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ECONOMIC BENEFITS OF A BAIT FISHERY FOR ALEWIVES ON THE ST. CROIX RIVER

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Table of Contents

Acknowledgements 3
Executive Summary 4
Introduction 5
Socioeconomic Profile of the St. Croix Watershed 5
Alewife Population Growth 7
Direct Benefits 10
    Revenue 11
    Infrastructure Costs 15
Indirect Benefits: Lobster Bait Savings 15
Total Benefits 19
Conclusion 20
References 21
Appendix 1: Population Growth and Harvest Model 23
Appendix 2: Sensitivity to Carrying Capacity Assumption 24
Appendix 3: Sensitivity to Growth Rate Assumption 25
Appendix 4: Sensitivity to Price Assumption 30
Appendix 5: Sensitivity to Discount Rate Assumption 31

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Executive Summary

This report estimates economic benefits of reopening the fish ladders on the St. Croix River and rebuilding its alewife run. Benefits considered would be derived from direct sale of alewives as bait and cost savings for lobstermen. Cost savings are achieved through providing a bait source that is less expensive, and also potentially more efficient and effective.

Other benefits likely to be derived from a rebuilt alewife run include recovery of local groundfish populations, improved bird watching and recreational fishing opportunities, and the alewife run itself as an attraction. Additionally, substituting locally caught alewife for non-native species sometimes used as bait not only keep the revenue within the local community, but would also reduce the risk and costs of introducing detrimental parasites or pathogens. Recovery of other diadromous species (e.g., Atlantic salmon) might provide benefits as well. However, all of those outcomes entail much greater uncertainty than alewife population dynamics and the economics of the lobster fishery, and the benefits are accordingly more difficult to quantify. Therefore, we focus on bait sales and cost savings for lobstermen, and consequently our estimates are likely an underestimate of the overall value to be generated.

To take into account uncertainty in biological and economic parameters, we explore the potential benefits under a range of different assumptions. We conclude that opening the alewife ladders on the St. Croix is likely to yield positive economic benefit to communities along the St. Croix River and to lobstermen in other areas of Maine, specifically:

- Direct Benefits: Under our preferred set of parameters, the net present value of bait sales from an optimally managed alewife fishery is $1.8 million. This additional revenue would accrue to a region of Maine that has historically had some of the lowest incomes and highest unemployment rates in the state.

- Indirect Benefits: The sale of alewives to lobstermen would reduce bait costs as they substitute alewife in place of more expensive baits. Many lobstermen report that alewives fish better than other baits, so we considered the benefits of lower overall bait use as well to achieve the same catch rates. Assuming optimal management of the alewife fishery, the net present value of these indirect benefits is in the range of $1.2 to $4 million.

The combined net present value of the direct and indirect benefits is in the range of $3.1 million to $5.9 million. Again, those are partial estimates of the value to be derived and do not include other ecosystem services linked to a rebuilt alewife run.

Introduction

As documented in Flagg (2007), healthy alewife populations historically existed in the St. Croix River. Populations fell when dams were constructed starting in the 1700's, but grew again in the 1980's when fish ladders were installed. In 1995, these fish ladders were closed due to concerns over smallmouth bass populations. Since this closure, alewives have been unable to return to these traditional spawning grounds.

The historic alewife population on the St. Croix River can be rebuilt by opening fish ladders and allowing the fish to return to their traditional spawning grounds.

This action will have economic impacts. Others have identified increased revenue from bird watching, from recreational fishing and from the rebuilding of the local groundfish population as potential economic benefits from such an action. This report focuses on the direct and indirect benefits that could result from alewife as lobster bait. Specifically it identifies:

(1) Direct benefits as the net revenue from the sale of lobster bait resulting from a functioning alewife fishery ('direct benefits'); and

(2) Indirect benefits as the savings in bait costs to the lobster fishery ('lobster bait savings benefits') resulting from a functioning alewife fishery.

