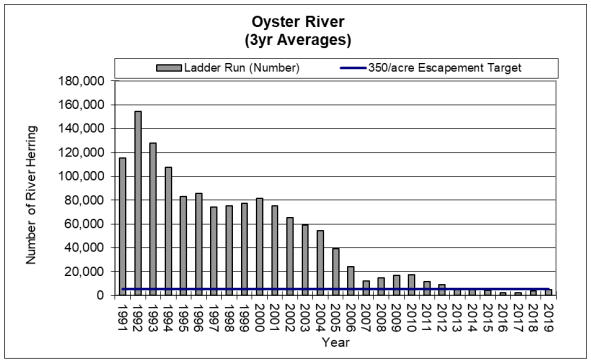
The Oyster River begins in the town of Barrington, NH. The size of the Oyster River watershed is approximately 67 square km. The Oyster flows southeasterly approximately 27.5 km through the towns of Lee and Durham and empties in Little Bay in the Great Bay Estuary (Figure 1). The mouth of the Oyster River lies approximately 19 km from the Atlantic Ocean. The head-of-tide dam occurs at rkm 4.8 in Durham, NH. There is a Denil fish ladder at this dam that was constructed in 1975. This fish ladder provides access to approximately 24 acres of potential spawning habitat. The next dam on the Oyster River occurs at rkm 8.0 and is a barrier to river herring passage.

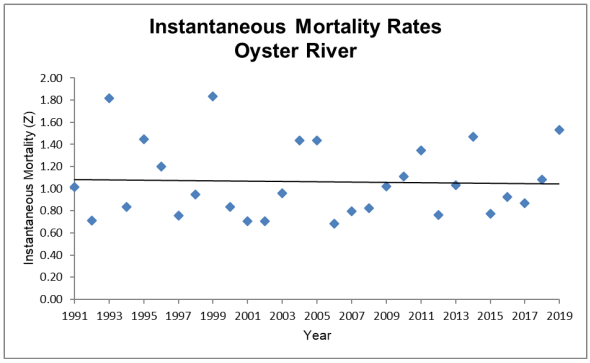
II. Description of fishery:

Prior to the harvest closure in 2012, there was typically very little river herring harvest that occurred in the Oyster River, usually less than 800 fish per year. The limited harvest that occurred was via dip net, cast net, or gill net.

The run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1), has a three year repeat spawning percentage of 29% (74% R-0, 19% R-1, 5% R-2, 1% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method appear steady (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The numbers of river herring returning to the Oyster River fishway have been decreasing since the mid 1990's. One possible explanation for the decline is diminishing water quality in the Mill Pond impoundment above the head-of-tide dam. Increasing eutrophication has been observed by NHFGD staff over the past several years. Due to this eutrophication, oxygen levels could be critically low while juvenile river herring are utilizing the impoundment as nursery habitat. In addition, the Oyster River is used as a municipal water supply. In years when river flows are lower than average very little water is observed flowing over the spillway of the head-of-tide dam. River herring can only emigrate from this impoundment over the spillway and thus become "trapped" in water with diminishing quality in years with low flows.

Squamscott/Exeter River

I. Physical Description of River, Watershed, and Impoundment:

The Exeter River drains an area of 326 square km in southern New Hampshire. The river flows east and north from the Town of Chester to the Town of Exeter and empties into Great Bay northeast of Exeter (Figure 1). The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River. The two former lowermost dams on the main stem Exeter River in Exeter at river kilometer (rkm) 13.5, were removed in the fall of 2016. The next barrier is the Pickpocket Dam at rkm 26.9 (4.6 km high). Removal of the lower dams and a Denil fish ladder at the Pickpocket Dam provide access to

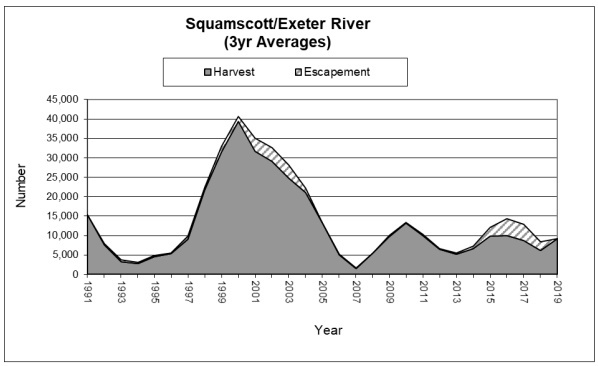
approximately 62 acres of potential spawning habitat. The next barrier above Pickpocket Dam is a set of natural falls at rkm 38.1. The mouth of the Squamscott River in Great Bay lies approximately 27.4 km inland from the sea.

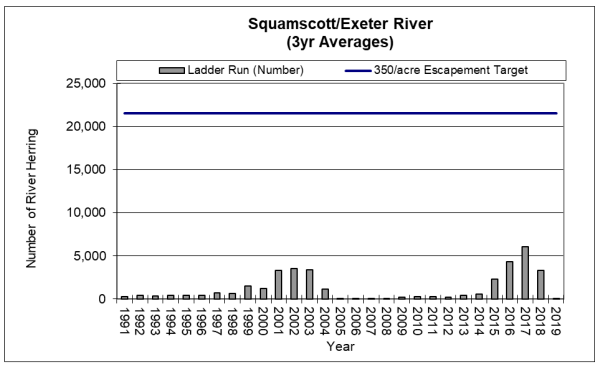
II. Description of fishery:

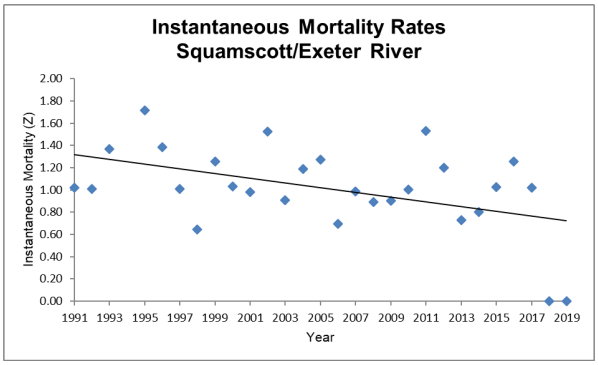
The river herring fishery that occurs in the Squamscott River is conducted to harvest river herring for personal use as bait for lobster and striped bass. The majority of the fishing occurs approximately 125 m downstream of the former Great Dam just to the northwest of the String Bridge. There is an elevated ledge under the String Bridge where migrating river herring gather in numbers waiting to ascend the falls. This is the area the harvesters focus their efforts. The gear types utilized by harvesters include; cast nets, gill nets, dip nets, and wire baskets. Despite being legally limited to just a two-day fishery and a one tote per day per angler limit, the Exeter River can still account for as much as 90% of the total New Hampshire harvest for river herring (Table 3).

In 2005, following a number of years of increased harvest in the Squamscott River, NHFGD implemented major changes to rules for river herring and shad in this river in order to reduce harvest levels. These changes included implementing a one-tote harvest limit per day and increasing the escapement days from one day per week to five days per week. Harvest levels since 2005 have been reduced by roughly 50% of the levels observed between 1998 and 2003 (Table 3) and estimates of instantaneous mortality since 2006 have been on average lower than those prior (Table A4). However, harvest in the Squamscott River has begun to increase in recent years.

The run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1) and has a three year repeat spawning percentage of 26% (74% R-0, 18% R-1, 8% R-2, 0% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The Exeter River is the only river monitored by the NHFGD that has available fresh water spawning habitat located below the fishway. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish. Fish ladder improvements occurred in 1994 and 1999 at the Great Dam fishway and a fish trap was constructed at the upriver end of the fish ladder. In addition, improvements were made in the vicinity of the ladder entrance to enhance attraction flow during normal river flow conditions. Despite work to improve fish passage efficiency of the fish ladder at the Great Dam, the vast majority of river herring spawned below the fish ladder in an approximately 0.50-acre area of fresh water that occurs between head-of-tide and the former Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gathered in large numbers below the former Great Dam and spawning was observed. These observations combined with relatively high levels of documented harvest occurring each year below the former dam and the inefficiency of the fish ladder in passing river herring indicated that escapement to spawn in this river was much higher than measured by the number of river herring passing up river through the fish ladder. The former Great Dam and associated fish ladder were removed in the fall of 2016 and fish were observed freely passing the location in the spring of 2017. Work completed in the fall of 2017 allowed for comparably monitoring of the river herring reaching the Pickpocket Dam beginning in 2018.

There is no downstream fish passage facility at the Pickpocket Dam so emigrating adults and juveniles pass over the spillway when river flows allow. Poor water quality had been documented in the critical nursery habitat above the former Great Dam. Periodic water quality monitoring had recorded low levels of dissolved oxygen (DO) between the two dam locations in some years since 1995 (Smith et al. 2005; Langan 1995).

Other Rivers of Interest:

I. Physical Description of Rivers, Watersheds, and Impoundments:

There are four other major rivers of interest that are not monitored regularly by NHFGD staff. They are the Winnicut, Taylor, Bellamy and Salmon Falls rivers. The rivers range in length from 14.6 km for the Winnicut to 61 km for the Salmon Falls. Watershed sizes range from approximately 855 square km for the Salmon Falls to 28.6 square km for the Taylor River.

The Winnicut River flows directly into Great Bay in Greenland, NH. The NHFGD operated a Canada step-weir fish passage from approximately 1957 until 2009 on the Winnicut River. During the summer of 2009, the fish ladder and associated NHFGD owned dam were removed to restore the Winnciut River. While the dam removal drained a 34-acre impoundment, a run-of-river fishway was built just above the head-of-tide under a bridge constriction that is currently ineffective at passing most fish species.

The Bellamy River enters the Great Bay Estuary at Little Bay in Dover, NH. A partially breached timber crib dam at the head-of-tide at rkm 6.9 was removed to restore anadromous fish habitat in 2004. Since the removal, NHFGD staff has observed large numbers of river herring below the next dam complex (two consecutive dams) approximately 0.6 km upstream. These two dams were removed between 2018 and 2020. The first investigation of effective fish passage past these former dams will occur in the spring of 2020.

The Salmon Falls River joins the Cocheco River to form the Piscataqua River within the Great Bay Estuary. The head-of-tide dam is located at approximately rkm 6.7. A Denil fish ladder has been operated at this dam since 2002. The Salmon Falls River is a border river between the states of Maine and New Hampshire and the fish ladder and associated hydroelectric facility are on the Maine side, in the town of South Berwick. The hydroelectric operator is responsible for operation and maintenance of the fish ladder with technical guidance by both NHFGD and Maine Division of Marine Resources. The Denil fish ladder at the head-of-tide dam provides river herring access to a 58-acre impoundment. New Hampshire harvest estimates from the Salmon Falls River are minimal, with no reported harvest since 2014. The minimal harvest and location of the fish ladder on the Maine side of the river in South Berwick, ME,

were considered justification for continuing to allow harvest in this river without direct annual monitoring by NHFGD.

The Taylor River is located in southeastern New Hampshire and is about 17.1 km long. The river begins on the border between Hampton Falls and Kensington, NH. It flows north, east, then southeast through Hampton Falls where it meets tidal water at Interstate 95. The lowermost 6.4 km of the river forms the boundary between Hampton and Hampton Falls. The first dam is located at rkm 3.2. There is a Denil fish ladder at this head-of-tide dam that was constructed in 1976. The next dam is a barrier to further fish passage and is located at rkm 5.1.

In December of 2014, the NHFGD submitted a proposal to the Atlantic States Marine Fisheries Commission (ASMFC) to withdraw its monitoring requirement of the Taylor River under Amendment 2 for the State of New Hampshire. The ASMFC Shad and River Herring Management Board approved the proposal in February 2015. Since spring 2015, the Taylor River fishway has been operated as a swim through with no regular monitoring or biological sampling performed by NHFGD. The fishway will be opened each spring in late April and closed in late June. Weekly visits by NHFGD staff to check for proper fishway operation will still occur.

River herring runs on the Taylor River have declined considerably from over 100,000 fish in 1986 (Table A1). The major cause of the decline is likely eutrophication of the Taylor River impoundment. The Taylor River fish run was estimated using a Smith-Root Model 1101 electronic fish counter. NHFGD staff made daily visits to the fishway during the migration to perform calibration counts and collect biological samples of river herring, if possible. The last time river herring were observed at the fishway was in 2008 when a total of seven fish were sampled. In addition to declining river herring returns, the Denil fishway at the Taylor River dam was constructed without a trap at the exit, which makes confirmation of fish passage difficult.

