

New Hampshire ASMFC River Herring Sustainable Fishing Plan
New Hampshire Fish and Game Department
March, 2015

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 data to substantiate it, 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 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 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 state-wide 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 a 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 state-wide 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. 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 a level approaching 100,000 fish. However, estimates of Z have shown a declining trend during this period and the percentages of repeat spawning fish in the rivers monitored in the Great Bay Estuary have ranged from 31 to 52% for all rivers combined over the past eight years.

Changes in return numbers are most pronounced in the Oyster River where, for unknown reasons, the number of returning fish increased steeply between 1985 and 1992 from less than 7,000 fish per year to more than 150,000 fish, followed by a steady, long term decline to less than 21,000 fish in recent years. *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. *Spawning activity has been observed occurring in significant numbers below the fish ladder and reported harvest in this river has consistently exceeded the ladder counts by large amounts indicating a much larger spawning stock than would be suggested by ladder counts.*

In the Lamprey and Cocheco Rivers, river herring returns have varied greatly without trend during the past two decades and are currently at moderate levels exceeding 30,000 to 40,000 fish per year. 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.

In addition, 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 of time 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 wide juvenile abundance index seine survey exhibited increases in the geometric mean occurrence of both river herring species. 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 downriver of the ladders.

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 four of the seven rivers in the Great Bay Estuary, each of which are monitored by the Department annually. 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. 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 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 also used 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 the information available from river herring populations in Maine, an analysis-based minimum annual escapement of 35 river herring per surface acre (207) of available spawning habitat was calculated. This escapement level would only provide a minimum of 7,229 river herring returning to the Great Bay Estuary annually. New Hampshire believes that number would be insufficient to maintain current population levels. 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 level is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990. *The fishery-independent target will be an interim target until the upcoming ASMFC stock assessment for river herring is completed and peer reviewed. Results of the stock assessment will then be reviewed for potential alternatives for this target.*

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 netters and through conduct of the cooperative state/federal Marine Recreational 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 netters; 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.

The fishery-independent and fishery-dependent targets will be monitored annually and reassessed following the completion of the upcoming ASMFC stock assessment for river herring or within five years. Results of the stock assessment or five year reassessment will be reviewed for potential alternatives for this target.

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 most 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.

'Great Bay Indicator Stock' Management Area:

I. Physical Description:

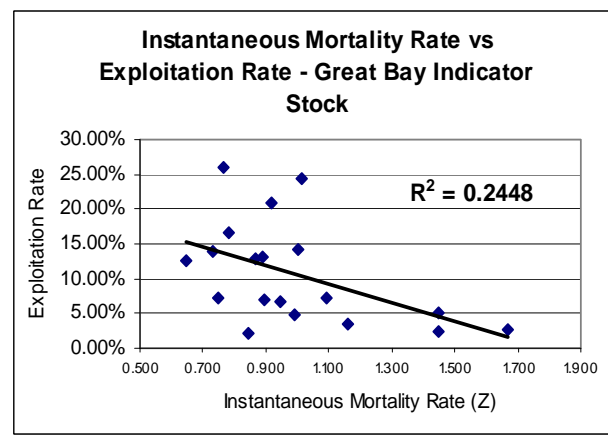
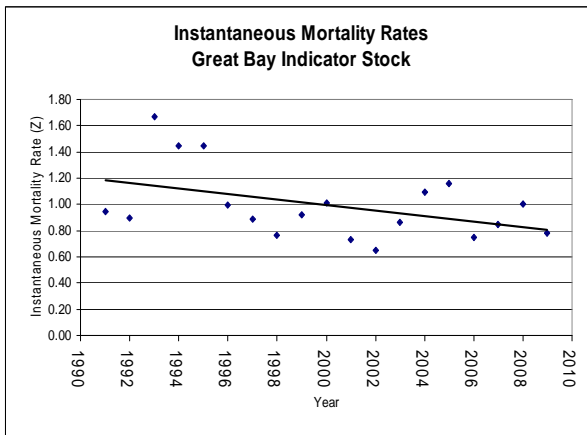
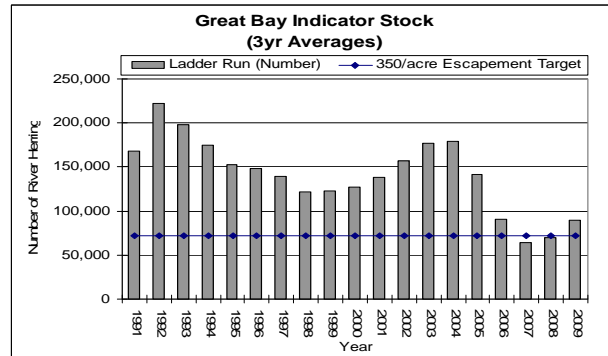
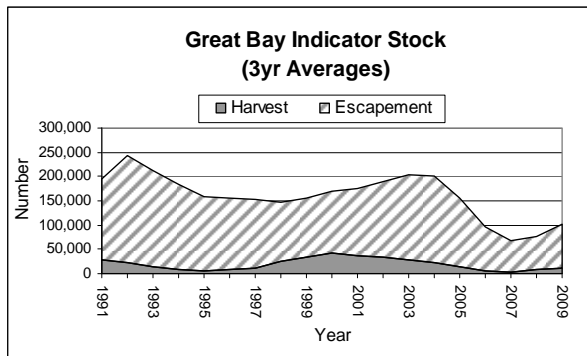
The unique ecosystem interactions found within a state or jurisdiction allow for targets to be “applied state-wide or can be river and species specific.” New Hampshire is proposing to use the extensive monitoring data from New Hampshire’s largest estuary, the Great Bay Estuary System, to evaluate whether 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 did 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 systems 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 fishermen and lobstermen. 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 1,900 fish to 44,400 fish.

The exploitation rate is currently below the fishery-dependent target of 20% and the run is currently above the fishery-independent target of 350 fish per acre, has a three year repeat spawning percentage of 31% (70% R-0, 21% R-1, 7% R-2, 2% R-3, 0% R-4), the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward, and there is a significant correlation between mortality rates and exploitation rates. However, the trend of the data indicates that as the exploitation rate increases the instantaneous mortality rate decreases.



a. River Descriptions

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.

Cochecho River

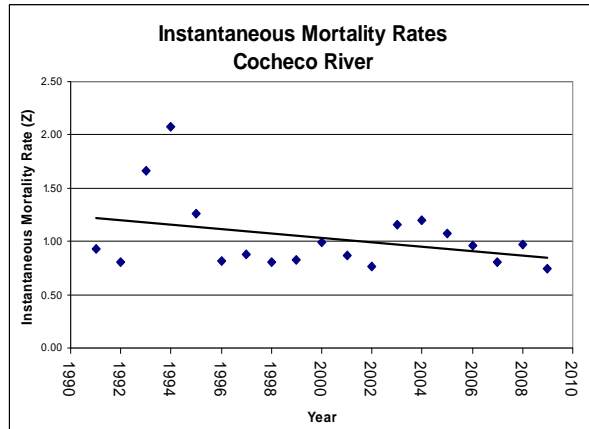
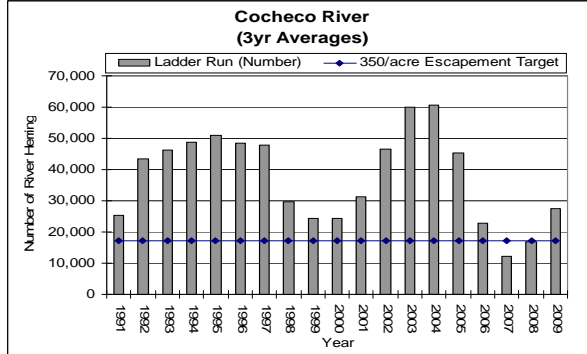
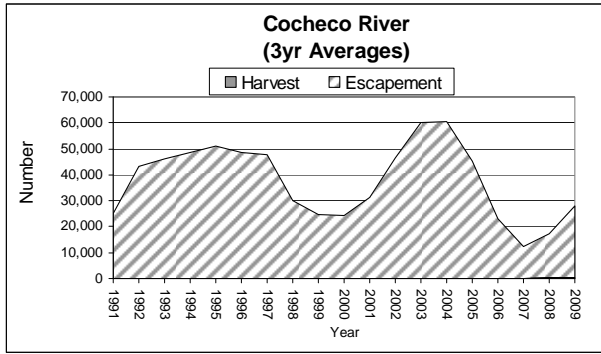
III. Physical Description of River, Watershed, and Impoundment:

The Cochecho River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River. The Piscataqua River flows approximately 20 km to the sea. The Cochecho 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 Cochecho 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 to approximately 49 acres of potential spawning habitat was constructed at the dam in 1969 to 1970 for anadromous fish by NHFGD, the owner also maintains a downstream migration structure which was replaced for increased efficiency in 2010. 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. During normal flow conditions river herring can ascend this natural falls and continue migrating upriver a distance of 1.3 km to the Watson Dam in Dover, NH. There is no fish ladder at this dam, but a downstream migration pipe is provided by the hydroelectric facility.