To put the relative impact of each in context, we first provide background information on the St. Croix watershed. We focus on the social and economic characteristics of the watershed to provide context for any monetary estimates of benefits. Next, we use biological parameters from prior studies of the St. Croix River alewife population to predict the future alewife population and the potential alewife harvest that would occur if the fish ladders were opened. Using the population estimates we then quantify the potential direct and indirect benefits defined above. Finally, we provide estimates of the total economic benefit (direct plus indirect benefits).

Socioeconomic Profile of the St. Croix Watershed

The St. Croix River borders both Maine and New Brunswick (see Figure 1) resulting in multi-jurisdictional management of the river by the International Joint Commission. The multi-jurisdictional nature of management requires consideration of the benefits that would accrue to both United States and Canadian interests. Therefore, we consider both the properties of the population of the overall St. Croix

watershed and the characteristics of the residents of Washington County, Maine, those closest to the St. Croix in the United States.

FIGURE 1: ST. CROIX RIVER (DILL ET. AL, 2010)

The total population in the St. Croix watershed in 2006 was estimated to be 24,300, with a higher percentage of the population located on the New Brunswick side of the river (FB Environmental, 2008). As of 2006, approximately 40% of the population lived in Maine, while the other 60% lived in New Brunswick (FB Environmental, 2008). The population in both Maine and New Brunswick is geographically concentrated along the river. Approximately 75% of the population of the St. Croix watershed is located within 10 miles of the estuary.

Within the St. Croix watershed, harvesting and manufacturing of wood products, as well as hunting, fishing, and tourism, are important sources of employment (FB Environmental, 2008). Historically the St. Croix watershed has been an economically depressed region, relative to areas in Maine and New Brunswick away from the watershed. However, from 1996 to 2006, the New Brunswick population remained stable and as of 2006 was no longer considered economically depressed relative to other areas of New Brunswick (FB Environmental, 2008). Conversely, the population on the Maine side of the river is trending down and the area remains economically depressed. From 1996 to 2006 the population on the Maine side of the river declined by approximately 13% (FB Environmental, 2008). Most of the affected population is in Washington County, Maine. Although there are portions of Washington County that are not in the St. Croix watershed, the entire county is influenced by the river and would be affected by a rebuilt alewife run.

The 2010 population of Washington County was approximately 32,900 people, a 3.2% decline from 2000 (U.S. Census Bureau, 2011). The Maine State Planning Office is predicting the decline in population will continue in the future (MSPO, 2010).

Young adults are leaving and the remaining population is growing older (Brookings Institution, 2006).

Washington County is the poorest county in the state of Maine. The median 2009 household income of the 14,256 households was estimated to be $31,861, and over 20% of the people in the county live below the poverty line (U.S. Census Bureau, 2011).

Several economic challenges face Washington County. Foremost is the exit of manufacturing (including paper making, textile and apparel) and natural resource based industries (including lumber, wood product manufacturing, aquaculture, and fish processing) that have traditionally been major employers in the region (Brookings Institution, 2006; Maine Department of Labor, 2006). Washington County has the second highest unemployment rate in the state of 11.1% (Bureau of Labor Statistics, 2011). Residents of Washington County are concerned about the loss of fishing and forestry jobs and how the associated income loss is affecting their families and communities (Safford and Hamilton, 2010).

Despite the loss of these types of jobs, the County is still heavily reliant on manufacturing and natural resource related industries. Service sector employment, such as tourism, is growing, but is still a relatively small part of the economy, especially in comparison to the rest of Maine (Hassan et al., 2011).

Alewife Population Growth

In the following section, we use biological assessments of alewife growth and production from prior studies of the St. Croix River alewife population to predict the future alewife population and the potential alewife harvest that would occur if the fish ladders were opened.

A summary of the inputs to the model is provided in Figure 2. There is uncertainty in some of the inputs. Specifically, the major sources of uncertainty include the number of years the population recovers before harvest begins, the percent of the alewife population that is harvested and the intrinsic growth rate used in the logistic model. The first two inputs (the years until harvest begins and the percent of the population harvested) are both policy decisions. The logistic model is based on studies of population growth that suggest that populations will grow rapidly when they are small relative to their environmental carrying capacity and will level out as they reach the limits of their food supply and other constraints on population growth. The third input, the intrinsic growth rate, refers to the maximum growth rate that is seen when populations are small.