II. Description of fishery:

The Bellamy, Winnicut, and Salmon Falls Rivers have a very sporadic harvest ranging from 0 fish to as many as 2,548 fish at the Salmon Falls in 1999 (Table A2). Like many other New Hampshire coastal rivers, it is very difficult to capture river herring efficiently at these locations so harvest can occur anywhere along the tidal portion. However, in the Bellamy River some harvest does occur within the fresh water reach of the river just above the head-of-tide. Typically, gill nets, cast nets, and dip nets are used to harvest river herring at these locations.

After river herring returns diminished from around 100,000 fish in 1986 to 1,397 fish in 2003 and 1,055 fish in 2004, the Taylor River was closed to the taking of river herring by any method of netting in 2005. The closed section of river extends upriver from the railroad trestle bridge near Hampton Harbor to the first

dam at the head-of-tide. No harvest of river herring was reported from the Taylor River from 1999-2004 and only 32 fish were harvested in 1998.

2. Current Regulations

The first law protecting river herring in New Hampshire state waters (inland and 0-3 miles) was enacted in 1967. This established that any resident or nonresident had to obtain a license to use a seine, net, or weir for the taking of river herring. In an effort to provide a day of escapement, the taking of river herring in state waters on Wednesdays by any method was prohibited in 1987.

The harvest of river herring by netting of any kind has been prohibited in the Taylor River from the section of the river upstream of the railroad trestle bridge to the first dam since 2005 due to declines in return numbers. Also, in response to a decline of river herring returns to the Exeter River fishway, new regulations were put in place in 2005 for the Exeter/Squamscott River in Exeter. The new regulations restricted netting to only Saturdays and Mondays. In addition, there is a one-tote limit per day. This location has consistently accounted for the vast majority of river herring harvest in New Hampshire (Tables 3 and A2). In response to diminishing returns of river herring to the Oyster River fishway, the Oyster River was closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond to the mouth of the river at Little Bay in 2012 (Tables 1 and A1).

Currently there are no regulations establishing a length limit or daily bag limit for recreational anglers on either alewives or blueback herring within any tidal water body of the state. Additionally, there are no closed seasons to the taking of river herring by recreational anglers, except that they are prohibited from harvesting river herring on Wednesdays.

3. Brief Description – Current Status of Stocks

The New Hampshire Fish and Game Department manages river herring as a single statewide stock, although annual return numbers are monitored on a river-specific level through fish passage structures along five of the major coastal rivers within the state.
Each of the monitored rivers (Cocheco, Lamprey, Oyster, Exeter, and Winnicut rivers) demonstrate inter-annual variability in the number of returning fish due to various factors which are specific to each river (Table 1). Major factors affecting return values include uncontrollable variables related to environmental conditions (river flow levels, temperatures) and controllable variables such as passage efficiency and harvest levels. Data collection efforts of the Department have also indicated that numbers of returning fish are likely underestimates of actual stock size due to likely successful spawning activity occurring within rivers downstream of the monitored fish passage structures as well as non-monitored river systems that support additional small numbers of river herring returns within the state.

a. Landings

Commercial landings of river herring (fish that are sold via dealers) within the state are monitored through mandatory landings reports submitted annually to the National Marine Fisheries Service. Landings of river herring from commercial fisheries are generally incidental catch, and cannot be differentiated to a level indicating whether harvest occurs within or beyond New Hampshire state waters (Table 2).

The landings of river herring are primarily made through netting activities of state-permitted coastal netters (Tables 3 and A2). All individuals participating in netting of river herring within the state are required to annually submit trip-level reports of both fishing effort and harvest weight or numbers of river herring taken. The estimates of harvest by recreational anglers using hook and line are determined through the cooperative state/federal Marine Recreational Survey.

b. Fisheries Independent / Fisheries Dependent

The New Hampshire Fish and Game Department collects both fishery-dependent and fishery-independent data on an annual basis.

Fishery-dependent data is submitted by all state-permitted coastal harvesters as well as through reported annual harvest estimates produced by the cooperative state/federal Marine Recreational Survey. The data obtained on netting activities is area specific, but recreational angler data is only attributable to state or federal waters.

The majority of fishery-independent data is collected annually through monitoring of the six major coastal rivers in which the primary runs of river herring occur. The data collected provides river-specific enumeration of fish successfully passing the fishway as well as population structure analysis from scale and length samples taken periodically throughout the runs. The biological sample analysis allows the Department to track age structure, species and sex ratios, length distributions, and repeat spawning success of river herring within each river. A beach seine survey is also conducted at 15 fixed stations along New Hampshire coastal waters each month between June and November. Mean catch rates of juvenile river herring within the beach seine survey are used as relative indicators of occurrence of spawning activity from year to year. Although, the information was not used in formulation of the fishery-independent target due to estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months.

Analysis of fishery-independent and fishery-dependent data indicate that New Hampshire's river herring stock is relatively stable, but currently below the minimum target level of 350 fish per surface acre of available spawning habitat. Values of return numbers to the Great Bay Indicator Stock have consistently increased from 2007-2017 , but declined in 2018 and 2019 (Table 1). Estimates of Z have shown a declining trend (Table A4), the percentage of repeat spawners have remained between 32% and 52% (Table 6), spawning escapement has consistently exceeded 80% and exploitation rates since 2001 have remained below 20% until 2019 (Table 4).

c. Other

(None)

4. Fisheries to be Closed

a. Commercial

No commercial fisheries directed at harvest of river herring within New Hampshire state waters will be closed.

b. Recreational

No recreational fisheries directed at harvest of river herring within New Hampshire state waters will be closed.

5. Fisheries Requested to be Open

a. Commercial

River herring harvested in New Hampshire state waters are for personal use as bait in a variety of fisheries. Since these fish are not sold, there are no commercial fisheries occurring within New Hampshire state waters directed towards the harvest of river herring. Additionally, the National Marine Fisheries Service federal landings database that is inclusive of fishing harvest outside of New Hampshire indicates the recent annual river herring landings are negligible (Table 2). All commercial fisheries of river herring will remain open and the existing regulations will continue until such time that either the fisheries-independent or dependent targets have been met.

b. Recreational

Harvest of river herring occurring in New Hampshire is primarily through state-permitted coastal harvesters that fish for personal use, such as bait. As a result, this fishery is classified as recreational in New Hampshire. Upon all water bodies in New Hampshire (with the exception of the Exeter River) harvest of river herring is prohibited on Wednesdays and no daily limit exists. Netting in the Exeter/Squamscott River is limited to Saturdays and Mondays only between April 1 and June 30, and harvest is limited to one tote per day.

Similarly, hook and line anglers target river herring to be used as bait in a few relatively isolated locations, which are monitored through the cooperative state/federal Marine Recreational Survey with low frequency of harvest and poor associated precision values associated with those landings. There is currently no size or bag limit on river herring taken by angling in New Hampshire, but a closure to all river herring harvest on Wednesdays is in place.

All recreational fisheries will remain open in New Hampshire and the regulations stated above will continue until such time that either the fisheries-independent or dependent targets have been met.

c. Incidental

(None)

6. Sustainability Target(s)

a. Definition

The sustainability target will be established as a reference point and defined as a point below which sufficient escapement of spawning populations of river herring occurs to maintain annual runs at sustainable levels in New Hampshire.

River herring in New Hampshire are currently managed as a statewide management unit, but two sustainability targets, one fishery-dependent and one fishery-independent, will be established using exploitation rates and numbers of returning river herring per surface acre of available spawning habitat in the Great Bay Estuary. This method was chosen because 1) river herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest, 2) New Hampshire Fish and Game monitors river herring spawning stock returns at fish ladders on 4 of the 7 major rivers in the Great Bay Estuary, and 3) monitors juvenile abundance on an estuary-wide basis via a seine survey. Historical monitoring of river herring runs within New Hampshire have shown that the numbers of returning river herring to these four rivers have accounted for greater than 80% of the returning fish enumerated annually at fish passage structures on New Hampshire coastal rivers (Tables 1 and A1). The Atlantic States Marine Fisheries Commission (ASMFC) Shad and River Herring FMP states that "Definitions of sustainable fisheries and restoration goals can be index-based or model-based" and that "Member states or jurisdictions could potentially develop different sustainability target(s) for river herring based on the unique ecosystem interactions and…Targets can be applied state-wide or can be river and species specific." Therefore, New Hampshire will be using the stocks of river herring returning to the Great Bay Estuary system as an indicator of statewide river herring abundance and refer to them as the 'Great Bay Indicator Stock'.

The fishery-dependent sustainability target will be set at a harvest level that results in a harvest percentage (exploitation) rate that does not exceed 20% in the 'Great Bay Indicator Stock', providing an 80% escapement level. Specifically, a three-year running average of the total annual river herring harvest from throughout Great Bay Estuary will be compared to a three-year running average of minimum annual counts of spawning river herring returns documented via fish ladder counts on four rivers in Great Bay Estuary plus annual harvest of river herring throughout the estuary system. This is a conservative target, since the harvest from throughout Great Bay Estuary System (including seven rivers, Great Bay, Little Bay, and Portsmouth Harbor) is being compared to river herring returns counted at fish ladders on only four of the seven major

rivers in Great Bay Estuary, which represents some fraction of the total spawning river herring in the estuary each year.

Table 4 shows the calculated harvest percentages for each year in New Hampshire since 1989, based on rolling three-year averages. New Hampshire has remained below the sustainability target level of 20% harvest within the 'Great Bay Indicator Stock' for all but three years (Table 4) and in subsequent years following the high harvest percentages, the annual returns of river herring continued to increase for three consecutive years. This sustainability target allows for limited harvest of river herring within New Hampshire while still maintaining healthy populations of river herring.

For the fishery-independent target, New Hampshire is proposing to use a target similar to that used in Maine's River Herring Sustainable Fishery Plan, which was previously approved by the Shad and River Herring Board. New Hampshire has never conducted studies to determine ideal densities of fish per acre of available spawning habitat. Therefore, the target was created based on studies conducted in the state of Maine during the 1970's and 1980's, which have indicated that an average escapement rate of 35 fish per surface acre, allows for adequate harvest, escapement to maintain the run, and available broodstock to increase the run if desired. Using that analysis-based minimum annual escapement of 35 river herring per surface acre, a target value was calculated for the 207 acres of currently accessible spawning habitat in New Hampshire. This escapement level would only require a minimum of 7,245 river herring returning to the Great Bay Estuary annually. New Hampshire believes that number would be insufficient to maintain current population levels. Therefore, a second approach of calculating half of the mean annual return of river herring in the past 20 years was used to establish the proposed fishery-independent target escapement level of 350 fish per surface acre of available spawning habitat (72,450 fish). This target is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990 (Table A1).

b. Methods Used to Develop Target

River herring runs in New Hampshire have been monitored by the Department at fish ladders since initiation of restoration programs in the early 1970's. Seven fish ladders have been operated and maintained along six coastal rivers, although the lowermost dams and associated fish passage structures on the Winnicut River and Exeter River were removed in the fall of 2009 and 2016, respectively. At five of the locations (Cocheco, Oyster, Lamprey, Winnicut, and Exeter), river herring runs are enumerated and sampled for biological information such as age, sex, species, and repeat spawning occurrence when possible.

The period of peak abundance of returning river herring in the Great Bay Indicator Stock, occurred in the early 1990's (Table 1). Using a three-year running average, the greatest returning numbers occurred in 1992 followed by six years of successive decline in number of river herring and then six years of continued increase back to level comparative of the early 1990's. Return numbers have steadily increased in most recent

years with values in 2017 that are more than double the time series low observed in 2007. The inter-annual variability of return numbers can be great, but many factors including weather, river levels, water temperature, and inefficiencies of fish passage structures play a large role in the variation.

An example of strong control by environmental conditions occurred in 2005, 2006, and 2007 when New Hampshire coastal rivers experienced flood conditions that reached "100-year flood" levels in 2006 and 2007. During years where persistent high river velocity exists in all coastal rivers in the state, many river herring are unable to reach or successfully ascend the fish ladders monitored by the Department. As a result, the passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years.

Although annual river herring return values for 2005–2007 declined significantly from 2004, the previously mentioned flooding conditions were a large reason for potential underestimation during those years. Reviews of supplemental data such as young-of-the-year indices (Table 5) and percentage of repeat spawners within each river (Table 6) provide evidence of the population's health and relative stability despite reduced passage numbers. The supplemental data from the Great Bay Estuary juvenile finfish seine survey conducted by the Department showed increases in young-of-the-year indices for the two species of river herring in both 2006 and 2007 (Table 5), when the number of fish able to ascend the ladder were low. Since return numbers to the fish ladders were down those two years, large numbers of river herring may have still successfully spawned downriver from the fish ladders. Additionally, Table 6 shows that the percentage of repeat spawning fish that have been observed in the four rivers being monitored for the Great Bay Indicator Stock has been consistently high, ranging from 32% of returning fish in 2009 to 52% in 2006.