IV. Description of fishery:

The river herring fishery in the Cochecho River is very sporadic with very few fish harvested over the course of the last several years. Total annual in-river harvest has ranged from zero fish to approximately 550 fish. Harvesters typically fish with cast nets, dip nets, or gill nets. The Cochecho 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 a distance approximately 0.50 km downstream. In addition, there is a popular striped bass fishery that occurs along this stretch of river. Recreational anglers “snag” river herring to be used as live striped bass bait.

The run is currently above the fishery-independent target of 350 fish per acre, has a three year repeat spawning percentage of 29% (70% R-0, 21% R-1, 6% R-2, 2% R-3, 0% R-4), the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward, 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 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.

Lamprey River

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

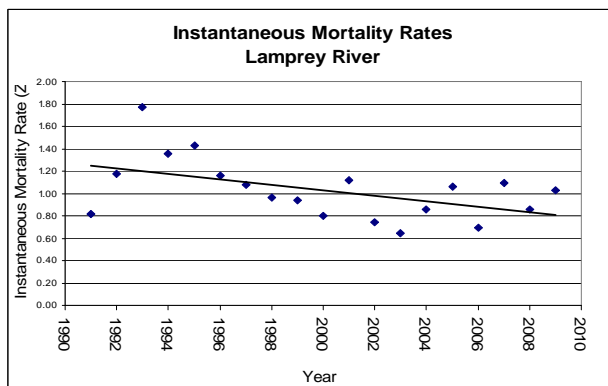
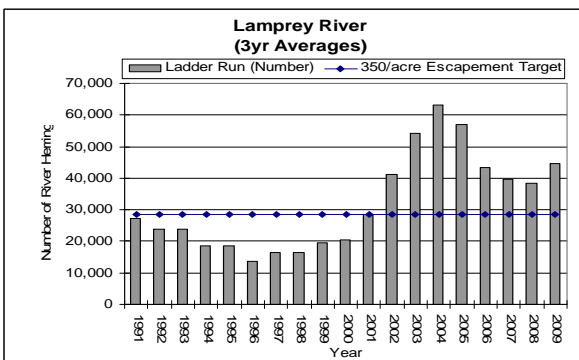
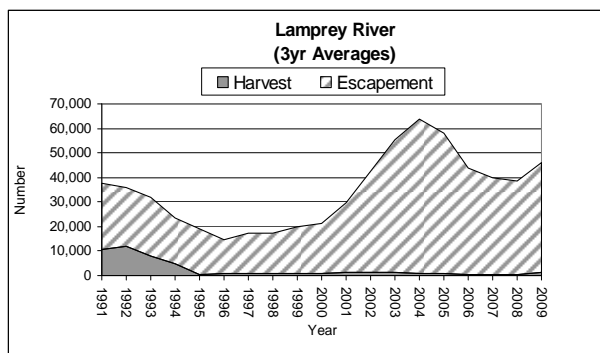
The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay Estuary just north of the mouth of the Exeter River. The mouth of the Lamprey River in Great Bay is approximately 27 km inland from the Atlantic coast. The Lamprey River 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 from 1969 to 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 is owned and operated by the Town of Durham, NH with technical advice 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:

The river herring harvest at the Lamprey River in recent years has been very low, usually less than 2,000 fish per year. The fishing activity is very sporadic. Landings are reported using a variety of methods including: cast net, gill net, dip net, and weir. Primarily the harvest occurs from approximately 70 m downstream of Macallen Dam to a distance of 0.50 km downstream. There is one weir fisherman that maintains his netting permit but has not fished his weir since 2003. It is worth noting that each spring there is a very popular striped bass fishery that occurs within 0.33 km downstream of Macallen Dam. Striped bass anglers “snag” river herring to use as live bait.

The run is currently above the fishery-independent target of 350 fish per acre, has a three year repeat spawning percentage of 47% (53% R-0, 29% R-1, 13% R-2, 3% R-3, 1% R-4), the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward, 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 of them 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

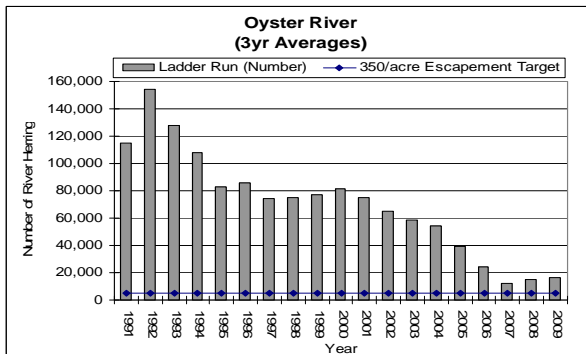
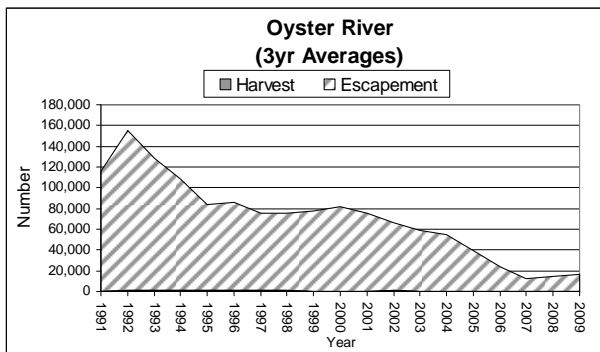
I. Physical Description of River, Watershed, and Impoundment:

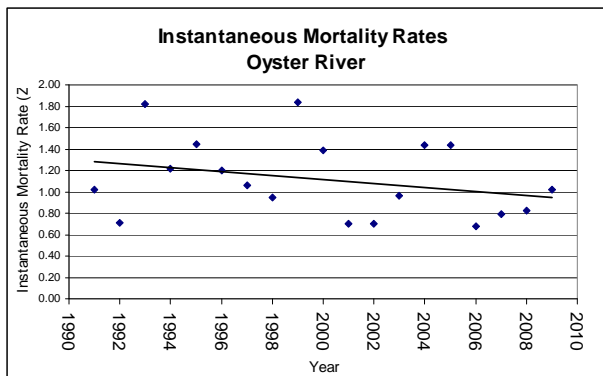
The Oyster River begins in the town of Barrington, NH. The size of the Oyster River watershed is approximately 67 square km. The Oyster flows southeasterly approximately 27.5 km through the towns of Lee and Durham on its way to Little Bay in the Great Bay Estuary. The mouth of the Oyster River lies approximately 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 above the fishery-independent target of 350 fish per acre, has a three year repeat spawning percentage of 36% (65% R-0, 26% R-1, 7% R-2, 2% R-3, 0% R-4), the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward, 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. It empties into Great Bay northeast of Exeter. The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River. The two lowermost dams on the main stem Exeter River are the Great Dam in Exeter at river kilometer (rkm) 13.5 and the Pickpocket Dam at rkm 26.9 (each 4.6 km high). Both dams have a Denil fish ladder, providing 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 Exeter River (Squamscott) in Great Bay lies approximately 27.4 km inland from the sea.