An important biological parameter is the growth rate of the population. The range in the alewife population growth rate reflects uncertainty in how fast the stock can

grow. We use the Atlantic States Marine Fisheries Commission's (ASMFC) estimate 0.38 for the growth rate of alewife on the St. Croix River (ASFMC, 1990). In Appendix 3 we also provide the results of our model using growth rates of 0.25 and 0.5, corresponding to the range of growth rates explored in Dill et. al (2010).

FIGURE 2: INPUTS TO THE POPULATION GROWTH MODEL

Inputs		Source
Alewife Carrying Capacity	23,601,357	Dill et al. (2010)
% Alewife Population Harvested	Low: 20% High: 40%	ASFMC (2010)
Years Population Regrows Before Harvest	Low: 5 High: 10	--
Year 0 Alewife Population	10,450	Dill et al. (2010)
Population Growth Rate	0.38	ASFMC (1990)

Harvesting decisions, including the years until harvest begins and the percent of the population harvested, impact the alewife population as well as the revenue to the fishery. There is clearly a relationship between current harvests and future harvests, and, as a consequence, current revenues and future revenues. In particular, forgoing harvest in the current period allows the stock to build, and results in larger harvests in the future. On the other hand, forgoing harvest in the current period also means forgoing revenue. Therefore, there is a tradeoff between harvesting the stock in the current period and receiving revenue immediately, and 'investing' in the stock and allowing it to grow and yield larger revenues in the future. The total present value of revenue in the current and future periods can be maximized by modeling this tradeoff and choosing a harvesting plan that maximizes the present value of revenue.

If the policy goal were to maximize the present value of revenue of the fishery, the optimal choice would be to allow the stock to regrow for 20 years without harvest and then to harvest 24% of the population annually.[1] We designate this scenario as the optimal management strategy.[2]

Recognizing that other scenarios are currently under consideration by policymakers, we also examine the benefits from a range of these scenarios. Specifically, we consider the case where the population is allowed to regrow (with no harvest) for both 5 and 10 years. We also examine the case where harvest (after initial regrowth) of 20% of the stock is permitted and where harvest of 40% of the

[1] We assume that the only value from the alewife fishery is the value from the harvest. More complex models could include additional values such as ecosystem services. If the additional values are substantial, the optimal number of years to allow the stock to grow before harvest and the percent of the population to harvest may change.

[2] Although we first introduce the concept of an optimal harvest plan in this section, the modeling requires inputs from the subsequent section including a discount rate and assumptions about alewife prices. Therefore, a more detailed discussion of the model is delayed until the subsequent section.

stock is permitted. These percentages were chosen to represent a range of harvest levels managers have chosen to implement in other rivers in Maine that harvest alewife (ASFMC, 2010). Appendix 1 provides more detail on the population model and the inputs.

Figures 3 and 4 show the growth and harvest of the alewife population through time under different assumptions about harvest rate, and the years the population is allowed to regrow unharvested.

The alewife population growth under various harvest scenarios is depicted in Figure 3. Figure 3 demonstrates the importance of both the wait time and harvest rate. The optimal harvest strategy includes a wait time of 20 years and a subsequent harvest rate of 24%.

Figure 4 shows alewife harvest (in fish) that will occur under different harvest scenarios. In later years the alewife harvest is much larger if the harvest rate chosen is low. After Year 20, the low-harvest (20% of alewife population) with a 5-year regrowth strategy yields a larger harvest than either of the high-harvest (40% of alewife population) scenarios. After Year 37, the optimal harvest strategy and the two low-harvest strategies produce similar alewife yields of about 2.0-2.2 million fish (or 1.0-1.1 million pounds). However, between Years 20 and 37, the optimal strategy allows for higher harvest levels because the population has been allowed to grow larger than in any other harvest scenario considered here.