The majority of fishing effort and resulting harvest directed towards river herring in New Hampshire is conducted through state-permitted coastal harvesters using gear such as cast nets, gill nets, and dip nets. The harvest levels reported by harvesters also fluctuates between years, but is much more stable than return numbers (Table 3). All reported landings are associated with an area of fishing activity, which indicates that the large majority of river herring harvest comes from a single location, the Squamscott River (Tables 3 & 4). Collection of the harvest data by netters also has indicated that the enumeration of returning fish in the Exeter River fish passage structure is greatly underestimating the actual number of fish within that river system. This is particularly noticeable when the harvest percentages in the tidal portion is several times higher than the number of fish ascending the ladder, which would suggest that even though few ascend the fishway, many river herring in that location continue to spawn below the fish ladder.

Harvest estimates of river herring by recreational finfish anglers are also available through the cooperative state/federal Marine Recreational Survey, but infrequency of occurrence and poor levels of precision associated with the estimates make the data to unreliable for inclusion at this time (Table 2).

The Department reviewed the harvest percentages (exploitation rates) of river herring within the 'Great Bay Indicator Stock' locations between 1989 and 2019. To limit the variation between years, three-year rolling averages were used to establish both the annual return and the harvest portions of the harvest percentage. The resulting harvest percentages have ranged from as high as 26% in 2000 to 4% in 1995 (Table 4). Exploitation rate data was plotted against instantaneous mortality rates calculated from age data using the Chapman-Robson method (Figure A1). When a linear regression correlation was applied to the Great Bay Indicator Stock there was a significant correlation between the two factors, however there is no significant correlation within each river alone. Although there is a correlation between changes in the calculated instantaneous mortality rate and the exploitation rate, the plot indicates that years of high exploitation coincide with years of low mortality rate, and conversely years of low exploitation coincide with years of a high instantaneous mortality rate. This suggests that the exploitation rate is likely more dependent on the mortality rate than the mortality rate being dependent on the exploitation rate. Specifically, in years of low calculated instantaneous mortality rates, there are more fish returning and available for individuals to harvest, whereas in years of high calculated instantaneous mortality rates, there are fewer fish for state-permitted netters to harvest. Great Bay Indicator Stock exploitation rates have remained relatively low, near or below 15%, since 1991 but did increase briefly to near or above 20% from 1998 to 2002. This was driven by an increased effort and resulting harvest in the Squamscott River for unknown reasons, but prompted NHFGD to enact new regulations to limit the permitted harvesting at that location to only two days per week as opposed to the previous six days, as well as implementing a daily harvest limit of one tote per person. A brief increase in exploitation again occurred between 2009 and 2011, but never reached the 20% target (Table 4).

NHFGD does not currently have available data sufficient for analysis to determine an escapement target below which the river herring stock would be negatively affected. Therefore, the 20% fishery-dependent and 350 fish per surface acre fishery-independent sustainability targets from the 'Great Bay Indicator Stock' were set based on the downward trend of calculated instantaneous mortality rates, the correlation of exploitation rate and mortality rate that does not indicate that increased harvest corresponds to increased mortality, and the historical observations of fishing effort and exploitation rates. NHFGD feels that these two targets will provide a large enough resource of spawning river herring to maintain current population levels.

c. Monitoring to be Conducted to Support Target(s)

New Hampshire Fish and Game Department staff will monitor the return of river herring on the Cocheco, Lamprey, Oyster, and Exeter rivers, collectively referred to as the 'Great Bay Indicator Stock', on an annual basis. Monitoring of these river specific returns will include enumeration of fish successfully ascending the fish passage structure,

maintenance of fishways to increase passage efficiency, and periodic biological sampling of river herring at each location throughout the run. Biological samples will be used to determine age, sex, repeat spawning percentage, and species distributions of the returning populations within each river in an effort to track relative health and stability of herring within each of the rivers. The enumeration from these four rivers of New Hampshire's primary river herring run will be used to calculate the return portion of the 3-year average harvest percentage of the 'Great Bay Indicator Stock.'

As supplemental information, a beach seine sampling study will be used to determine a mean catch per seine haul index of juvenile river herring within the Great Bay System. This relative annual index can be used to determine successful occurrence of river herring spawning activity between years, although the information was not used in formulation of the fishery-independent target due to estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months.

Mandatory reporting of harvested quantities and directed effort toward river herring is required by the ASMFC's FMP. The reported information must provide harvest data specific to a location or river system within the state. The harvest portion of the 'Great Bay Indicator Stock' will be calculated annually by totaling the number of river herring reported to be harvested from the Great Bay Estuary System. This will include the Great Bay, Little Bay, and Cocheco, Lamprey, Exeter, Bellamy, Salmon Falls, and Piscataqua rivers. The harvest and return portions of the 'Great Bay Indicator Stock' will then be used to ensure that the annual harvest percentage (exploitation rate) does not exceed the fishery-dependent sustainability target level of 20%.

The ladder counts and harvest information at each location will be used to ensure that the number of returning fish to the Great Bay Indicator Stock will remain above the fishery-independent target of 350 fish per acre of spawning habitat within the Great Bay Estuary (approximate 207 acre area), resulting in a target return of 72,450 river herring.

7. Proposed Regulation Modification to Support Target(s)

Since exploitation rates have remained well below 20% in recent years (Table 4), there are no proposed modifications to existing river herring management plans within New Hampshire state waters and no additional regulations or enforcement measures will be implemented until such a time that the sustainability targets are not met.

8. Adaptive Management

a. Evaluation Schedule

The New Hampshire Fish and Game Department annually monitors, evaluates, and quantifies fish passage levels along five major coastal rivers in New Hampshire (Cocheco, Oyster, Lamprey, Winnicut, and Exeter rivers). Returning fish are enumerated

and sampled for biological information, including species, sex, age, and levels of repeat spawning. Monitoring of specified rivers will continue on an annual basis with the exception of the Winnicut River due to removal of the dam and associated fishway in the fall of 2009.

The harvest of river herring is determined through mandatory reporting of all landings by netters in New Hampshire state waters. Additional estimates of angling harvest are provided by the cooperative state/federal Marine Recreational Survey on an annual basis, but precision of those estimates is often very poor and are not reliable enough to be included in the annual harvest calculation. The harvest percentage (exploitation rate) will be determined annually and used to calculate a 3-year average value to compare to the sustainability target level of 20%.

b. Consequences or Control Rules

If the statewide harvest of river herring, determined by combining reported landings by state-permitted coastal harvesters from the 'Great Bay Indicator Stock' results in an exploitation rate that exceeds the fishery-dependent 20% sustainability target, the New Hampshire Fish and Game Department will take the following action:

i) Use landings and return data to identify the problem area(s) to determine whether over harvest of river herring is river or fishery specific.

ii) Once problem area is identified, one or more of the following measures may be used:

1) Add additional days of prohibited harvest of river herring. This could be statewide or in identified problem areas.

2) Implement or lower a daily harvest limit for state-permitted coastal netters at all areas or identified problem areas.

3) Implement a daily catch limit for recreational anglers statewide or in identified problem areas.

If the fishery-dependent target of 350 river herring per surface acre of available spawning habitat, 72,450 river herring, is not met, the New Hampshire Fish and Game Department will take the following action:

i) Implement a prohibition on harvest of river herring to all fisheries operating within state waters.

References:

Langan, R. 2004. Cooperative Institute for Coastal and Estuarine Environmental Technology. Unpublished data.

Smith, B., K. Weaver, and D. Berlinsky. 2005. The Effects of Passage Impediments and Environmental Conditions on Out-Migrating Juvenile American Shad. Final Report for NMFS Federal Aid Project no. NA03NMF4050199. 20 pp.

Table 1. **Three-year running average of the number* of river herring successfully ascending fish passage structures in New Hampshire by river between 1989 and 2019. The Great Bay Indicator Stock rivers set the sustainability target.**

	'Great Bay Indicator Stock'								
Year	Cocheco River	Lamprey River	Oyster River	Exeter River	Winnicut River+	Taylor River	Annual River Herring Return (# Fish)	'Great Bay Indicator Stock' Return (# Fish)	Percentage of Annual Return
1989	--	--	--	--	--	--	--	--	--
1990	--	--	--	--	--	--	--	--	--
1991	25,302	27,159	115,163	313	--	38,332	206,269	167,728	81%
1992	43,314	23,946	154,529	425	--	40,903	263,117	222,072	84%
1993	46,205	23,890	127,596	376	--	60,120	258,187	198,067	77%
1994	48,668	18,640	107,595	408	--	58,710	234,021	175,174	75%
1995	50,966	18,437	82,886	435	--	47,260	199,984	152,579	76%
1996	48,431	13,741	85,744	420	--	22,345	170,680	148,195	87%
1997	47,778	16,447	74,392	714	--	15,097	154,428	139,331	90%
1998	29,742	16,461	75,133	647	--	14,171	136,154	121,983	90%
1999	24,379	19,417	77,033	1,505	--	19,199	141,533	122,334	86%
2000	24,298	20,564	81,351	1,249	350	27,062	154,873	127,461	82%
2001	31,402	28,358	75,308	3,352	649	25,424	164,495	138,421	84%
2002	46,667	41,024	65,347	3,526	2,895	18,968	178,426	156,564	88%
2003	60,087	53,960	58,901	3,372	4,529	4,764	185,613	176,320	95%
2004	60,535	62,961	54,216	1,165	6,837	2,760	188,475	178,878	95%
2005	45,193	56,948	39,117	73	5,391	895	147,618	141,332	96%
2006	22,899	43,277	23,950	55	3,856	478	94,516	90,181	95%
2007	12,193	39,574	12,113	41	3,689	199	67,809	63,920	94%
2008	16,940	38,314	14,745	75	5,575	447	76,095	70,076	92%
2009	27,555	44,632	16,621	240	6,959	597	96,604	89,051	92%
2010	33,168	37,333	17,149	250	4,636	825	93,362	87,902	94%
2011	37,303	42,066	11,807	279	1,874	367	93,697	91,456	98%
2012	34,451	56,879	8,778	234	218	275	100,835	100,342	100%
2013	29,678	72,239	4,826	407	26	93	107,269	107,150	100%
2014	25,304	83,713	4,650	585	2	92	114,346	114,252	100%
2015	37,587	78,040	4,393	2,313	0	93	122,425	122,333	100%
2016	64,555	82,358	2,298	4,324	0	57	153,592	153,535	100%
2017	64,208	66,042	2,386	6,092	0	--	138,728	136,697	99%
2018	50,970	59,723	3,690	3,327	18	--	117,728	116,601	99%
2019	18,450	40,496	5,059	30	18	--	64,053	64,025	100%

** All numbers shown are 3-yr running average values of number of river herring returning.*

+ Winnicut River return numbers have been excluded from the return portion of the 'Great Bay Indicator Stock' because the dam and associated fish passage structure were removed in fall of 2009.

Table 2. Estimates of annual river herring harvest occurring in New Hampshire waters, derived from the cooperative state/federal Marine Recreational Fisheries Statistics Survey, with associated proportional standard error (PSE) values, and reported commercial landings[+] from the federal landings database between 1989 and 2019.