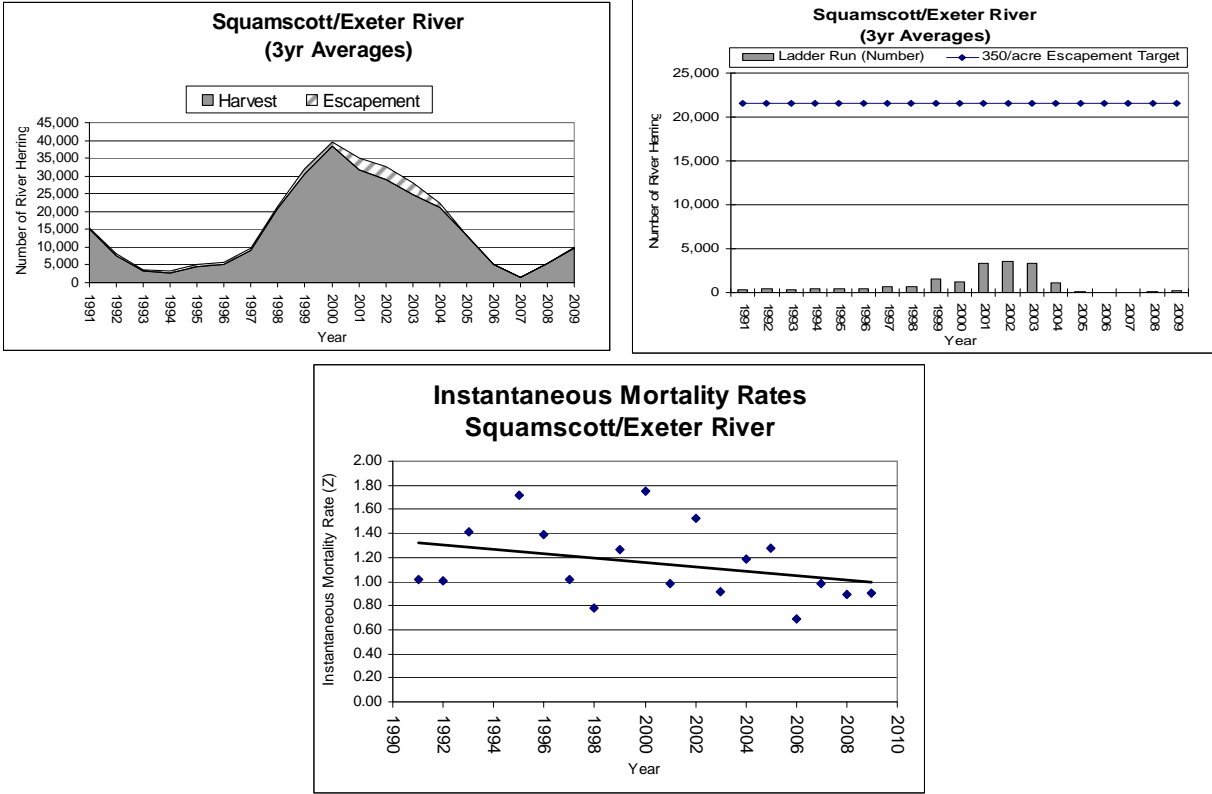
II. Description of fishery:

The river herring fishery that occurs at the Exeter River is conducted to harvest river herring for personal use as bait in fisheries for lobster and striped bass. The majority of the fishing occurs approximately 125 meters downstream of The 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.

In 2005, following a number of years of increased harvest in the Squamscott/Exeter River, NHFGD implemented major changes to rules for river herring and shad in this river in order to reduce the harvest levels. These changes included implementing a one tote harvest limit per day and increasing the escapement days from one day per week to 5 days per week. Harvest levels since 2005 have been reduced by at least 50% of the levels observed between 1998 and 2003 (Table 3) and estimates of instantaneous mortality from 2006 to 2009 have been some of the lowest in the time series.

The run is currently below the fishery-independent target of 350 fish per acre, has a three year repeat spawning percentage of 13% (88% R-0, 11% R-1, 1% R-2, 0% R-3, 0% R-4), the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward, 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. The Exeter River is also the only coastal river with upstream fish passage available on the first two dams providing access to the greatest amount of spawning habitat on the New Hampshire coast. 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. 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 the recent work to improve fish passage efficiency of the fish ladder at Great Dam, the vast majority of river herring choose to spawn below the fish ladder in an approximately 0.50 acre area of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gather in very large numbers below the Great Dam and spawning has been observed. These observations combined with relatively high levels of documented harvest occurring each year below the first dam and the inefficiency of the fish ladder in passing river herring indicates that escapement to spawn in this river is much higher than measured by the number of river herring passing up river through the fish ladder.*

There are no downstream fish passage facilities on either dam so emigrating adults and juveniles pass over the spillway when river flows allow. There are no hydroelectric operations at either fishway, however, at the Great Dam there is a condominium complex that utilizes a small amount of water from the penstock for cooling of their heating and air conditioning system. This minimal flow through the penstock does not have an impact on emigrating river herring.

In addition, poor water quality has been documented in the critical nursery habitat above Great Dam. Periodic water quality monitoring has recorded low levels of dissolved oxygen (DO) between the two dams 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. During the summer of 2009 the fish ladder and associated NHFGD owned dam were removed to restore anadromous fish habitat. The dam removal drained a 34 acre impoundment and the Winnicut River became the only major tributary to Great Bay with no man-made barriers along its entire length.

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 have observed large numbers of river herring below the next dam approximately 0.6 km upstream.

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.

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, New Hampshire. It flows north, east, then southeast through Hampton Falls where it meets tide 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. Beginning in the spring of 2015 the Taylor River fishway will be operated as a swim through only 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 to an estimated 92 fish in 2012 from over 100,000 fish in 1986. 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. This makes confirmation of fish passage very difficult.

The Taylor River dam is owned by the NH Department of Transportation (NHDOT). In 2005 a letter of deficiency was issued to NHDOT from the NH Department of Environmental Services (NHDES). This letter requires NHDOT to repair/replace or remove the Taylor River dam. In the event that an updated dam/fishway is constructed or dam removal occurs and river herring habitat quality improves, we can reassess the need to implement river herring monitoring.

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. The combined harvest from all three rivers ranges from as few as 111 fish in 1992 to 3,127 in 1999. 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. 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.

Currently there are no regulations establishing a length limit or daily bag limit for recreational anglers on either alewives or blueback herring within any 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 controlling 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 have been zero in all but two years since 1993, 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 (Table 3). All individuals participating in netting of river herring with the state are required to annually submit 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 Dependant

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

Fishery-dependent data is submitted by all state-permitted coastal netters 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 and above the minimum target level of 350 fish per surface acre of available spawning habitat. Although values of return numbers to the Great Bay Indicator Stock have exhibited a decline since 2003, estimates of Z have shown a declining trend, the percentage of repeat spawners have remained between 31% and 52%, spawning escapement has consistently exceeded 80% and exploitation rates have remained below 20%.

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 which is inclusive of fishing harvest outside of New Hampshire indicates that 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 fishery-dependent targets have been met. .

b. Recreational

Harvest of river herring occurring in New Hampshire is primarily through state-permitted coastal netters harvesting fish for personal use, such as bait. As a result, this fishery is classified a 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 fishery-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 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 (Table 1.) 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 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.

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 of the past 18 years (Table 4) and in subsequent years following the high harvest percentages, the annual returns of river herring continued to increase for four 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, but 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 information an analysis-based minimum annual return of 235 fish per surface acre and escapement of 35 river herring per surface acre of available spawning habitat (207) was examined. This escapement level would only require a minimum of 7,229 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 (72,293 fish). This target is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990 (Table A1). *The fishery-independent target will be an interim target until the upcoming ASMFC stock assessment for river herring is completed and peer reviewed. Results of the stock assessment will then be reviewed for potential alternatives for this target.*

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 are operated and maintained along six coastal rivers, although the dam and the associated fish passage structure on the Winnicut River were removed in the fall of 2009. 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.

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. 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 have declined significantly from 2004 - 2007, 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 wide 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, when the number of fish able to ascend the ladder were low (Table 5). Since return numbers to the fish ladders were down those two years, this suggests that 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 consistently high, ranging from 31% 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 netters using gear such as cast nets, gill nets, and dip nets. The harvest levels reported by netters 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 Exeter 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 size of fish within that system. This is particularly noticeable in the fact that the harvest percentages in the Exeter River reach as high as 181 times 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 2008. To limit the variation between years, three year rolling averages were used to establish both the annual return portion and the harvest portion of the harvest percentage. The resulting harvest percentages have ranged from as high as 25% 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. 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 10%, since 1991 but did increase sharply to above or near 20% from 1998 to 2002. This was driven by an increased effort and resulting harvest in the Squamscott/Exeter river for unknown reasons, but prompted NHFGD to enact new regulations to limit the permitted fishing at that location to only two days per week as opposed to the previous 6 days, as well as implementing a daily harvest limit of one tote per person.

NHFGD does not currently have available data sufficient for analysis to be used 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.

Analysis of fishery-independent and fishery-dependent data indicate that New Hampshire's river herring stock is relatively stable. Although values of return numbers to the Great Bay Indicator Stock have exhibited a decline since 2003, estimates of Z have shown a declining trend, the percentage of repeat spawners have remained between 31% and 52%, and spawning escapement has consistently exceeded 80%.