FIGURE 3: ALEWIFE POPULATION BY YEAR AND HARVEST SCENARIO

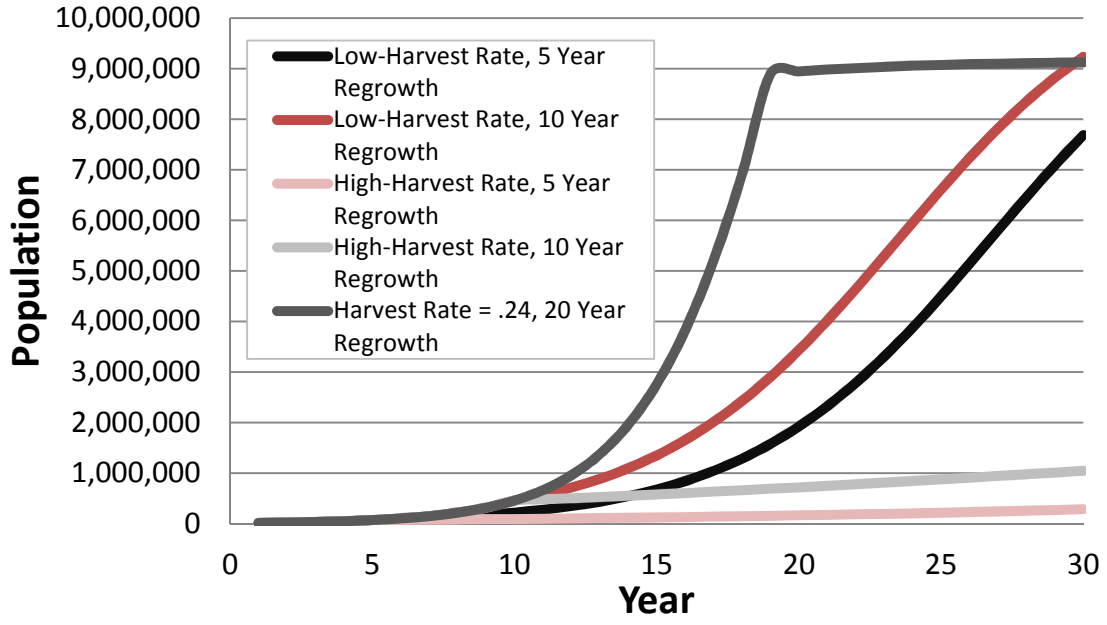
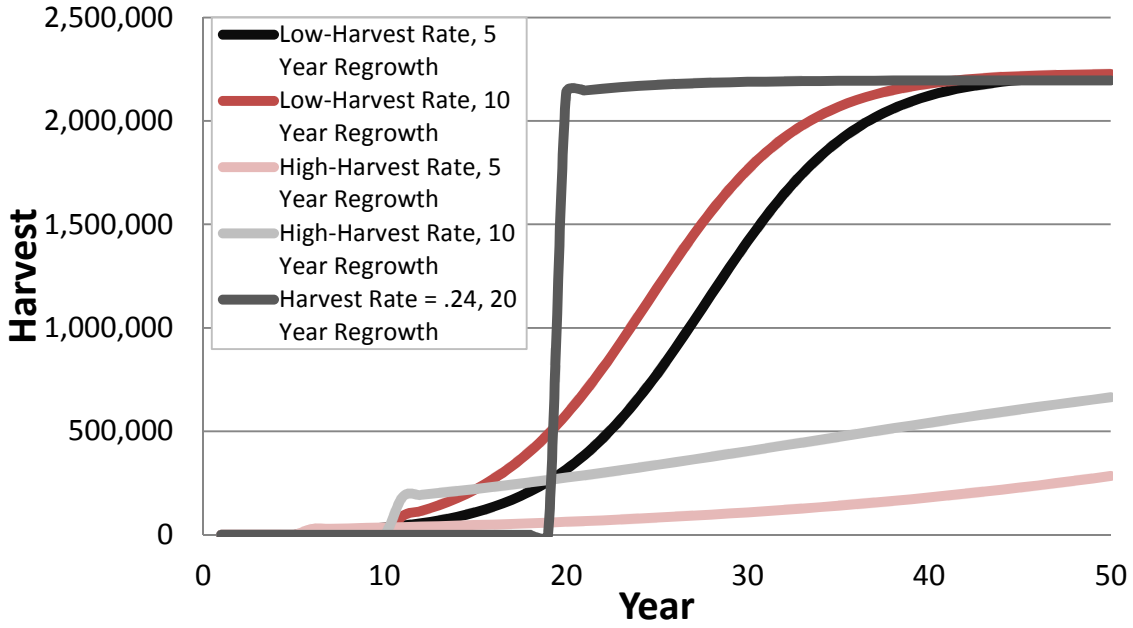