	State/MRIP				Federal Landings Database	
	Blueback Herring		Alewife		Blueback Herring	Alewife
Year	Estimated Harvest (# Fish)	PSE	Estimated Harvest (# Fish)	PSE	Reported Landings (# Fish)	Reported Landings (# Fish)
1989	0	--	0	--	0	22,400
1990	0	--	0	--	0	0
1991	0	--	0	--	0	0
1992	0	--	0	--	0	19,604
1993	0	--	0	--	0	5,352
1994	0	--	0	--	0	0
1995	0	--	408	77.7	0	0
1996	0	--	0	--	0	0
1997	0	--	0	--	0	0
1998	0	--	0	--	0	51,988
1999	0	--	0	--	0	0
2000	0	--	0	--	0	0
2001	267	102.8	15,073	98.6	0	0
2002	0	--	0	--	0	0
2003	5,121	103.3	0	--	0	0
2004	0	--	0	--	0	0
2005	78	72.7	0	--	0	0
2006	0	--	0	--	0	0
2007	0	--	63,323	51.5	0	2,816
2008	0	--	154,208	71.6	0	16,264
2009	278	76.7	8,045	88.8	0	1,880
2010	0	--	14,681	89.0	0	14,932
2011	0	--	0	--	0	8,226
2012	42	102.6	34,991	84.2	0	5,362
2013	64	104.0	22,074	57.2	0	8,840
2014	5,246	98.4	61,271	54.0	0	0
2015	0	--	0	--	0	0
2016	0	--	0	--	0	0
2017	86	108.4	691	85.9	0	0
2018	0	--	13,581	85.4	0	0
2019	10,331	97.6	2,340	96.7	0	0

[+] *Landings values are in numbers of fish landed by commercial harvesters within New Hampshire waters, but the location of harvest is exclusively from the EEZ*

Table 3. Number* of river herring harvested by state-permitted coastal netters in New Hampshire by location between 1989 and 2019; Areas used to calculate the harvest portion of the annual 'Great Bay Indicator Stock' used to set the sustainability target are shown.

Year	Cocheco River+	Lamprey River+	Oyster River+	Exeter River+	Winnicut River+	Bellamy River+	Salmon Falls River+	Great Bay+	Little Bay+	Portsmouth+	Piscataqua River+	All Other Locations	Statewide Total River Herring Harvested (# Fish)	Great Bay Estuary River Herring Harvested (# Fish)	% of Statewide Total
1989	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1990	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1991	0	10,565	385	15,224	297	1,163	61	13	0	0	326	1,467	29,502	28,035	95%
1992	19	12,058	620	7,618	74	946	68	4	0	0	20	1,023	22,451	21,428	95%
1993	34	7,952	927	3,315	80	551	112	4	3	0	20	532	13,530	12,998	96%
1994	34	4,900	855	2,767	44	47	98	13	3	0	0	468	9,229	8,761	95%
1995	16	410	621	4,606	27	164	180	13	3	0	1	98	6,139	6,041	98%
1996	2	703	522	5,274	366	238	223	14	0	0	7	44	7,393	7,349	99%
1997	105	1,053	715	9,068	375	237	594	5	0	0	17	42	12,211	12,170	100%
1998	116	917	752	21,792	368	445	1,045	1	63	0	25	634	26,158	25,524	98%
1999	140	730	384	31,432	23	543	1,807	3	63	83	43	930	36,182	35,253	97%
2000	70	897	386	39,347	24	770	1,871	3	72	83	65	1,243	44,831	43,588	97%
2001	57	1,228	504	31,631	24	820	1,762	3	62	83	76	628	36,879	36,251	98%
2002	47	1,135	574	29,097	24	1,007	997	0	62	0	52	317	33,312	32,995	99%
2003	25	1,214	444	24,808	0	844	650	15	53	0	20	3	28,077	28,074	100%
2004	82	770	475	21,051	0	518	232	15	0	0	0	127	23,270	23,143	99%
2005	85	873	363	13,215	19	369	158	15	0	0	0	127	15,224	15,097	99%
2006	114	614	305	5,084	163	435	32	2	0	0	0	127	6,875	6,748	98%
2007	171	505	103	1,552	243	610	15	2	0	0	0	0	3,202	3,202	100%
2008	334	438	86	5,488	282	569	18	3	0	0	10	0	7,228	7,228	100%
2009	482	1,279	74	9,685	137	694	31	1	0	0	10	0	12,394	12,394	100%
2010	579	1,912	96	13,152	58	569	55	1	0	0	10	0	16,432	16,432	100%
2011	399	2,940	69	10,015	0	580	59	0	0	0	0	0	14,062	14,062	100%
2012	211	2,230	39	6,459	4	505	48	10	0	0	0	0	9,506	9,506	100%
2013	7	1,730	2	5,169	4	575	20	10	0	0	0	0	7,516	7,516	100%
2014	8	1,298	0	6,645	4	604	3	16	20	0	0	0	8,599	8,599	100%
2015	8	1,473	0	9,844	0	505	0	6	20	0	0	0	11,856	11,856	100%
2016	1	1,328	0	10,020	1	394	0	6	20	0	0	0	11,771	11,771	100%
2017	0	1,482	0	8,787	1	288	0	0	0	0	0	0	10,558	10,558	100%
2018	0	1,927	0	6,116	1	402	0	0	0	0	0	0	8,447	8,447	100%
2019	0	3,380	0	9,149	0	565	0	0	0	0	0	0	13,094	13,094	100%

** All numbers shown are 3-year running average values of number of river herring reported harvested; landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

+ These reported locations are within the Great Bay Estuary and used to calculate the 'Harvest Portion' of the 'Great Bay Indicator Stock' sustainability target.

Table 4. Number* of river herring harvested, number of river herring returning, and percentage of river herring harvested by state-permitted coastal netters in New Hampshire at 'Great Bay Indicator Stock' locations between 1989 and 2019.

	Cocheco River				Lamprey River				Oyster River				Exeter River				'Great Bay Indicator Stock' Harvest to Return Percentage			
Year	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest Portion+ (# Fish)	Return Portion (# Fish)	Percent Harvest	Sustainability Target Status
	H	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*∑H*	*∑R*	*(∑H / ∑R)* 100*	
1989	--	--		--	--	--		--	--	--		--	--	--		--	--	--	--	--
1990	--	--		--	--	--		--	--	--		--	--	--		--	--	--	--	--
1991	0	25,302	25,302	0%	10,565	27,159	37,724	28%	385	115,163	115,548	0%	15,224	104	15,329	99%	28,035	193,902	14%	Below Target
1992	19	43,314	43,333	0%	12,058	23,946	36,005	33%	620	154,529	155,149	0%	7,618	283	7,902	96%	21,428	242,388	9%	Below Target
1993	34	46,205	46,239	0%	7,952	23,890	31,842	25%	927	127,596	128,523	1%	3,315	376	3,691	90%	12,998	210,295	6%	Below Target
1994	34	48,668	48,702	0%	4,900	18,640	23,540	21%	855	107,595	108,450	1%	2,767	272	3,039	91%	8,761	183,731	5%	Below Target
1995	16	50,966	50,982	0%	410	18,437	18,847	2%	621	82,886	83,507	1%	4,606	290	4,896	94%	6,041	158,232	4%	Below Target
1996	2	48,431	48,433	0%	703	13,741	14,444	5%	522	85,744	86,266	1%	5,274	280	5,554	95%	7,349	154,696	5%	Below Target
1997	105	47,778	47,883	0%	1,053	16,447	17,500	6%	715	74,392	75,108	1%	9,068	714	9,782	93%	12,170	150,273	8%	Below Target
1998	116	29,742	29,858	0%	917	16,461	17,378	5%	752	75,133	75,884	1%	21,792	647	22,440	97%	25,524	145,560	18%	Below Target
1999	140	24,379	24,519	1%	730	19,417	20,147	4%	384	77,033	77,417	0%	31,432	1,505	32,937	95%	35,253	155,019	**23%**	**Above Target**
2000	70	24,298	24,368	0%	897	20,564	21,461	4%	386	81,351	81,737	0%	39,347	1,249	40,596	97%	43,588	168,161	**26%**	**Above Target**
2001	57	31,402	31,460	0%	1,228	28,358	29,586	4%	504	75,308	75,813	1%	31,631	3,352	34,983	90%	36,251	171,842	**21%**	**Above Target**
2002	47	46,667	46,713	0%	1,135	41,024	42,160	3%	574	65,347	65,921	1%	29,097	3,526	32,623	89%	32,995	187,416	18%	Below Target
2003	25	60,087	60,112	0%	1,214	53,960	55,174	2%	444	58,901	59,346	1%	24,808	3,372	28,180	88%	28,074	202,812	14%	Below Target
2004	82	60,535	60,617	0%	770	62,961	63,731	1%	475	54,216	54,691	1%	21,051	1,165	22,216	95%	23,143	201,256	11%	Below Target
2005	85	45,193	45,278	0%	873	56,948	57,822	2%	363	39,117	39,481	1%	13,215	73	13,288	99%	15,097	155,869	10%	Below Target
2006	114	22,899	23,013	0%	614	43,277	43,891	1%	305	23,950	24,255	1%	5,084	55	5,139	99%	6,748	96,298	7%	Below Target
2007	171	12,193	12,364	1%	505	39,574	40,079	1%	103	12,113	12,216	1%	1,552	41	1,593	97%	3,202	66,252	5%	Below Target
2008	334	16,940	17,273	2%	438	38,314	38,753	1%	86	14,745	14,832	1%	5,488	75	5,563	99%	7,228	76,420	9%	Below Target
2009	482	27,555	28,038	2%	1,279	44,632	45,912	3%	74	16,621	16,695	0%	9,685	240	9,925	98%	12,394	100,570	12%	Below Target
2010	579	33,168	33,747	2%	1,912	37,333	39,245	5%	96	17,149	17,245	1%	13,152	250	13,402	98%	16,432	103,639	16%	Below Target
2011	399	37,303	37,702	1%	2,940	42,066	45,007	7%	69	11,807	11,876	1%	10,015	279	10,294	97%	14,062	104,879	13%	Below Target
2012	211	34,451	34,662	1%	2,230	56,879	59,108	4%	39	8,778	8,817	0%	6,459	234	6,693	96%	9,506	109,280	9%	Below Target
2013	7	29,678	29,685	0%	1,730	72,239	73,969	2%	2	4,826	4,828	0%	5,169	407	5,576	93%	7,516	114,058	7%	Below Target
2014	8	25,304	25,312	0%	1,298	83,713	85,010	2%	0	4,650	4,650	0%	6,645	585	7,230	92%	8,599	122,203	7%	Below Target
2015	8	37,587	37,595	0%	1,473	78,040	79,512	2%	0	4,393	4,393	0%	9,844	2,313	12,157	81%	11,856	133,657	9%	Below Target
2016	1	64,555	64,556	0%	1,328	82,358	83,687	2%	0	2,298	2,298	0%	10,020	4,324	14,344	70%	11,771	164,885	7%	Below Target
2017	0	64,208	64,208	0%	1,482	66,042	67,524	2%	0	2,386	2,386	0%	8,787	4,061	12,848	68%	10,558	146,966	7%	Below Target
2018	0	50,970	50,970	0%	1,927	59,723	61,649	3%	0	3,690	3,690	0%	6,116	2,218	8,334	73%	8,447	124,644	7%	Below Target
2019	0	18,450	18,450	0%	3,380	40,496	43,876	8%	0	5,059	5,059	0%	9,149	20	9,169	100%	13,094	76,555	17%	Below Target

** All numbers shown are 3-year running average values of number of river herring reported harvested or returning; landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

+ 'Harvest Portion' of the Great Bay Indicator Stock uses reported harvest from all areas within the Great Bay Estuary (see Table 3); therefore, it will exceed the sum of the harvest from the four rivers monitored for the 'Return Portion'.