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-yr 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 Department. The reported information must provide harvest 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 Cochecho, 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, which is currently an approximate 207 acre area, resulting in a target return of 72,293 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 (Cochecho, 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-yr average value to compare to the sustainability target level of 20%.

The fishery-independent and fishery-dependent targets will be monitored annually and reassessed following the completion of the upcoming ASMFC stock assessment for river herring or within five years. Results of the stock assessment or five year reassessment will be reviewed for potential alternatives for this target.

b. Consequences or Control Rules

If the statewide harvest of river herring, determined by combining reported landings by state-permitted coastal netters 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, 72,293 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. Number* of river herring successfully ascending fish passage structures in New Hampshire by river between 1989 and 2009; Areas used to calculate the return portion of the annual ‘Great Bay Indicator Stock’ used to set the sustainability target are shown.

Year	'Great Bay Indicator Stock'				Winnicut River+	Taylor River	Annual River Herring Return (# Fish)	'Great Bay Indicator Stock' Return (# Fish)	Percentage of Annual Return
	Cocheco River	Lamprey River	Oyster River	Exeter River					
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	41,204	65,347	3,526	2,895	18,968	178,606	156,744	88%
2003	60,087	54,140	58,901	3,372	4,529	4,764	185,793	176,500	95%
2004	60,535	63,141	54,216	1,165	6,837	2,760	188,655	179,058	95%
2005	45,193	56,948	39,117	73	5,391	892	147,615	141,332	96%
2006	22,899	43,277	23,950	55	3,856	475	94,513	90,181	95%
2007	12,193	39,574	12,113	41	3,689	196	67,805	63,920	94%
2008	16,940	38,314	14,745	77	5,575	447	76,097	70,076	94%
2009	27,555	44,632	16,621	242	6,959	723	96,732	89,051	94%

* 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 state 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 2009.

Year	State/Federal MRFSS Survey				Federal Landings Database	
	Blueback Herring		Alewife		Blueback Herring	Alewife
	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	--	0	--	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	196	99.6	6,875	99.6	0	0
2002	0	--	0	--	0	0
2003	3,015	100.1	0	--	0	0
2004	0	--	0	--	0	0
2005	0	--	0	--	0	0
2006	0	--	0	--	0	0
2007	0	--	35,414	50.8	0	0
2008	0	--	9,954	57.0	0	16,274
2009	217	100.3	1,637	56.8	Not Yet Available	Not Yet Available

⁺ Landings values are in numbers of fish landed by commercial fisherman 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 2009; 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	20,792	368	445	1,045	1	63	0	25	634	25,158	24,524	97%
1999	140	730	384	30,432	23	543	1,807	3	63	83	43	930	35,182	34,253	97%
2000	70	897	386	38,347	24	770	1,871	3	72	83	65	1,243	43,831	42,588	97%
2001	71	1,228	504	31,631	24	820	1,762	3	62	83	76	628	36,892	36,264	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	0	53	0	20	3	28,062	28,059	100%
2004	68	770	475	21,051	0	518	232	0	0	0	0	127	23,242	23,115	99%
2005	85	873	363	13,215	19	369	158	0	0	0	0	127	15,209	15,082	99%
2006	114	614	305	5,084	163	435	32	2	0	0	0	127	6,874	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	9,635	137	694	31	1	0	0	10	0	12,344	12,344	100%

* All numbers shown are 3-yr 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 are 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 2009.

Year	Cocheco River				Lamprey River				Oyster River				Exeter River				'Great Bay Indicator Stock' Harvest to Return Percentage			Sustainability Target Status
	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	
	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	ΣH	ΣR	(ΣH / ΣR) * 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	313	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	425	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	408	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	435	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	420	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%	20,792	647	21,440	97%	24,524	144,560	17%	Below Target
1999	140	24,379	24,519	1%	730	19,417	20,147	4%	384	77,033	77,417	0%	30,432	1,505	31,937	95%	34,253	154,019	22%	Above Target
2000	70	24,298	24,368	0%	897	20,564	21,461	4%	386	81,351	81,737	0%	38,347	1,249	39,596	97%	42,588	167,161	25%	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%	36,264	171,842	21%	Above Target
2002	47	46,667	46,713	0%	1,135	41,204	42,340	3%	574	65,347	65,921	1%	29,097	3,526	32,623	89%	32,995	187,596	18%	Below Target
2003	25	60,087	60,112	0%	1,214	54,140	55,354	2%	444	58,901	59,346	1%	24,808	3,372	28,180	88%	28,059	202,992	14%	Below Target
2004	82	60,535	60,617	0%	770	63,141	63,911	1%	475	54,216	54,691	1%	21,051	1,165	22,216	95%	23,115	201,436	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%	15,082	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	77	5,565	99%	7,228	76,422	9%	Below Target
2009	482	27,555	28,038	2%	1,279	44,632	45,912	3%	74	16,621	16,695	0%	9,635	242	9,877	98%	12,344	100,522	12%	Below Target

* All numbers shown are 3-yr 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 2009.

Year	Alewife		Blueback Herring		Combined	
	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average
1997	0.07	--	0.42	--	0.44	--
1998	0.04	--	0.66	--	0.67	--
1999	0.27	0.13	0.97	0.68	1.14	0.75
2000	0.26	0.19	0.74	0.79	0.89	0.90
2001	0.14	0.22	0.97	0.89	1.05	1.03
2002	0.34	0.25	0.26	0.66	0.45	0.80
2003	0.32	0.27	0.71	0.65	0.98	0.83
2004	0.14	0.27	0.22	0.40	0.28	0.57
2005	0.11	0.19	0.35	0.43	0.43	0.56
2006	0.32	0.19	0.42	0.33	0.68	0.46
2007	0.21	0.21	0.5	0.42	0.69	0.60
2008	0.15	0.23	0.13	0.35	0.23	0.53
2009	0.10	0.15	0.20	0.28	0.25	0.39

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 2009.

Year	Cocheco River			Lamprey River			Oyster River			Exeter River			'Great Bay Indicator Stock' Annual 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	Scale Samples	Repeat Spawners	Repeat Spawning Percentage
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2002	140	53	38%	160	88	56%	144	65	45%	97	31	27%	541	238	44%
2003	141	52	36%	142	83	58%	146	74	51%	83	35	37%	513	243	47%
2004	134	57	44%	148	84	57%	141	72	52%	55	19	34%	478	232	49%
2005	127	61	49%	144	77	53%	135	76	56%	59	20	34%	465	234	50%
2006	110	61	55%	138	76	55%	133	71	53%	46	15	34%	426	223	52%
2007	123	52	44%	134	75	56%	149	64	44%	40	9	26%	446	200	45%
2008	130	46	37%	139	69	50%	156	57	36%	67	9	22%	493	180	38%
2009	132	39	29%	147	69	47%	143	50	36%	167	20	13%	589	178	31%

* All numbers shown are 3-yr 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 2009.

Year	Cocheco River					Lamprey River					Oyster River					Exeter River					'Great Bay Indicator Stock'									
	% 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	% of r0	% of r1	% of r2	% of r3	% of r4
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
2002	62%	25%	12%	1%	0%	45%	33%	19%	4%	0%	55%	28%	13%	4%	0%	68%	21%	10%	1%	0%	56%	27%	14%	3%	0%	56%	27%	14%	3%	0%
2003	63%	25%	9%	2%	0%	42%	34%	20%	5%	0%	49%	30%	16%	4%	0%	58%	27%	13%	2%	0%	53%	29%	15%	3%	0%	53%	29%	15%	3%	0%
2004	57%	28%	13%	2%	0%	43%	28%	23%	6%	0%	49%	25%	21%	5%	0%	66%	22%	11%	1%	0%	51%	26%	18%	4%	0%	51%	26%	18%	4%	0%
2005	52%	29%	15%	4%	0%	47%	30%	18%	5%	0%	44%	31%	21%	4%	0%	66%	22%	10%	2%	0%	50%	29%	17%	4%	0%	50%	29%	17%	4%	0%
2006	44%	33%	16%	6%	1%	45%	32%	18%	5%	0%	47%	28%	20%	5%	0%	68%	22%	8%	2%	0%	48%	30%	17%	5%	0%	48%	30%	17%	5%	0%
2007	58%	22%	13%	6%	1%	44%	32%	19%	4%	1%	57%	29%	11%	3%	0%	78%	18%	3%	2%	0%	55%	27%	13%	4%	0%	55%	27%	13%	4%	0%
2008	65%	22%	9%	4%	1%	51%	27%	17%	5%	1%	64%	24%	9%	4%	0%	86%	11%	2%	0%	0%	63%	22%	10%	4%	0%	63%	22%	10%	4%	0%
2009	70%	21%	6%	2%	0%	53%	29%	13%	3%	1%	65%	26%	7%	2%	0%	88%	11%	1%	0%	0%	70%	21%	7%	2%	0%	70%	21%	7%	2%	0%