FIGURE 4: ALEWIFE HARVEST (IN FISH) BY YEAR AND HARVEST SCENARIO



Direct Benefits

The most obvious direct benefit of establishing an alewife fishery with a healthy alewife population in the St. Croix is the revenue that would result from the sale of alewife as lobster bait. It is expected the fishery will be similar to the fisheries that occur throughout the state of Maine in other rivers (ASFMC, 2010; Dill et al., 2010). If such a fishery is established on the St. Croix, it could provide an important new source of jobs and income for residents of the watershed.

A full analysis of the profitability of an alewife fishery would require estimates of revenue and operating costs for each year the fishery is projected to be in operation, as well as estimates of the up-front costs to set up the infrastructure on the St. Croix. Operating costs would be particularly useful in estimating the expected profit for the owners of an alewife harvest site; however, they are not necessary to get a sense for the impact on the region as a whole, since the bulk of yearly operational costs in this labor-intensive industry are payments to alewife harvesters (ASFMC, 2010). Given that alewife harvesters in Maine are local residents (ASFMC, 2010), the payments to alewife fishermen are retained in the local economy. This allows us to focus on the total revenue from the alewife fishery as a measure of increased economic activity that will occur in the St. Croix watershed if an alewife fishery opens.

Revenue

The revenue from a functioning alewife fishery will be the total pounds of alewife harvested multiplied by the price per pound. Given that the benefits of alewife restoration will extend into the future, it is also important to consider the fact that monetary payments received in the future are not as valuable as payments received today. We do that by using a discount rate. The discount rate accounts for the fact that most people do not value a dollar that they will receive in the distant future as highly as they value a dollar received today. The theory behind discounting future revenue is well-accepted, but the choice of discount rate is controversial. We use a discount rate of 5%, but also provide the results of our calculations using discount rates of 3% and 7% in Appendix 5.

Expected Alewife Price

To estimate the price that alewife harvesters on the St. Croix would receive if the fishery opened, we gathered data on the prices alewife harvesters currently receive for their harvest on other Maine rivers. We also conducted interviews to understand how the introduction of harvest from the St. Croix may impact prices throughout the region, how St. Croix prices will likely compare to prices of alewife from other rivers, and how prices for alewife may change in the future.

Throughout this process we identified three important factors to consider when establishing the range of prices. Because alewives are primarily harvested and sold to lobstermen as lobster bait, the first factor that needs consideration is the linkage between the harvest of alewife on the St. Croix and the larger market for lobster bait. The second factor is the geographic extent of alewife markets and whether the harvest of alewives on the St. Croix will change the price of alewife in other areas. The final factor to consider is how the price of alewife from the St. Croix may change over time. Each of these factors is discussed below.

The market for alewives is part of a broader market for lobster bait in the State of Maine. Traditionally, Atlantic herring has been the primary lobster bait used by Maine lobstermen. Small quantities of other types of bait, such as frozen redfish from Canada, frozen bait from the Pacific Coast, and menhaden from states further south like New Jersey have made up the remaining portion of bait used. In recent years, the herring quota has decreased significantly and the price of herring has increased. This has caused lobstermen to rely more heavily on other types of bait such as menhaden and frozen bait. Frozen bait usage is now more widespread, and usage of exotic frozen species from throughout the U.S., as well as other countries like New Zealand occurs. An impending reduction in the menhaden quota is likely to create further stress on lobster bait supplies, and higher prices in the near-term. Furthermore, the reduction will likely cause lobstermen to adjust the species composition of their bait usage once again.