Table 5. **Geometric mean catch per seine haul of alewife, blueback herring, and both species combined from a juvenile finfish seine survey conducted in the Great Bay Estuary between 1997 and 2019.**

	Alewife		Blueback Herring		Combined	
Year	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average
1997	0.07	--	0.43	--	0.51	--
1998	0.04	--	0.66	--	0.67	--
1999	0.27	0.13	0.97	0.69	1.09	0.76
2000	0.26	0.19	0.74	0.79	0.89	0.89
2001	0.14	0.22	0.89	0.87	0.98	0.99
2002	0.34	0.25	0.26	0.63	0.56	0.81
2003	0.32	0.27	0.71	0.62	1.17	0.90
2004	0.14	0.27	0.22	0.40	0.32	0.68
2005	0.11	0.19	0.35	0.43	0.47	0.65
2006	0.32	0.19	0.42	0.33	0.63	0.47
2007	0.21	0.21	0.5	0.42	0.77	0.62
2008	0.15	0.23	0.13	0.35	0.28	0.56
2009	0.10	0.15	0.20	0.28	0.26	0.44
2010	0.08	0.11	0.17	0.17	0.22	0.25
2011	0.08	0.09	0.05	0.14	0.12	0.20
2012	0.02	0.06	0.08	0.10	0.09	0.14
2013	0.22	0.11	0.04	0.06	0.27	0.16
2014	0.05	0.10	0.14	0.09	0.20	0.18
2015	0.31	0.19	0.06	0.08	0.34	0.27
2016	0.14	0.17	0.21	0.14	0.24	0.26
2017	0.21	0.22	0.30	0.19	0.50	0.36
2018	0.23	0.19	0.34	0.28	0.48	0.41
2019	0.07	0.17	0.17	0.27	0.22	0.40

Table 6. **Number* of river herring scale samples analyzed, number of repeat spawning fish, and associated repeat spawning percentage during annual river herring runs occurring in New Hampshire at 'Great Bay Indicator Stock' locations between 2000 and 2019.**

	Cocheco River			Lamprey River			Oyster River			Exeter River			'Great Bay Indicator Stock'		
Year	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2002	140	53	38%	160	88	55%	144	65	45%	97	31	32%	541	238	44%
2003	141	52	37%	142	83	58%	146	74	51%	83	35	42%	513	243	47%
2004	134	57	43%	148	84	57%	141	72	51%	55	19	34%	478	232	49%
2005	127	61	48%	144	77	53%	135	76	56%	59	20	34%	465	234	50%
2006	110	61	56%	138	76	55%	133	71	53%	46	15	32%	426	223	52%
2007	123	52	42%	134	75	56%	149	64	43%	40	9	23%	446	200	45%
2008	130	46	35%	139	69	49%	156	57	36%	67	9	14%	493	180	37%
2009	164	51	31%	165	78	47%	154	55	36%	167	20	12%	650	205	32%
2010	135	50	37%	145	69	48%	128	48	38%	166	21	13%	574	189	33%
2011	111	45	41%	126	67	53%	120	51	43%	139	18	13%	495	182	37%
2012	70	39	55%	85	45	53%	112	50	45%	54	12	22%	321	146	45%
2013	76	37	48%	81	40	49%	120	42	35%	64	16	24%	342	135	39%
2014	87	47	53%	87	46	53%	117	50	43%	77	26	33%	369	169	46%
2015	93	44	48%	88	50	57%	117	53	45%	92	31	33%	391	178	45%
2016	89	44	50%	86	55	64%	121	64	53%	103	37	35%	398	200	50%
2017	76	39	51%	77	53	69%	119	45	38%	84	28	34%	356	165	46%
2018	79	44	55%	78	52	66%	108	34	32%	58	18	32%	315	147	47%
2019	94	47	49%	80	48	60%	99	29	29%	31	8	26%	288	127	44%

** All numbers shown are 3-year running average values of number of river herring scale samples.*

Table 7. Distribution of repeat spawning frequency* of river herring in New Hampshire at 'Great Bay Indicator Stock' locations, from scale samples aged between 2000 and 2019.

	Cocheco River					Lamprey River					Oyster River					Exeter River					'Great Bay Indicator Stock'				
Year	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2002	62%	25%	12%	1%	0%	44%	33%	19%	4%	0%	55%	28%	13%	4%	0%	73%	18%	8%	1%	0%	56%	27%	14%	3%	0%
2003	64%	25%	9%	2%	0%	42%	34%	20%	5%	0%	49%	30%	16%	4%	0%	63%	24%	12%	1%	0%	53%	29%	15%	3%	0%
2004	56%	29%	13%	2%	0%	43%	28%	23%	6%	0%	48%	25%	22%	5%	0%	66%	22%	11%	1%	0%	51%	26%	18%	4%	0%
2005	51%	30%	15%	4%	0%	47%	30%	18%	5%	0%	44%	31%	21%	4%	0%	66%	22%	10%	2%	0%	50%	29%	17%	4%	0%
2006	45%	32%	16%	6%	1%	45%	32%	18%	5%	0%	47%	28%	20%	5%	0%	66%	24%	8%	2%	0%	48%	30%	17%	5%	0%
2007	56%	23%	13%	6%	1%	44%	32%	18%	4%	1%	56%	29%	11%	3%	0%	74%	21%	4%	1%	0%	55%	27%	13%	4%	0%
2008	63%	22%	9%	4%	1%	50%	27%	17%	5%	1%	64%	23%	9%	4%	0%	78%	18%	4%	0%	0%	62%	23%	11%	4%	0%
2009	71%	21%	6%	1%	0%	53%	29%	13%	3%	1%	64%	27%	7%	2%	0%	87%	11%	2%	0%	0%	69%	21%	7%	2%	0%
2010	60%	27%	12%	0%	0%	51%	33%	12%	3%	0%	61%	25%	10%	3%	0%	85%	13%	1%	1%	0%	65%	24%	9%	2%	0%
2011	57%	26%	14%	4%	0%	46%	34%	15%	6%	0%	57%	30%	10%	3%	0%	84%	14%	0%	1%	0%	61%	25%	10%	3%	0%
2012	44%	32%	19%	4%	1%	48%	31%	15%	6%	0%	55%	27%	13%	4%	0%	77%	19%	3%	1%	0%	54%	28%	14%	4%	0%
2013	51%	28%	14%	6%	1%	51%	28%	15%	6%	0%	65%	23%	10%	2%	0%	76%	19%	6%	0%	0%	60%	25%	11%	4%	0%
2014	46%	30%	17%	7%	1%	48%	34%	14%	4%	0%	56%	33%	9%	1%	0%	67%	25%	7%	0%	0%	55%	30%	12%	3%	0%
2015	53%	23%	14%	10%	0%	43%	32%	18%	7%	0%	54%	34%	10%	2%	0%	67%	25%	7%	1%	0%	55%	28%	12%	4%	0%
2016	51%	27%	13%	8%	0%	35%	34%	22%	10%	1%	46%	37%	12%	5%	0%	65%	26%	8%	1%	0%	50%	31%	13%	6%	0%
2017	49%	28%	17%	6%	1%	31%	27%	32%	9%	0%	63%	21%	11%	5%	0%	67%	21%	11%	1%	0%	54%	24%	17%	5%	0%
2018	44%	26%	26%	3%	0%	33%	21%	35%	10%	0%	73%	18%	6%	4%	0%	72%	19%	8%	0%	0%	56%	20%	19%	5%	0%
2019	48%	19%	28%	4%	1%	39%	21%	29%	9%	0%	74%	19%	5%	1%	0%	74%	18%	8%	0%	0%	59%	19%	18%	4%	0%

** All frequencies shown are 3-year running average values of number of river herring scale samples.*

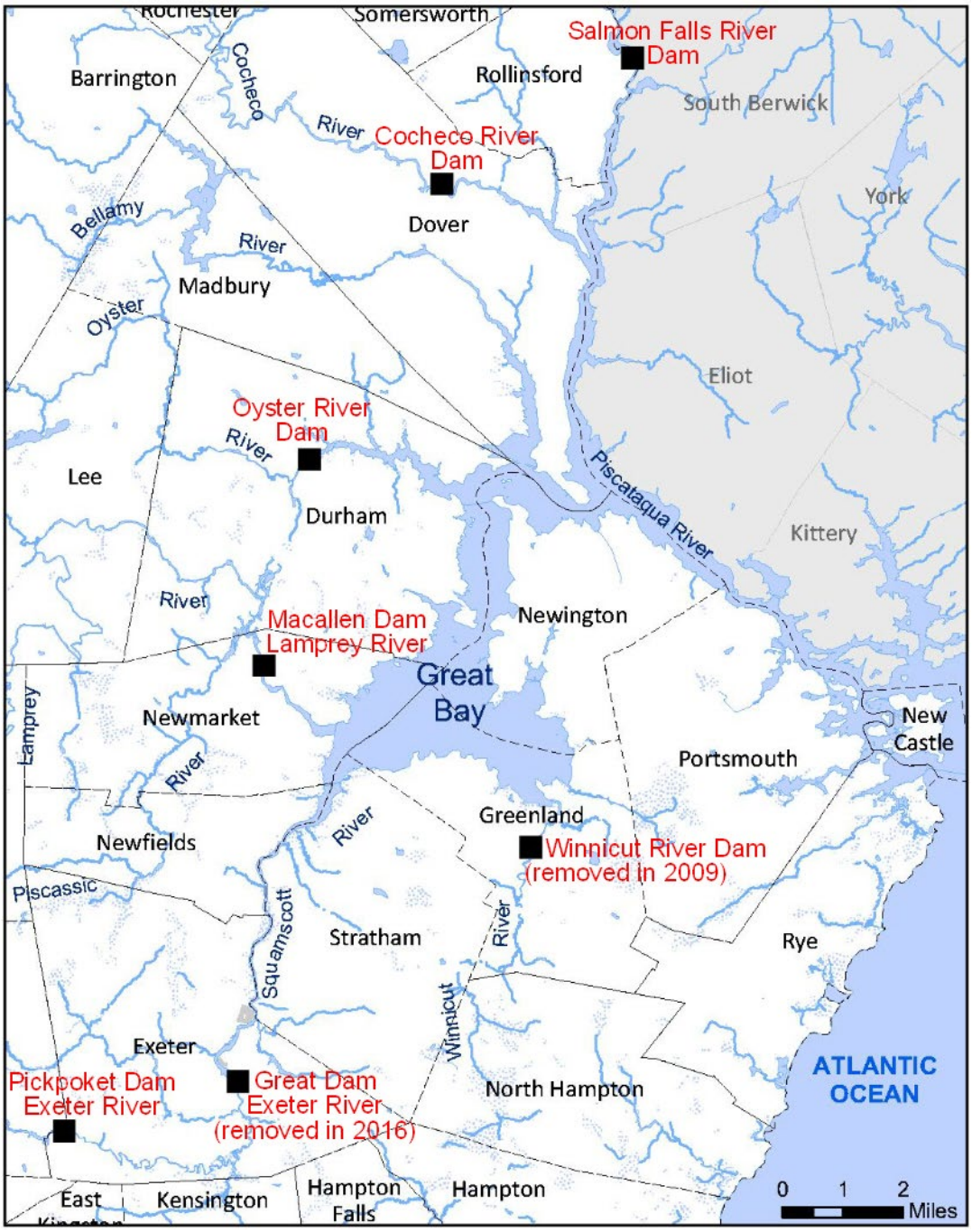


Figure 1. Map of the Great Bay Estuary showing major coastal rivers, and dam locations.

APPENDIX 1.

Table A1. Number of river herring successfully ascending fish passage structures in New Hampshire by river between 1978 and 2019.

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	Taylor River	Winnicut River	Annual total
1978	1,925	205	419	20,461	168,256	3,229++	194,495
1979	586	186	496	23,747	375,302	3,410++	403,727
1980	7,713	2,516	2,921	26,512	205,420	4,393++	249,475
1981	6,559	15,626	5,099	50,226	94,060	2,316++	173,886
1982	4,129	542	6,563	66,189	126,182	2,500++	206,105
1983	968	1	8,866	54,546	151,100	+	215,481
1984	477		5,179	40,213	45,600	+	91,469
1985	974		4,116	54,365	108,201	+	167,656
1986	2,612	1,125	93,024	46,623	117,000	1,000++	261,384
1987	3,557	220	57,745	45,895	63,514	+	170,931
1988	3,915		73,866	31,897	30,297	+	139,975
1989	18,455		38,925	26,149	41,395	+	124,924
1990	31,697		154,588	25,457	27,210	+	238,952
1991	25,753	313	151,975	29,871	46,392	+	254,304
1992	72,491	537	157,024	16,511	49,108	+	295,671
1993	40,372	278	73,788	25,289	84,859	+	224,586
1994	33,140	*	91,974	14,119	42,164	+	181,397
1995	79,385	592	82,895	15,904	14,757	+	193,533
1996	32,767	248	82,362	11,200	10,113	+	136,690
1997	31,182	1,302	57,920	22,236	20,420	+	133,060
1998	25,277	392	85,116	15,947	11,979	219	138,930
1999	16,679	2,821	88,063	20,067	25,197	305	153,132
2000	30,938	533	70,873	25,678	44,010	528	172,560
2001	46,590	6,703	66,989	39,330	7,065	1,118	167,795
2002	62,472	3,341	58,179	58,065	5,829	7,041	194,927
2003	71,199	71	51,536	64,486	1,397	5,427	194,116
2004	47,934	83	52,934	66,333	1,055	8,044	176,383
2005	16,446	66	12,882	40,026	233	2,703	72,356
2006	4,318	16	6,035	23,471	147	822	34,809
2007	15,815	40	17,421	55,225	217**	7,543	96,261
2008	30,686	168	20,780	36,247	976	8,359	97,214
2009	36,165	513	11,661	42,425	*	4,974	95,737
2010	32,654	69	19,006	33,327	675	576+++	86,307
2011	43,090	256	4,755	50,447	59	72+++	99,338
2012	27,608	378	2,573	86,862	92	5+++	117,518
2013	18,337	588	7,149	79,408	128	0	105,610
2014	29,968	789	4,227	84,868	57	0	119,909
2015	64,456	5,562	1,803	69,843	*	0	141,664
2016	99,241	6,622	863	92,364	*	0	199,090
2017	28,926	--	4,492	35,920	*	0	69,338
2018	24,743	32	5,716	50,884	*	53	81,375
2019	1,682	28	4,969	34,684	*	0	41,363

** - Due to damage to the fish trap, fishway became a swim through operation.*
*** - Due to fish counter malfunction there was up to two weeks where passing fish were not enumerated.*
**** - Fishway operated but not monitored due to staffing constraints.*
+ - Fishway unable to pass fish until modifications in 1997.
++ - Fish netted below and hand passed over Winnicut River Dam.