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

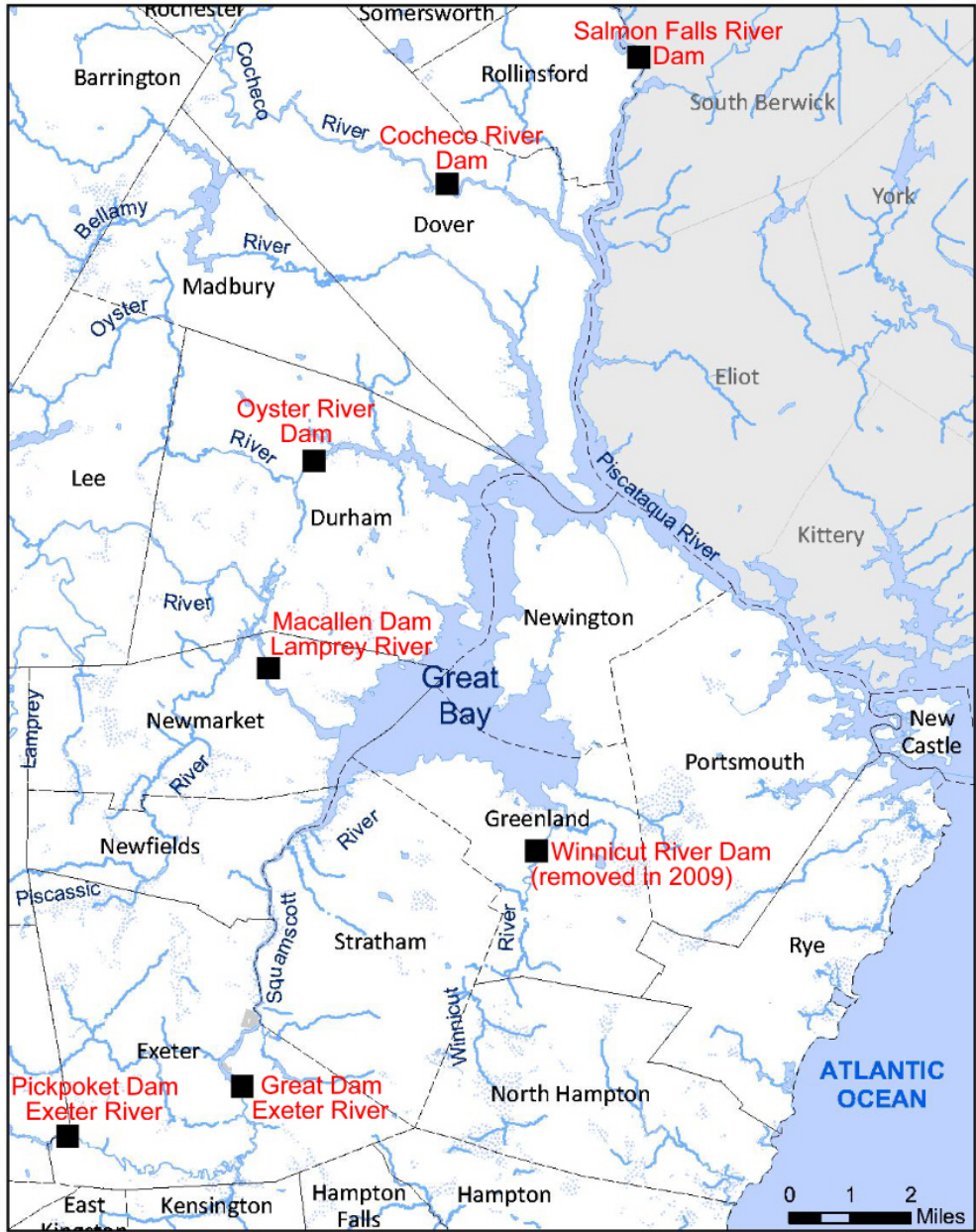


Figure 1. Map of the Great Bay Estuary showing major coastal rivers, and dam locations.

APPENDIX 1.

Table A1. Number of river herring successfully ascending fish passage structures in New Hampshire by river between 1978 and 2009.

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	525	172,557
2001	46,590	6,703	66,989	39,330	7,065	1,118	167,795
2002	62,472	3,341	58,179	58,605	5,829	7,041	195,467
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	223	2,703	72,346
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	174	20,780	36,247	976	8,359	97,214
2009	36,165	513	11,661	42,425	***	4,974	95,737

* - 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 netters in New Hampshire by location between 1989 and 2009; Areas used to calculate the harvest portion of the annual ‘Great Bay Indicator Stock’ used to set the sustainability target are shown.

Year	Cochecho 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	81	0	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	43,368	0	974	1,642	0	190	0	25	1,854	49,115	47,261	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	40	1,814	558	23,219	0	1,123	1,314	0	160	0	60	10	28,298	28,288	100%
2002	0	42	473	25,443	0	1,142	255	0	0	0	0	0	27,355	27,355	100%
2003	34	1,786	302	25,763	0	267	382	0	0	0	0	0	28,534	28,534	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	0	0	0	0	0	3,257	3,257	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	13,810	0	838	43	0	0	0	0	0	18,879	18,879	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 2009.

Year	Cocheco River				Lamprey River				Oyster River				Exeter River [†]				‘Great Bay Indicator Stock’ Harvest to Return Percentage			
	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	ΣH	ΣR	(ΣH/ΣR)* 100	
1989	0	18,455	18,455	0%	10,220	26,149	36,369	28%	92	38,925	39,017	0%	25,498	--	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	--	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	--	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%	43,368	392	43,760	99%	44,429	171,161	26%	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	58,605	58,647	0%	473	58,179	58,652	1%	25,443	3,341	28,784	88%	25,998	208,595	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	174	13,915	99%	14,519	102,406	14%	Below Target
2009	566	36,165	36,731	2%	3,532	42,425	45,957	8%	90	11,661	11,751	1%	13,810	513	14,323	96%	17,998	108,762	17%	Below 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 2009.

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	1.41	1.82	1.77	1.67
1994	2.08		1.22	1.35	1.45
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	1.06	1.08	0.89
1998	0.81	0.78	0.95	0.96	0.77
1999	0.82	1.26	1.83	0.94	0.92
2000	0.99	1.75	1.39	0.80	1.01
2001	0.86	0.98	0.71	1.11	0.73
2002	0.76	1.53	0.70	0.74	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	0.67	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

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 2009 (Plots in Figure A1).

Cocheco River			Lamprey River			Oyster River		
Year	Z	Annual Ladder Return (single years)	Year	Z	Annual Ladder Return (single years)	Year	Z	Annual Ladder Return (single years)
1991	0.92	25,753	1991	0.81	29,871	1991	1.02	151,975
1992	0.81	72,491	1992	1.17	16,511	1992	0.71	157,024
1993	1.67	40,372	1993	1.77	25,289	1993	1.82	73,788
1994	2.08	33,140	1994	1.35	14,119	1994	1.22	91,974
1995	1.27	79,385	1995	1.43	15,904	1995	1.44	82,895
1996	0.82	32,767	1996	1.16	11,200	1996	1.20	82,362
1997	0.87	31,182	1997	1.08	22,236	1997	1.06	57,920
1998	0.81	25,277	1998	0.96	15,947	1998	0.95	85,116
1999	0.82	16,679	1999	0.94	20,067	1999	1.83	88,063
2000	0.99	30,938	2000	0.80	25,678	2000	1.39	70,873
2001	0.86	46,590	2001	1.11	39,330	2001	0.71	66,989
2002	0.76	62,472	2002	0.74	58,605	2002	0.70	58,179
2003	1.16	71,199	2003	0.64	64,486	2003	0.96	51,536
2004	1.20	47,934	2004	0.86	66,333	2004	1.44	52,934
2005	1.08	16,446	2005	1.06	40,026	2005	1.44	12,882
2006	0.96	4,318	2006	0.70	23,471	2006	0.67	6,035
2007	0.81	15,815	2007	1.09	55,225	2007	0.80	17,421
2008	0.97	30,686	2008	0.85	36,247	2008	0.82	20,780
2009	0.74	36,165	2009	1.02	42,425	2009	1.02	11,661
$r^2 = 0.013$		$P > 0.05$	$r^2 = 0.211$		$P < 0.05$	$r^2 = 0.011$		$P > 0.05$
Not Significant			Significant			Not Significant		