The current lobster bait situation highlights the ability of lobstermen to substitute across baits and to use baits from different regions of the country and the world. Furthermore, it demonstrates that lobstermen are often subject to fluctuating bait prices that can significantly impact their profitability. As such, the projected future price for bait must recognize that current high prices for lobster may result in new geographic bait sources within the projected recovery periods for the alewife population on the St. Croix.

However, interviews of bait dealers uncovered that the unpredictable and small supply of bait from current alewife markets in Maine makes them potentially less attractive than the potential supply coming from the St. Croix. Current alewife markets in Maine tend to be local in nature. Lobstermen often travel to the alewife sites and purchase the alewives directly from harvesters. Given the small total harvests available from many of the sites, it is not profitable for bait dealers to send larger trucks to pick up alewife to sell. Furthermore, bait dealers we interviewed suggested that unpredictability in supply from the smaller harvest sites also impeded the profitability of their purchasing alewife. The St. Croix has the potential for much larger harvests than other rivers (ASFMC, 2010). Therefore, bait dealers we interviewed suggested the potential for broader geographic distribution of alewife from the St. Croix. In particular, larger operations would be able to truck and sell alewife to lobstermen in ports in Washington County and ports south of Washington County.

The composition of species used as lobster bait, as well as the geographic origin of bait can change through time. All the alewife harvesters and bait dealers interviewed agreed that there is currently excess demand for alewife by lobstermen. Additionally, no interviewee expected a decrease in the price of alewives if larger harvests from the St. Croix were to occur in the future.[3] Instead, it was suggested that, with larger harvests, harvesters could develop better infrastructure to get supply to market (e.g. large and consistent supply justifies trucking alewife to lobster ports) and could therefore charge higher prices for alewife. Justification for the perpetual demand for alewife as bait is three-fold. First, alewife, like Atlantic herring, has properties that make it an effective bait for lobstermen. Second, the quality of herring is low during the weeks of the alewife run. Third, alewife will remain one of the cheapest baits because the harvest costs are low (see descriptions of harvesting techniques in ASFMC (2010)), and transportation costs are low relative to bait shipped from further distances. For example, menhaden must be trucked up from southern locations like New Jersey, and therefore the price to lobstermen is higher to cover the transportation costs and multiple dealers.

[3] Without a model to forecast future alewife prices, it is impossible to predict whether the price would go up or down. It is unclear why the alewife price is currently so far below the frozen bait price since there appears to be excess demand for alewife (according to interviews there are often lines of lobstermen willing to buy more alewife than available). One explanation is that the supply is unreliable. The price might rise when the supply is more reliable. On the other hand, we could also make the traditional prediction that price will decrease with an increase in supply.

Using this information, we assumed that the real price would be constant through time. However, we use a range of bait prices to demonstrate the sensitivity of total revenues to changes in alewife prices. Our preferred estimate for the bait price is the bait price observed in other regions of Maine over the past 5 years. We use the average of the alewife prices from the Maine Lobstermen's Association bait data (MLA, 2011), Maine Department of Marine Resources (MDMR, 2011), and reports from bait dealer interviews to develop our best estimate of current prices. This average price is $19/bushel, while the range of alewife prices lobstermen, bait dealer, and alewife harvester interviewees cited was from $16-$25/bushel. We also estimate the present value of the revenue assuming a reduction in alewife bait price to $15 per bushel and an increase in bait price to $30 per bushel.

Discount Rate

To calculate the present value of revenue from alewife harvest, we also need to discount the revenue in future years. Higher discount rates are associated with preferences for revenue sooner rather than later.

The presence of a discount rate puts a higher value on revenue closer to the present, so there is a benefit from harvesting early. However, the population grows logistically and is starting off very low. When the population is low the harvest will also be low because harvest is set to be a constant percentage of the population. This creates an incentive to forego current harvest to allow the population to grow larger faster. Therefore, it is not clear whether a delayed harvest scenario or an early harvest scenario will maximize the present value of revenues.

Total Revenue Estimates

Given the uncertainty in alewife price, we calculate the total revenue from the fishery under various assumptions about the price of alewives. Figure 5 summarizes the inputs.