Table A2. Annual number of river herring harvested by state-permitted coastal harvesters in New Hampshire by location between 1989 and 2019; Areas used to calculate the harvest portion of the annual 'Great Bay Indicator Stock' used to set the sustainability target are shown.

Year	Cocheco River+	Lamprey River+	Oyster River+	Exeter River+	Winnicut River+	Bellamy River+	Salmon Falls River+	Great Bay+	Little Bay+	Portsmouth+	Piscataqua River+	All Other Locations	Statewide Total River Herring Harvested (# Fish)	Great Bay Estuary River Herring Harvested (# Fish)	% of Statewide Total
1989	0	10,220	92	25,498	740	651	20	40	0	0	916	2,518	40,695	38,177	94%
1990	0	12,320	744	15,035	0	1,244	0	0	0	0	0	1,683	31,026	29,343	95%
1991	0	9,155	320	5,139	152	1,594	163	0	0	0	61	200	16,784	16,584	99%
1992	58	14,700	796	2,681	70	0	41	12	0	0	0	1,186	19,544	18,358	94%
1993	43	0	1,666	2,124	18	60	132	0	10	0	0	210	4,263	4,053	95%
1994	2	0	103	3,497	43	81	120	26	0	0	0	8	3,880	3,872	100%
1995	4	1,230	94	8,197	20	351	288	13	0	0	2	77	10,276	10,199	99%
1996	0	880	1,369	4,127	1,034	283	262	2	0	0	18	48	8,023	7,975	99%
1997	310	1,050	683	14,882	70	77	1,232	0	0	0	32	0	18,336	18,336	100%
1998	38	820	203	46,368	0	974	1,642	0	190	0	25	1,854	52,115	50,261	96%
1999	72	320	265	33,045	0	579	2,548	10	0	250	73	935	38,097	37,162	98%
2000	100	1,550	690	38,628	73	757	1,423	0	25	0	96	940	44,282	43,342	98%
2001	0	1,814	558	23,219	0	1,123	1,314	0	160	0	60	10	28,258	28,248	100%
2002	40	42	473	25,443	0	1,142	255	0	0	0	0	0	27,395	27,395	100%
2003	34	1,786	302	25,763	0	267	382	45	0	0	0	0	28,579	28,579	100%
2004	171	481	650	11,948	0	145	60	0	0	0	0	380	13,835	13,455	97%
2005	50	353	138	1,934	56	694	32	1	0	0	0	0	3,258	3,258	100%
2006	120	1,009	126	1,369	433	465	4	5	0	0	0	0	3,531	3,531	100%
2007	343	154	45	1,354	239	672	10	0	0	0	0	0	2,817	2,817	100%
2008	538	152	88	13,741	173	571	40	4	0	0	30	0	15,337	15,337	100%
2009	566	3,532	90	13,960	0	838	43	0	0	0	0	0	19,029	19,029	100%
2010	632	2,053	111	11,754	0	298	83	0	0	0	0	0	14,931	14,931	100%
2011	0	3,236	6	4,330	0	603	51	0	0	0	0	0	8,226	8,226	100%
2012	1	1,400	0	3,293	12	615	10	30	0	0	0	0	5,361	5,361	100%
2013	20	553	0	7,883	0	506	0	0	0	0	0	0	8,962	8,962	100%
2014	3	1,940	0	8,760	0	692	0	19	60	0	0	0	11,474	11,474	100%
2015	0	1,925	0	12,889	0	317	0	0	0	0	0	0	15,131	15,131	100%
2016	0	120	0	8,411	4	173	0	0	0	0	1	0	8,709	8,709	100%
2017	0	2,400	0	5,060	0	375	0	0	0	0	0	0	7,835	7,835	100%
2018	0	3,260	0	4,877	0	659	0	0	0	0	0	0	8,796	8,796	100%
2019	0	4,480	0	17,511	0	661	0	0	0	0	0	0	22,652	22,652	100%

+ These reported locations are within the Great Bay Estuary and are used to calculate the 'Return Portion' of the 'Great Bay Indicator Stock' sustainability target.

Table A3. Number* of river herring harvested, number of river herring returning, and percentage of river herring harvested by state-permitted coastal netters in New Hampshire at 'Great Bay Indicator Stock' locations between 1989 and 2019.

	Cocheco River				Lamprey River				Oyster River				Exeter River+				'Great Bay Indicator Stock' Harvest to Return Percentage			
Year	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest Portion (Number of Fish)	Return Portion (Number of Fish)	Percent Harvest	Sustainability Target Status
	H	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*∑H*	*∑R*	*(∑H / ∑R)* 100*	
1989	0	18,455	18,455	0%	10,220	26,149	36,369	28%	92	38,925	39,017	0%	25,498	0	25,498	100%	35,810	119,339	**30%**	**Above Target**
1990	0	31,697	31,697	0%	12,320	25,457	37,777	33%	744	154,588	155,332	0%	15,035	0	15,035	100%	28,099	239,841	12%	Below Target
1991	0	25,753	25,753	0%	9,155	29,871	39,026	23%	320	151,975	152,295	0%	5,139	313	5,452	94%	14,614	222,526	7%	Below Target
1992	58	72,491	72,549	0%	14,700	16,511	31,211	47%	796	157,024	157,820	1%	2,681	537	3,218	83%	18,235	264,798	7%	Below Target
1993	43	40,372	40,415	0%	0	25,289	25,289	0%	1,666	73,788	75,454	2%	2,124	278	2,402	88%	3,833	143,560	3%	Below Target
1994	2	33,140	33,142	0%	0	14,119	14,119	0%	103	91,974	92,077	0%	3,497	0	3,497	100%	3,602	142,835	3%	Below Target
1995	4	79,385	79,389	0%	1,230	15,904	17,134	7%	94	82,895	82,989	0%	8,197	592	8,789	93%	9,525	188,301	5%	Below Target
1996	0	32,767	32,767	0%	880	11,200	12,080	7%	1,369	82,362	83,731	2%	4,127	248	4,375	94%	6,376	132,953	5%	Below Target
1997	310	31,182	31,492	1%	1,050	22,236	23,286	5%	683	57,920	58,603	1%	14,882	1,302	16,184	92%	16,925	129,565	13%	Below Target
1998	38	25,277	25,315	0%	820	15,947	16,767	5%	203	85,116	85,319	0%	46,368	392	46,760	99%	47,429	174,161	**27%**	**Above Target**
1999	72	16,679	16,751	0%	320	20,067	20,387	2%	265	88,063	88,328	0%	33,045	2,821	35,866	92%	33,702	161,332	**21%**	**Above Target**
2000	100	30,938	31,038	0%	1,550	25,678	27,228	6%	690	70,873	71,563	1%	38,628	533	39,161	99%	40,968	168,990	**24%**	**Above Target**
2001	0	46,590	46,590	0%	1,814	39,330	41,144	4%	558	66,989	67,547	1%	23,219	6,703	29,922	78%	25,591	185,203	14%	Below Target
2002	40	62,472	62,512	0%	42	58,065	58,107	0%	473	58,179	58,652	1%	25,443	3,341	28,784	88%	25,998	208,055	12%	Below Target
2003	34	71,199	71,233	0%	1,786	64,486	66,272	3%	302	51,536	51,838	1%	25,763	71	25,834	100%	27,885	215,177	13%	Below Target
2004	171	47,934	48,105	0%	481	66,333	66,814	1%	650	52,934	53,584	1%	11,948	83	12,031	99%	13,250	180,534	7%	Below Target
2005	50	16,446	16,496	0%	353	40,026	40,379	1%	138	12,882	13,020	1%	1,934	66	2,000	97%	2,475	71,895	3%	Below Target
2006	120	4,318	4,438	3%	1,009	23,471	24,480	4%	126	6,035	6,161	2%	1,369	16	1,385	99%	2,624	36,464	7%	Below Target
2007	343	15,815	16,158	2%	154	55,225	55,379	0%	45	17,421	17,466	0%	1,354	40	1,394	97%	1,896	90,397	2%	Below Target
2008	538	30,686	31,224	2%	152	36,247	36,399	0%	88	20,780	20,868	0%	13,741	168	13,909	99%	14,519	102,400	14%	Below Target
2009	566	36,165	36,731	2%	3,532	42,425	45,957	8%	90	11,661	11,751	1%	13,960	513	14,473	96%	18,148	108,912	17%	Below Target
2010	632	32,654	33,286	2%	2,053	33,327	35,380	6%	111	19,006	19,117	1%	11,754	69	11,823	99%	14,550	99,606	15%	Below Target
2011	0	43,090	43,090	0%	3,236	50,447	53,683	6%	6	4,755	4,761	0%	4,330	256	4,586	94%	7,572	106,120	7%	Below Target
2012	1	27,608	27,609	0%	1,400	86,862	88,262	2%	0	2,573	2,573	0%	3,293	378	3,671	90%	4,694	122,115	4%	Below Target
2013	20	18,337	18,357	0%	553	79,408	79,961	1%	0	7,149	7,149	0%	7,883	588	8,471	93%	8,456	113,938	7%	Below Target
2014	3	29,968	29,971	0%	1,940	84,868	86,808	2%	0	4,227	4,227	0%	8,760	789	9,549	92%	10,703	130,555	8%	Below Target
2015	0	64,456	64,456	0%	1,925	69,843	71,768	3%	0	1,803	1,803	0%	12,889	5,562	18,451	70%	14,814	156,478	9%	Below Target
2016	0	99,241	99,241	0%	120	92,364	92,484	0%	0	863	863	0%	8,411	6,622	15,033	56%	8,531	207,621	4%	Below Target
2017	0	28,926	28,926	0%	2,400	35,920	38,320	6%	0	4,492	4,492	0%	5,060	0	5,060	100%	7,460	76,798	10%	Below Target
2018	0	24,743	24,743	0%	3,260	50,884	54,144	6%	0	5,716	5,716	0%	4,877	32	4,909	99%	8,137	89,512	9%	Below Target
2019	0	1,682	1,682	0%	4,480	34,684	39,164	11%	0	4,969	4,969	0%	17,511	28	17,539	100%	21,991	63,354	**35%**	**Above Target**

**Landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

Table A4. Instantaneous mortality rates (Z) calculated using Chapman-Robson method from age data obtained through scale samples from 'Great Bay Indicator Stock' locations between 1991 and 2019.

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	GBI
1991	0.92	1.02	1.02	0.81	0.95
1992	0.81	1.01	0.71	1.17	0.90
1993	1.67	1.37	1.82	1.77	1.66
1994	0.99		0.84	1.35	0.85
1995	1.27	1.72	1.44	1.43	1.45
1996	0.82	1.39	1.20	1.16	0.99
1997	0.87	1.01	0.76	1.08	0.89
1998	0.81	0.64	0.95	0.96	0.77
1999	0.82	1.26	1.83	0.94	0.92
2000	0.78	1.03	0.84	0.80	0.72
2001	0.86	0.98	0.71	1.11	0.73
2002	0.76	1.53	0.70	1.23	0.65
2003	1.16	0.91	0.96	0.64	0.87
2004	1.20	1.19	1.44	0.86	1.10
2005	1.08	1.27	1.44	1.06	1.16
2006	0.96	0.69	0.68	0.70	0.75
2007	0.81	0.99	0.80	1.09	0.85
2008	0.97	0.89	0.82	0.85	1.00
2009	0.74	0.90	1.02	1.02	0.78
2010	0.94	1.00	1.11	0.87	1.00
2011	0.82	1.53	1.35	1.01	0.92
2012	0.77	1.20	0.76	0.96	1.00
2013	0.60	0.73	1.03	0.57	0.71
2014	0.70	0.80	1.47	0.56	0.92
2015	0.57	1.03	0.78	0.55	0.71
2016	1.21	1.25	0.92	1.06	0.87
2017	0.80	1.02	0.87	1.06	0.59
2018	1.84	--	1.08	0.47	0.52
2019	0.49	--	1.53	0.60	0.95

Table A5. Correlation tests between instantaneous mortality rates (Z) and annual ladder returns of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A1*).