Squamscott/Exeter River			Great Bay Indicator Stock		
Year	Z	Annual Ladder Return (single years)	Year	Z	Annual Ladder Return (single years)
1991	1.02	313	1991	0.95	207,912
1992	1.01	537	1992	0.90	246,563
1993	1.41	278	1993	1.67	139,727
1994			1994	1.45	139,233
1995	1.72	592	1995	1.45	178,776
1996	1.39	248	1996	0.99	126,577
1997	1.01	1,302	1997	0.89	112,640
1998	0.78	392	1998	0.77	126,732
1999	1.26	2,821	1999	0.92	127,630
2000	1.75	533	2000	1.01	128,022
2001	0.98	6,703	2001	0.73	159,612
2002	1.53	3,341	2002	0.65	182,597
2003	0.91	71	2003	0.87	187,292
2004	1.19	83	2004	1.10	167,284
2005	1.27	66	2005	1.16	69,420
2006	0.69	16	2006	0.75	33,840
2007	0.99	40	2007	0.85	88,501
2008	0.89	174	2008	1.00	87,887
2009	0.90	513	2009	0.78	90,764
$r^2 = 0.005$		$P > 0.05$	$r^2 = 0.006$		$P > 0.05$
Not Significant			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 2009 (Plots in Figure A2).

Cocheco River			Lamprey River			Oyster River		
Year	Z	Annual Harvest (single years)	Year	Z	Annual Harvest (single years)	Year	Z	Annual Harvest (single years)
1991	0.92	0	1991	0.92	9,155	1991	0.92	320
1992	0.81	58	1992	0.81	14,700	1992	0.81	796
1993	1.67	43	1993	1.67	0	1993	1.67	1,666
1994	2.08	2	1994	2.08	0	1994	2.08	103
1995	1.27	4	1995	1.27	1,230	1995	1.27	94
1996	0.82	0	1996	0.82	880	1996	0.82	1,369
1997	0.87	310	1997	0.87	1,050	1997	0.87	683
1998	0.81	38	1998	0.81	820	1998	0.81	203
1999	0.82	72	1999	0.82	320	1999	0.82	265
2000	0.99	100	2000	0.99	1,550	2000	0.99	690
2001	0.86	0	2001	0.86	1,814	2001	0.86	558
2002	0.76	40	2002	0.76	42	2002	0.76	473
2003	1.16	34	2003	1.16	1,786	2003	1.16	302
2004	1.20	171	2004	1.20	481	2004	1.20	650
2005	1.08	50	2005	1.08	353	2005	1.08	138
2006	0.96	120	2006	0.96	1,009	2006	0.96	126
2007	0.81	343	2007	0.81	154	2007	0.81	45
2008	0.97	538	2008	0.97	152	2008	0.97	88
2009	0.74	566	2009	0.74	3,532	2009	0.74	90
$r^2 = 0.085$		$P > 0.05$	$r^2 = 0.065$		$P > 0.05$	$r^2 = 0.015$		$P > 0.05$
Not Significant			Not Significant			Not Significant		

Squamscott/Exeter River			Great Bay Indicator Stock		
Year	Z	Annual Harvest (single years)	Year	Z	Annual Harvest (single years)
1991	0.92	5,139	1991	0.92	14,614
1992	0.81	2,681	1992	0.81	18,235
1993	1.67	2,124	1993	1.67	3,833
1994	2.08	3,497	1994	2.08	3,602
1995	1.27	8,197	1995	1.27	9,525
1996	0.82	4,127	1996	0.82	6,376
1997	0.87	14,882	1997	0.87	16,925
1998	0.81	43,368	1998	0.81	44,429
1999	0.82	33,045	1999	0.82	33,702
2000	0.99	38,628	2000	0.99	40,968
2001	0.86	23,219	2001	0.86	25,591
2002	0.76	25,443	2002	0.76	25,998
2003	1.16	25,763	2003	1.16	27,885
2004	1.20	11,948	2004	1.20	13,250
2005	1.08	1,934	2005	1.08	2,475
2006	0.96	1,369	2006	0.96	2,624
2007	0.81	1,354	2007	0.81	1,896
2008	0.97	13,741	2008	0.97	14,519
2009	0.74	13,810	2009	0.74	17,998
$r^2 = 0.104$		$P > 0.05$	$r^2 = 0.163$		$P > 0.05$
Not Significant			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 2009 (Plots in Figure A3).

Cocheco River			Lamprey River			Oyster River		
Year	Z	Exploitation Rate (single years)	Year	Z	Exploitation Rate (single years)	Year	Z	Exploitation Rate (single years)
1991	0.92	0.0%	1991	0.81	23.5%	1991	1.02	0.2%
1992	0.81	0.1%	1992	1.17	47.1%	1992	0.71	0.5%
1993	1.67	0.1%	1993	1.77	0.0%	1993	1.82	2.2%
1994	2.08	0.0%	1994	1.35	0.0%	1994	1.22	0.1%
1995	1.27	0.0%	1995	1.43	7.2%	1995	1.44	0.1%
1996	0.82	0.0%	1996	1.16	7.3%	1996	1.20	1.6%
1997	0.87	1.0%	1997	1.08	4.5%	1997	1.06	1.2%
1998	0.81	0.2%	1998	0.96	4.9%	1998	0.95	0.2%
1999	0.82	0.4%	1999	0.94	1.6%	1999	1.83	0.3%
2000	0.99	0.3%	2000	0.80	5.7%	2000	1.39	1.0%
2001	0.86	0.0%	2001	1.11	4.4%	2001	0.71	0.8%
2002	0.76	0.1%	2002	0.74	0.1%	2002	0.70	0.8%
2003	1.16	0.0%	2003	0.64	2.7%	2003	0.96	0.6%
2004	1.20	0.4%	2004	0.86	0.7%	2004	1.44	1.2%
2005	1.08	0.3%	2005	1.06	0.9%	2005	1.44	1.1%
2006	0.96	2.7%	2006	0.70	4.1%	2006	0.67	2.0%
2007	0.81	2.1%	2007	1.09	0.3%	2007	0.80	0.3%
2008	0.97	1.7%	2008	0.85	0.4%	2008	0.82	0.4%
2009	0.74	1.5%	2009	1.02	7.7%	2009	1.02	0.8%
$r^2 = 0.075$		$P > 0.05$	$r^2 = 0.001$		$P > 0.05$	$r^2 = 0.027$		$P > 0.05$
Not Significant			Not Significant			Not Significant		

Squamscott/Exeter River			Great Bay Indicator Stock		
Year	Z	Exploitation Rate (single years)	Year	Z	Exploitation Rate (single years)
1991	1.02	94.3%	1991	0.95	6.6%
1992	1.01	83.3%	1992	0.90	6.9%
1993	1.41	88.4%	1993	1.67	2.7%
1994			1994	1.45	2.5%
1995	1.72	93.3%	1995	1.45	5.1%
1996	1.39	94.3%	1996	0.99	4.8%
1997	1.01	92.0%	1997	0.89	13.1%
1998	0.78	99.1%	1998	0.77	26.0%
1999	1.26	92.1%	1999	0.92	20.9%
2000	1.75	98.6%	2000	1.01	24.2%
2001	0.98	77.6%	2001	0.73	13.8%
2002	1.53	88.4%	2002	0.65	12.5%
2003	0.91	99.7%	2003	0.87	13.0%
2004	1.19	99.3%	2004	1.10	7.3%
2005	1.27	96.7%	2005	1.16	3.4%
2006	0.69	98.8%	2006	0.75	7.2%
2007	0.99	97.1%	2007	0.85	2.1%
2008	0.89	98.7%	2008	1.00	14.2%
2009	0.90	96.4%	2009	0.78	16.5%
$r^2 = 0.017$		$P > 0.05$	$r^2 = 0.245$		$P < 0.05$
Not Significant			Significant		