FIGURE 5: INPUTS TO THE TOTAL REVENUE MODEL

Inputs		Source
Price per bushel of alewife	Low: $15 Average: $19 High: $30	Maine lobstermen Association bait-price data (MLA, 2011), Maine Department of Marine Resources reports (MDMR, 2011), Personal interviews with bait dealers and lobstermen
# Alewife/Bushel	180	Dill et al. (2010)
Lbs Alewife/Bushel	90	Interviews with lobstermen, bait dealers, and alewife harvesters
Discount Rate	5%	--

We calculate the present value of the stream of revenue from alewife harvesting under the five scenarios from the Population Growth section. For the remainder of the report the figures and text will be based on the preferred price of $19/bushel for alewife. The present value of total revenue, using the preferred price of $19/bushel, is given in Figure 6. The sensitivity of the results to the price of alewife is shown in Appendix 4.

As expected, the highest revenues are obtained by using the optimal management strategy. The results of modeling the low and high-harvest rate and regrowth scenarios highlight the impact (on the present value) of the low-harvest rate in comparison to the high-harvest rate. The present value of harvest revenue for these scenarios can be compared across multiple dimensions including the growth rate, the length of the unharvested regrowth period, and the harvest rate. Between the 5- and 10-year options, the revenue-maximizing choice of the period to regrow without harvest is the 10-year choice.

FIGURE 6: PRESENT VALUE OF ALEWIFE HARVEST REVENUE, CURRENT ALEWIFE PRICES

Scenario	Present Value of Revenue
Optimal Management	
Optimal Harvest Rate, Optimal Regrowth	$1,827,134
Management Alternatives	
Low-Harvest Rate, 5 Year Regrowth	$1,344,338
Low-Harvest Rate, 10 Year Regrowth	$1,551,749
High-Harvest Rate, 5 Year Regrowth	$210,974
High-Harvest Rate, 10 Year Regrowth	$522,339

Another way to think about the revenue from the fishery is the revenue it could yield per year. As shown in Figure 3, the population increases quickly at first and eventually reaches a stable value. This results in a stable yearly harvest. For example, if the alewife ladders had been left open 30 years ago and the population had been harvested at the optimal harvest rate of 0.24 beginning in Year 21, the population would be 9.1 million.[4] The harvest would be 2.2 million fish, or approximately 12,000 bushels. At $19 per bushel this equates to approximately $231,000 per year. See Figure 7 for a summary of these values.[5]

Comparing these values to economic statistics describing Washington County, Maine, can help put the values in context. In 2009, the 40 forestry, fishing, hunting, and agriculture support establishments in Washington County paid their employees a total of $7.6 million. An increase of $231,000 would represent a 3% increase.

[4] It is worth noting that there is little difference between the population in year 30 and year 79: the population is 9.125 million.

[5] Given that revenue is simply the product of harvest and price, the nominal revenue at different points in time for each of the scenarios can be inferred from the graph of harvest (Figure 4).

When making this comparison it is also important to consider the amount of time spent working. The alewife run generally occurs in late May through June. Harvesting only occurs when the alewife run is open, so the money can be earned over a period of less than two months.[6]

Another potential comparison is between the revenue and median household incomes. As previously reported, the median household income of Washington County is $31,861.

FIGURE 7: YEARLY REVENUE FROM ALEWIFE HARVEST IF LADDERS REMAINED OPEN SINCE 1980

Scenario	Estimated Harvest (Bushels)	Nominal Revenue (Estimated Harvest * 2011 Price)
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	12,160	$231,402

Infrastructure Costs

The development of harvest sites will require initial infrastructure investments. There is no way to predict with certainty the number and location of harvesting sites that will be developed along the St. Croix. There is also significant heterogeneity in the type of alewife harvesting operations observed across the state of Maine (ASFMC, 2010). Interviews with alewife harvesters suggest that the St. Croix could support approximately 6 harvest sites along the river. Interviews suggest the infrastructure costs could be as low as $3,000 per site. Relative to the $1.8 million estimate of the present value of revenues described in the previous section, a $3,000 up-front cost is small.