	Cocheco River	
Year	Z	Annual Ladder Return (single years)
1991	0.92	25,753
1992	0.81	72,491
1993	1.67	40,372
1994	0.99	33,140
1995	1.27	79,385
1996	0.82	32,767
1997	0.87	31,182
1998	0.81	25,277
1999	0.82	16,679
2000	0.78	30,938
2001	0.86	46,590
2002	0.76	62,472
2003	1.16	71,199
2004	1.20	47,934
2005	1.08	16,446
2006	0.96	4,318
2007	0.81	15,815
2008	0.97	30,686
2009	0.74	36,165
2010	0.94	32,654
2011	0.82	43,090
2012	0.77	27,608
2013	0.60	18,337
2014	0.70	29,968
2015	0.57	64,456
2016	1.21	99,241
2017	0.80	28,926
2018	1.84	24,743
2019	0.49	1,682
r^2 = 0.054		P > 0.05
Not Significant		

	Lamprey River	
Year	Z	Annual Ladder Return (single years)
1991	0.81	29,871
1992	1.17	16,511
1993	1.77	25,289
1994	1.35	14,119
1995	1.43	15,904
1996	1.16	11,200
1997	1.08	22,236
1998	0.96	15,947
1999	0.94	20,067
2000	0.80	25,678
2001	1.11	39,330
2002	1.23	58,065
2003	0.64	64,486
2004	0.86	66,333
2005	1.06	40,026
2006	0.70	23,471
2007	1.09	55,225
2008	0.85	36,247
2009	1.02	42,425
2010	0.87	33,327
2011	1.01	50,447
2012	0.96	86,862
2013	0.57	79,408
2014	0.56	84,868
2015	0.55	69,843
2016	1.06	92,364
2017	1.06	35,920
2018	0.47	50,884
2019	0.60	34,684
r^2 = 0.186		P = 0.02
Significant		

	Oyster River	
Year	Z	Annual Ladder Return (single years)
1991	1.02	151,975
1992	0.71	157,024
1993	1.82	73,788
1994	0.84	91,974
1995	1.44	82,895
1996	1.20	82,362
1997	0.76	57,920
1998	0.95	85,116
1999	1.83	88,063
2000	0.84	70,873
2001	0.71	66,989
2002	0.70	58,179
2003	0.96	51,536
2004	1.44	52,934
2005	1.44	12,882
2006	0.68	6,035
2007	0.80	17,421
2008	0.82	20,780
2009	1.02	11,661
2010	1.11	19,006
2011	1.35	4,755
2012	0.76	2,573
2013	1.03	7,149
2014	1.47	4,227
2015	0.78	1,803
2016	0.92	863
2017	0.87	4,492
2018	1.08	5,716
2019	1.53	4,969
r^2 = 0.000		P > 0.05
Not Significant		

	Squamscott/Exeter River	
Year	Z	Annual Ladder Return (single years)
1991	1.02	313
1992	1.01	537
1993	1.37	278
1994	0.00	--
1995	1.72	592
1996	1.39	248
1997	1.01	1,302
1998	0.64	392
1999	1.26	2,821
2000	1.03	533
2001	0.98	6,703
2002	1.53	3,341
2003	0.91	71
2004	1.19	83
2005	1.27	66
2006	0.69	16
2007	0.99	40
2008	0.89	168
2009	0.90	513
2010	1.00	69
2011	1.53	256
2012	1.20	378
2013	0.73	588
2014	0.80	789
2015	1.03	5,562
2016	1.25	6,622
2017	1.02	--
2018	--	32
2019	--	28
r^2 = 0.013		P > 0.05
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Annual Ladder Return (single years)
1991	0.95	207,912
1992	0.90	246,563
1993	1.66	139,727
1994	0.85	139,233
1995	1.45	178,776
1996	0.99	126,577
1997	0.89	112,640
1998	0.77	126,732
1999	0.92	127,630
2000	0.72	128,022
2001	0.73	159,612
2002	0.65	182,057
2003	0.87	187,292
2004	1.10	167,284
2005	1.16	69,420
2006	0.75	33,840
2007	0.85	88,501
2008	1.00	87,887
2009	0.78	90,764
2010	1.00	85,056
2011	0.92	98,548
2012	1.00	117,421
2013	0.71	105,482
2014	0.92	119,852
2015	0.71	141,664
2016	0.87	199,090
2017	0.59	69,338
2018	0.52	81,375
2019	0.95	41,363
r^2 = 0.026		P > 0.05
Not Significant		

Table A6. Correlation tests between instantaneous mortality rates (Z) and annual harvest numbers of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A2*).

	Cocheco River	
Year	Z	Annual Harvest (single years)
1991	0.92	0
1992	0.81	58
1993	1.67	43
1994	0.99	2
1995	1.27	4
1996	0.82	0
1997	0.87	310
1998	0.81	38
1999	0.82	72
2000	0.78	100
2001	0.86	0
2002	0.76	40
2003	1.16	34
2004	1.20	171
2005	1.08	50
2006	0.96	120
2007	0.81	343
2008	0.97	538
2009	0.74	566
2010	0.94	632
2011	0.82	0
2012	0.77	1
2013	0.60	20
2014	0.70	3
2015	0.57	0
2016	1.21	0
2017	0.80	0
2018	1.84	0
2019	0.49	0
r^2 = 0.004		P > 0.05
Not Significant		

	Lamprey River	
Year	Z	Annual Harvest (single years)
1991	0.81	9,155
1992	1.17	14,700
1993	1.77	0
1994	1.35	0
1995	1.43	1,230
1996	1.16	880
1997	1.08	1,050
1998	0.96	820
1999	0.94	320
2000	0.80	1,550
2001	1.11	1,814
2002	1.23	42
2003	0.64	1,786
2004	0.86	481
2005	1.06	353
2006	0.70	1,009
2007	1.09	154
2008	0.85	152
2009	1.02	3,532
2010	0.87	2,053
2011	1.01	3,236
2012	0.96	1,400
2013	0.57	553
2014	0.56	1,940
2015	0.55	1,925
2016	1.06	120
2017	1.06	2,400
2018	0.47	3,260
2019	0.60	4,480
r^2 = 0.010		P > 0.05
Not Significant		

	Oyster River	
Year	Z	Annual Harvest (single years)
1991	1.02	320
1992	0.71	796
1993	1.82	1,666
1994	0.84	103
1995	1.44	94
1996	1.20	1,369
1997	0.76	683
1998	0.95	203
1999	1.83	265
2000	0.84	690
2001	0.71	558
2002	0.70	473
2003	0.96	302
2004	1.44	650
2005	1.44	138
2006	0.68	126
2007	0.80	45
2008	0.82	88
2009	1.02	90
2010	1.11	111
2011	1.35	6
2012	0.76	0
2013	1.03	0
2014	1.47	0
2015	0.78	0
2016	0.92	0
2017	0.87	0
2018	1.08	0
2019	1.53	0
r^2 = 0.040		P > 0.05
Not Significant		

	Squamscott/Exeter River	
Year	Z	Annual Harvest (single years)
1991	1.02	5,139
1992	1.01	2,681
1993	1.37	2,124
1994		3,497
1995	1.72	8,197
1996	1.39	4,127
1997	1.01	14,882
1998	0.64	46,368
1999	1.26	33,045
2000	1.03	38,628
2001	0.98	23,219
2002	1.53	25,443
2003	0.91	25,763
2004	1.19	11,948
2005	1.27	1,934
2006	0.69	1,369
2007	0.99	1,354
2008	0.89	13,741
2009	0.90	13,960
2010	1.00	11,754
2011	1.53	4,330
2012	1.20	3,293
2013	0.73	7,883
2014	0.80	8,760
2015	1.03	12,889
2016	1.25	8,411
2017	1.02	5,060
2018	--	4,877
2019	--	17,511
r^2 = 0.044		P > 0.05
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Annual Harvest (single years)
1991	0.95	14,614
1992	0.90	18,235
1993	1.66	3,833
1994	0.85	3,602
1995	1.45	9,525
1996	0.99	6,376
1997	0.89	16,925
1998	0.77	47,429
1999	0.92	33,702
2000	0.72	40,968
2001	0.73	25,591
2002	0.65	25,998
2003	0.87	27,885
2004	1.10	13,250
2005	1.16	2,475
2006	0.75	2,624
2007	0.85	1,896
2008	1.00	14,519
2009	0.78	18,148
2010	1.00	14,550
2011	0.92	7,572
2012	1.00	4,694
2013	0.71	8,456
2014	0.92	10,703
2015	0.71	14,814
2016	0.87	8,531
2017	0.59	7,460
2018	0.52	8,137
2019	0.95	21,991
r^2 = 0.081		P > 0.05
Not Significant		

Table A7. Correlation tests between instantaneous mortality rates (Z) and annual exploitation rates of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A3*).

	Cocheco River	
Year	Z	Exploitation Rate (single years)
1991	0.92	0.0%
1992	0.81	0.1%
1993	1.67	0.1%
1994	0.99	0.0%
1995	1.27	0.0%
1996	0.82	0.0%
1997	0.87	1.0%
1998	0.81	0.2%
1999	0.82	0.4%
2000	0.78	0.3%
2001	0.86	0.0%
2002	0.76	0.1%
2003	1.16	0.0%
2004	1.20	0.4%
2005	1.08	0.3%
2006	0.96	2.7%
2007	0.81	2.1%
2008	0.97	1.7%
2009	0.74	1.5%
2010	0.94	1.9%
2011	0.82	0.0%
2012	0.77	0.0%
2013	0.60	0.1%
2014	0.70	0.0%
2015	0.57	0.0%
2016	1.21	0.0%
r^2 = 0.002		P > 0.05
Not Significant		

	Lamprey River	
Year	Z	Exploitation Rate (single years)
1991	0.81	23.5%
1992	1.17	47.1%
1993	1.77	0.0%
1994	1.35	0.0%
1995	1.43	7.2%
1996	1.16	7.3%
1997	1.08	4.5%
1998	0.96	4.9%
1999	0.94	1.6%
2000	0.80	5.7%
2001	1.11	4.4%
2002	1.23	0.1%
2003	0.64	2.7%
2004	0.86	0.7%
2005	1.06	0.9%
2006	0.70	4.1%
2007	1.09	0.3%
2008	0.85	0.4%
2009	1.02	8.3%
2010	0.87	6.2%
2011	1.01	6.4%
2012	0.96	1.6%
2013	0.57	0.7%
2014	0.56	2.3%
2015	0.55	2.8%
2016	1.06	0.1%
r^2 = 0.004		P > 0.05
Not Significant		

	Oyster River	
Year	Z	Exploitation Rate (single years)
1991	1.02	0.2%
1992	0.71	0.5%
1993	1.82	2.2%
1994	0.84	0.1%
1995	1.44	0.1%
1996	1.20	1.6%
1997	0.76	1.2%
1998	0.95	0.2%
1999	1.83	0.3%
2000	0.84	1.0%
2001	0.71	0.8%
2002	0.70	0.8%
2003	0.96	0.6%
2004	1.44	1.2%
2005	1.44	1.1%
2006	0.68	2.0%
2007	0.80	0.3%
2008	0.82	0.4%
2009	1.02	0.8%
2010	1.11	0.6%
2011	1.35	0.1%
2012	0.76	0.0%
2013	1.03	0.0%
2014	1.47	0.0%
2015	0.78	0.0%
2016	0.92	0.0%
r^2 = 0.022		P > 0.05
Not Significant		

	Squamscott/Exeter River	
Year	Z	Exploitation Rate (single years)
1991	1.02	94.3%
1992	1.01	83.3%
1993	1.37	88.4%
1994		
1995	1.72	93.3%
1996	1.39	94.3%
1997	1.01	90.9%
1998	0.64	99.2%
1999	1.26	92.1%
2000	1.03	98.6%
2001	0.98	77.6%
2002	1.53	88.4%
2003	0.91	99.7%
2004	1.19	99.3%
2005	1.27	96.7%
2006	0.69	98.8%
2007	0.99	97.1%
2008	0.89	98.8%
2009	0.90	96.5%
2010	1.00	99.4%
2011	1.53	82.5%
2012	1.20	89.7%
2013	0.73	93.1%
2014	0.80	91.7%
2015	1.03	69.9%
2016	1.25	56.0%
r^2 = 0.066		P > 0.05
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Exploitation Rate (single years)
1991	0.95	7.0%
1992	0.90	7.4%
1993	1.66	2.7%
1994	0.85	2.6%
1995	1.45	5.3%
1996	0.99	5.0%
1997	0.89	15.0%
1998	0.77	35.1%
1999	0.92	26.4%
2000	0.72	32.0%
2001	0.73	16.0%
2002	0.65	14.2%
2003	0.87	14.9%
2004	1.10	7.9%
2005	1.16	3.6%
2006	0.75	7.8%
2007	0.85	2.1%
2008	1.00	16.5%
2009	0.78	19.8%
2010	1.00	17.1%
2011	0.92	7.6%
2012	1.00	4.0%
2013	0.71	8.0%
2014	0.92	8.9%
2015	0.71	10.5%
2016	0.87	4.3%
r^2 = 0.163		P = 0.04
Significant		