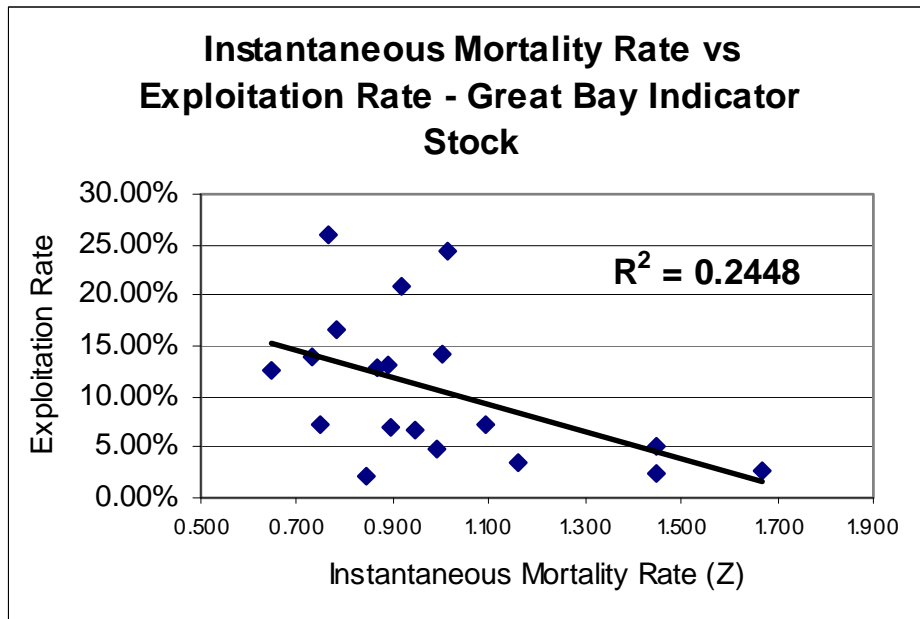
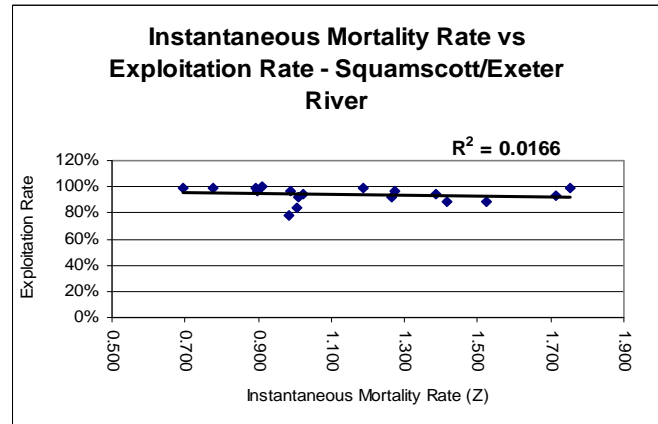
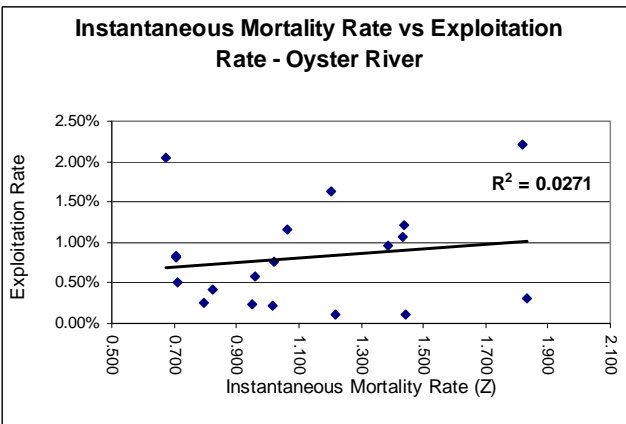
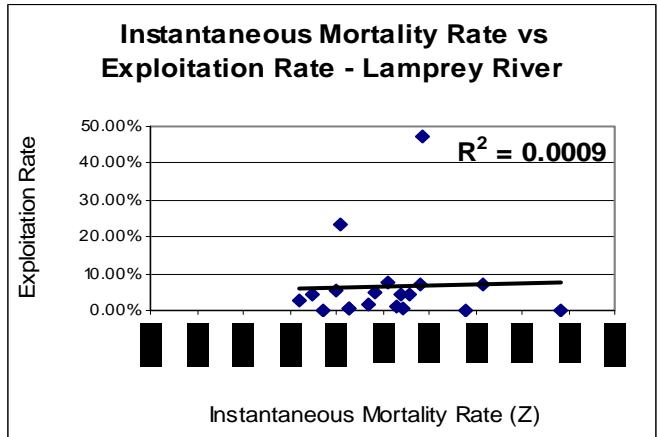
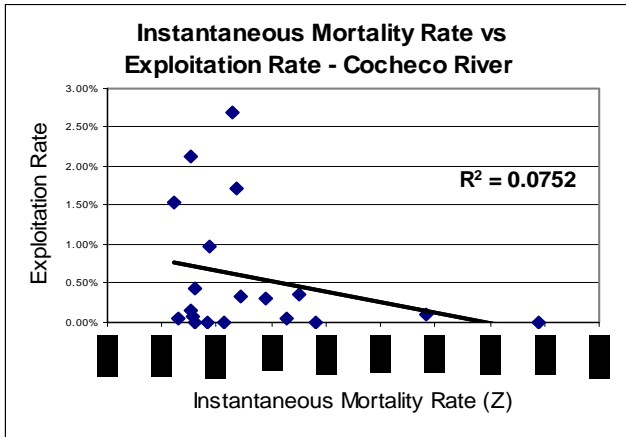


Figure A1. Plots of instantaneous mortality rate against river herring exploitation rates for individual years, 1991-2009, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

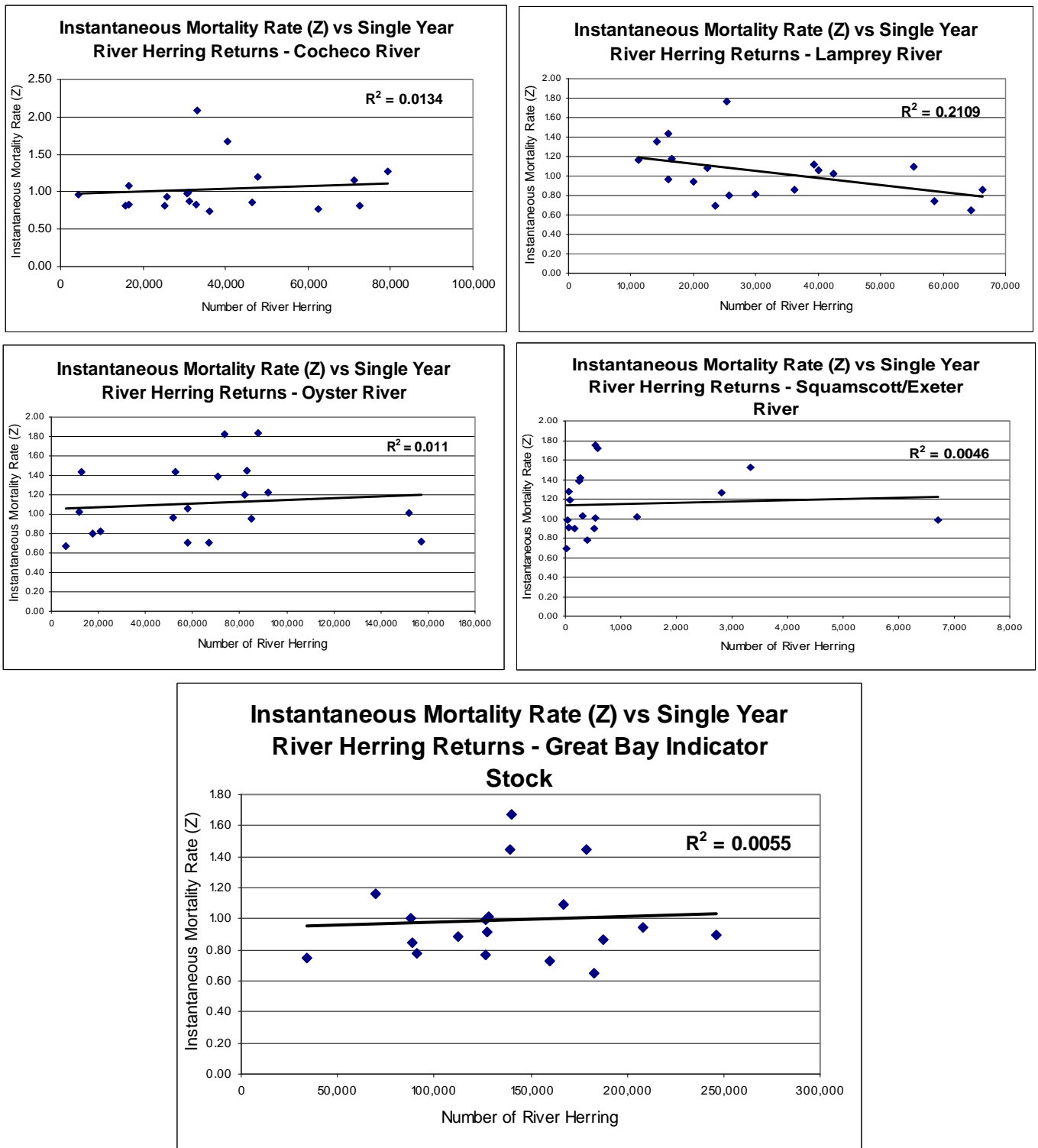


Figure A2. Plots of instantaneous mortality rate against river herring ladder returns for individual years, 1991-2009, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