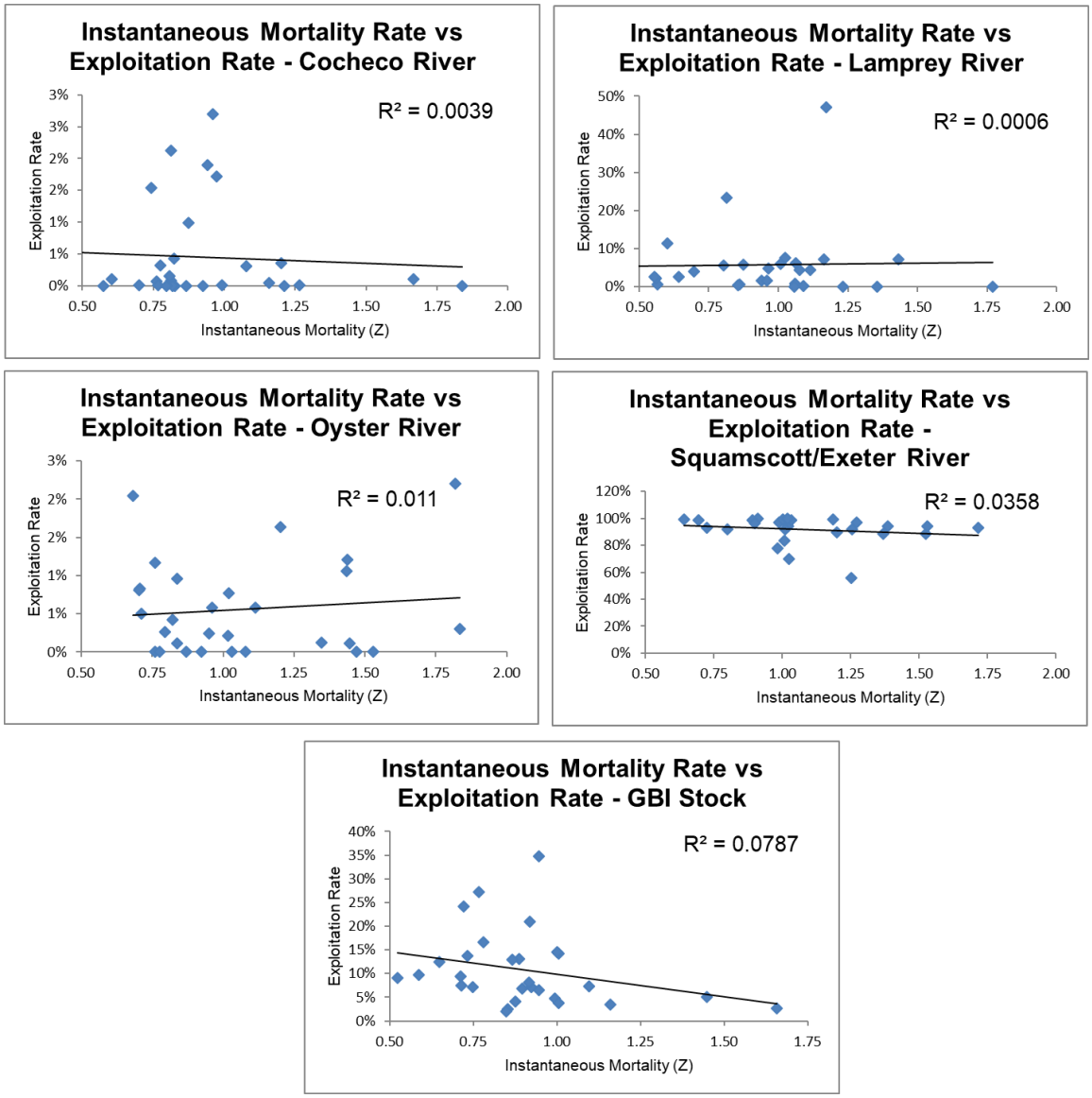


Figure A1. Plots of instantaneous mortality rate against river herring exploitation rates for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

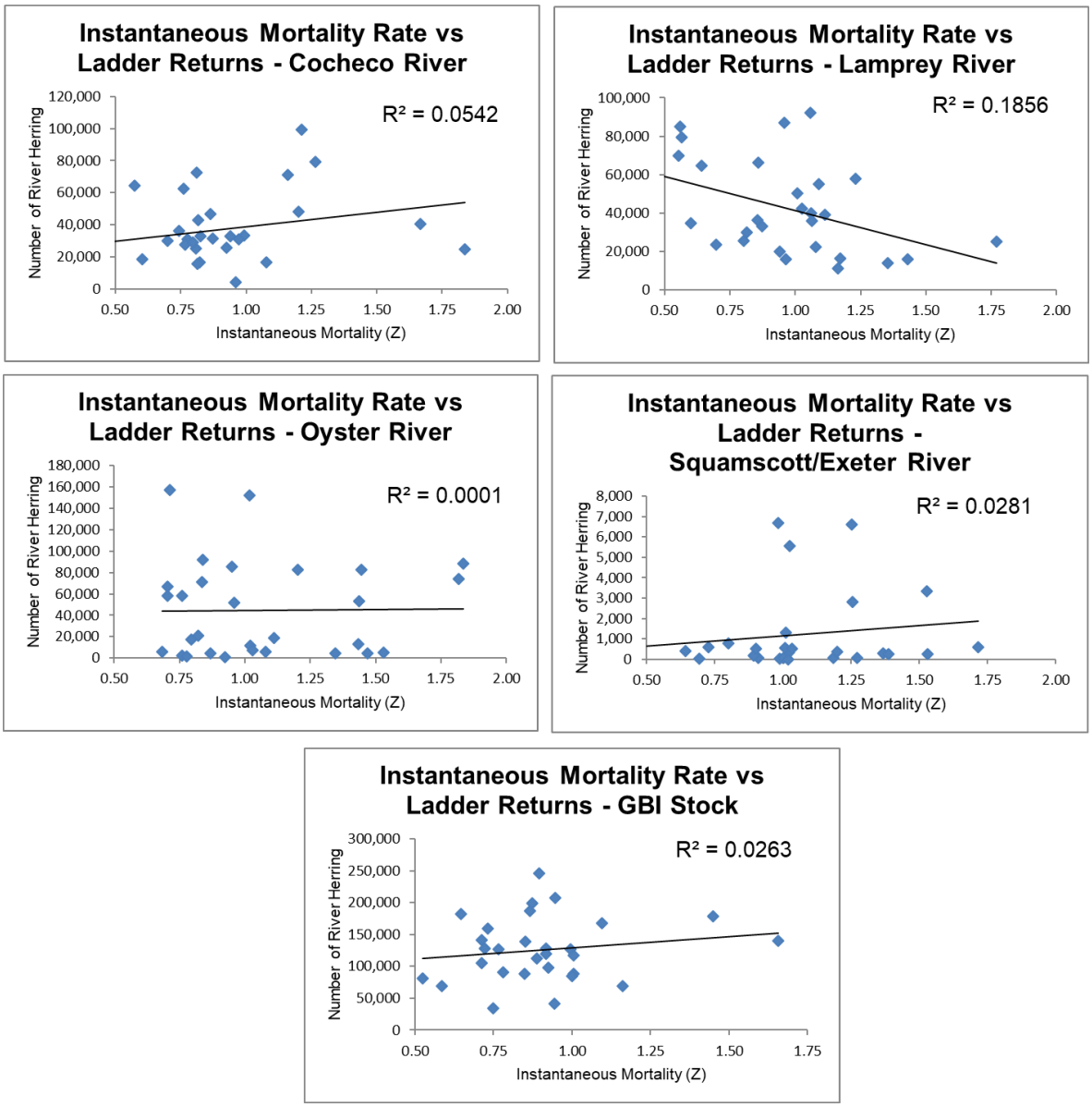


Figure A2. Plots of instantaneous mortality rate against river herring ladder returns for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

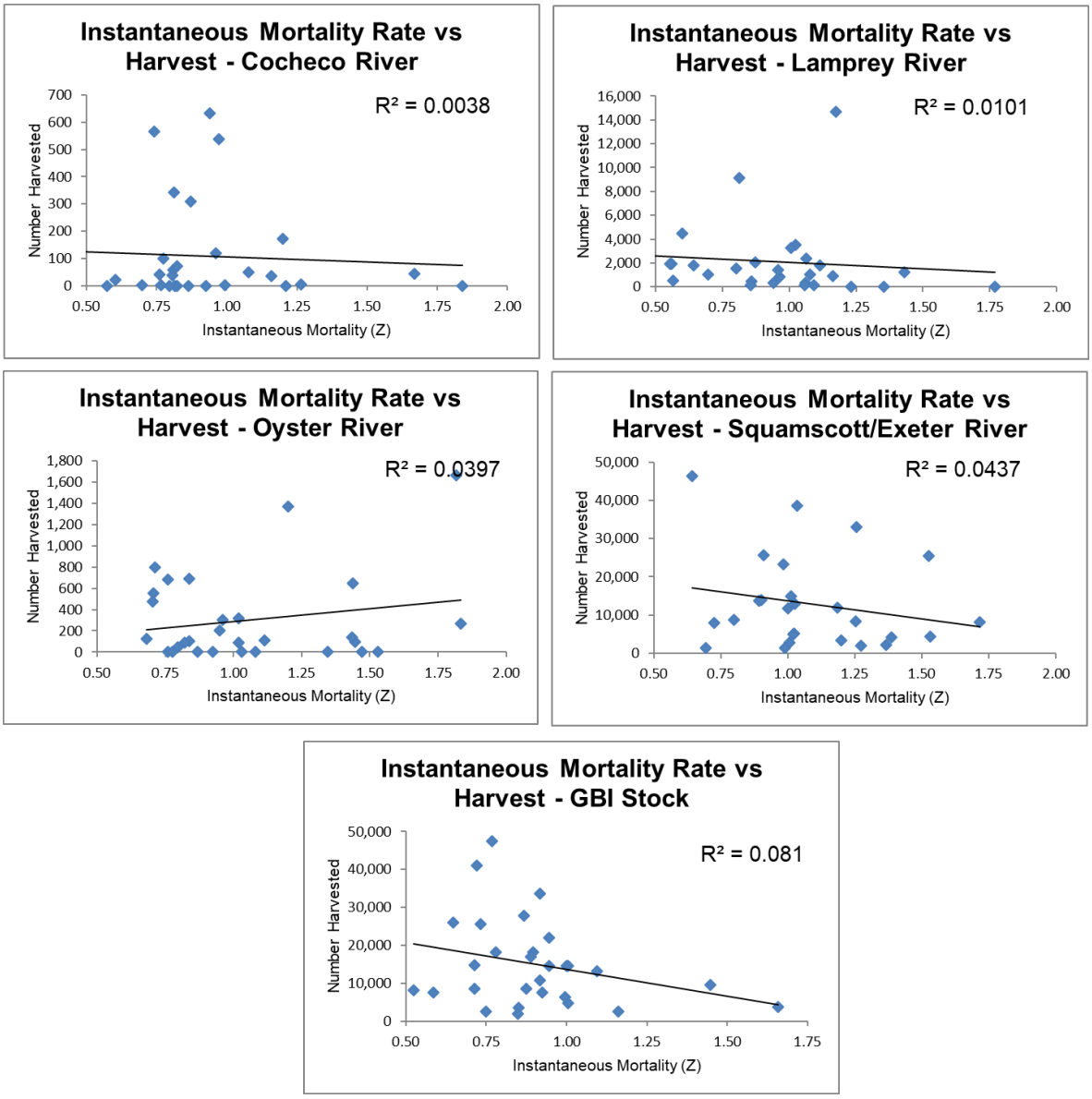


Figure A3. Plots of instantaneous mortality rate against river herring harvest for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.