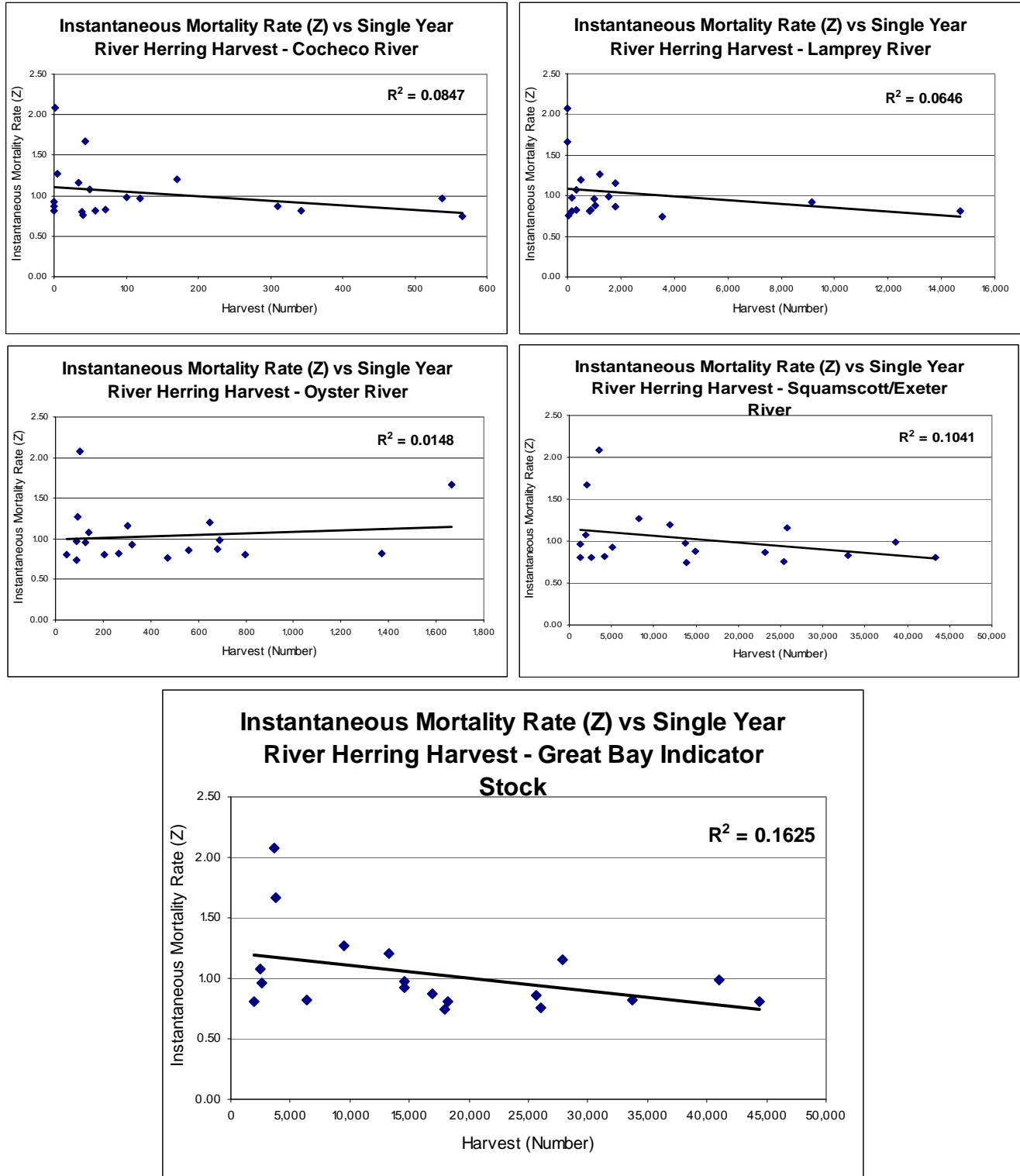


Figure A3. Plots of instantaneous mortality rate against river herring harvest for individual years, 1991-2009, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

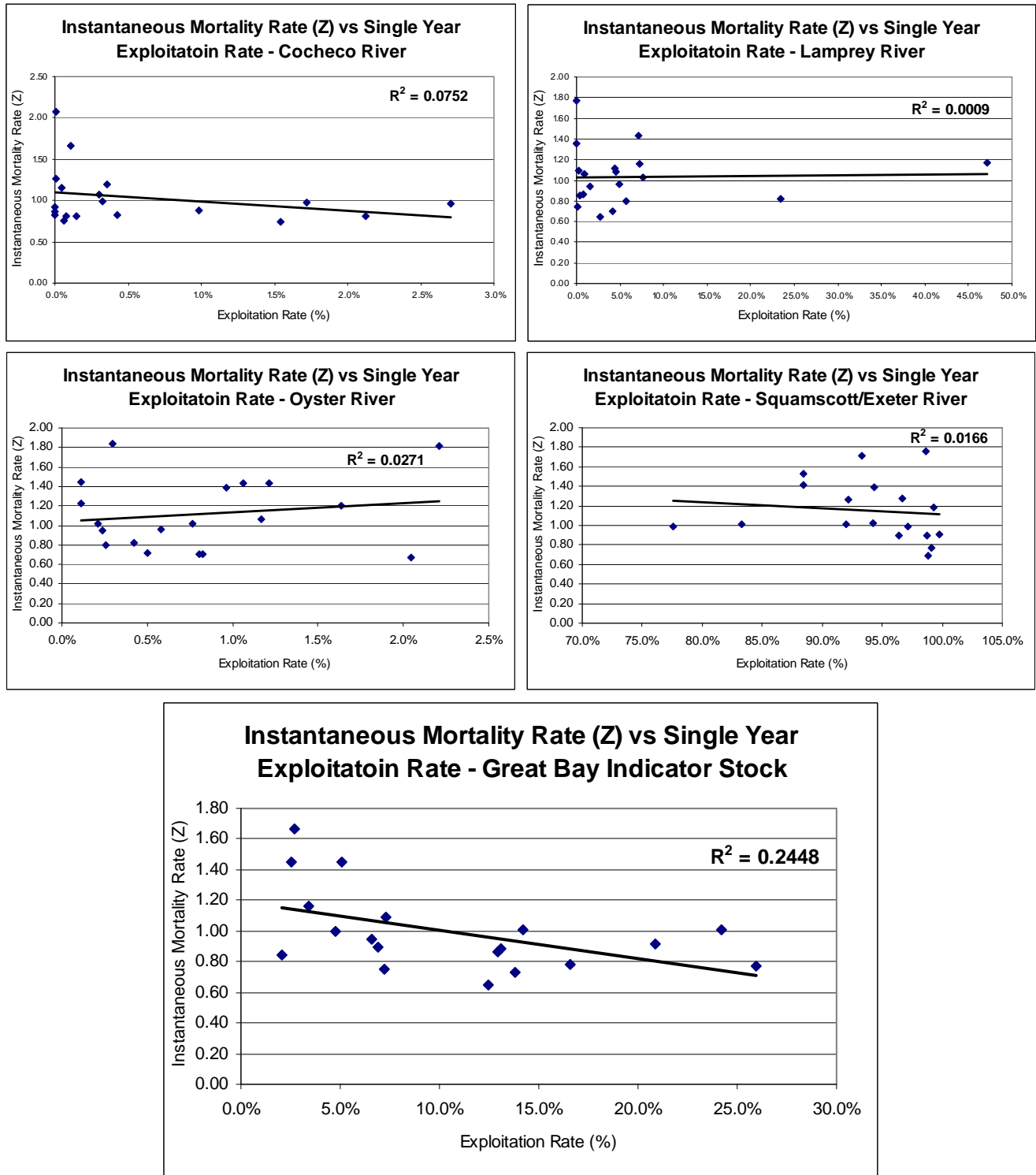


Figure A4. Plots of instantaneous mortality rate against exploitation rates of river herring for individual years, 1991-2009, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.