It is also important to note that, in Maine, the development of sites is at the discretion of the municipality. Municipalities have the option of either restricting harvest in their municipality out of concern for the health of the alewife population or allocating permits granting the right to fish. As such, municipalities along the St. Croix could choose to generate tax revenues (fishing permits) from this infrastructure investment.

Indirect Benefits: Lobster Bait Savings

Alewives are one of the cheapest sources of lobster bait. Therefore, having a larger supply of alewives should also result in bait savings to lobstermen. Estimating the

[6] Another advantage is that alewife harvesting falls under the category of resource-based employment. As previously discussed, this sector of the Washington County economy has suffered significant job losses recently. Although it is difficult to predict if the demand for these types of jobs will persist in the future, alewife harvesting could play an important role in helping workers skilled in traditional Washington County jobs stay employed.

bait savings requires understanding what the alewives will replace. As was the case for the estimation of direct benefits, uncertainty over future bait availability and prices complicates this analysis.

Interviews with lobstermen and bait dealers suggest the low cost of alewives and the low quality and availability of Atlantic herring during the springtime alewife run are primary drivers for alewife purchases. Furthermore, interviews suggest that alewife will likely replace, to some degree, expensive frozen bait that is used when the supply of fresh bait is limited and/or unreliable. The Maine Lobstermen's Association bait price data suggest that, during the springtime run of alewife, lobstermen in ports including Stonington, Rockland, Bailey Island, and Portland are fishing with frozen bait including redfish, pogies and more exotic species including orange roughy, Asian carp, mud shad, pacific hake and sole (MLA, 2011). This frozen bait is generally more expensive than alewife. The prices for alewife we use in this report ($15, $19, and $30 per bushel) equate to $0.17, $0.21, and $0.33 per pound. The lowest observed prices for frozen bait are $0.33, and most frozen bait prices are much higher. The range in prices for frozen bait during the springtime alewife run is $0.33-$0.50 per pound.

Although frozen bait is the most expensive type of bait, and therefore the most logical candidate for alewife to replace, alewives will possibly also replace non-frozen bait. Herring will likely not be replaced, as long as the demand from lobstermen for herring is more than its available quota (the likely case for the foreseeable future). Alewives will more likely replace the non-frozen, non-herring bait used by fishermen. Interviews suggest that the only other primary source of bait is pogies (menhaden).

To quantify the bait savings from increased alewife supply, we make assumptions about the price differential between alternative baits and alewife. Frozen bait prices listed in the Maine Lobstermen's Association bait price data for species excluding pogies average approximately $0.47/pound, approximately $0.26/pound (122%), or $23/bushel, higher than our preferred estimate of the alewife price. The average price of pogies in the Maine Lobstermen's Association bait price data is $21.81/bushel. This is approximately $2.80/bushel (15%) higher than our preferred estimate of the alewife price. Given that pogies need to be trucked from New Jersey, it is likely their price will remain higher than the alewife price due to the additional transportation costs.

In reality, alewife will probably replace some combination of frozen bait and pogies,[7] Therefore we examine two scenarios: St. Croix alewife replaces frozen bait

[7] One concern is that there are some regions and/or some fishermen that have a strict preference for frozen bait and will not switch to alewives. Therefore, if the total alewife harvest was close to the total frozen bait use, it might be unreasonable to expect a large percentage of the alewife harvest would replace frozen bait. However, even under the largest harvest scenarios the alewife harvest from the St. Croix is never projected at more than 2.7 million pounds. Interviewees estimated frozen

50% of the time and pogies the other 50% of the time, and St. Croix alewife replaces frozen bait 95% of the time and pogies the other 5% of the time. These scenarios represent an average bait savings of approximately $13 and $22 per bushel, respectively. The inputs for the bait substitution calculations are presented in Figure 8, and the total present value of bait savings under the different population scenarios is given in Figure 9.

FIGURE 8: INPUTS TO THE BAIT SAVINGS MODEL

Inputs		Source
Percentage of alewife harvest replacing frozen bait	Low: 50% High: 95%	Interviews with lobstermen and bait dealers
Per bushel price difference between frozen bait and alewife	$23.00	Maine lobstermen Association bait-price data (MLA, 2011)
Per bushel price difference between pogies and alewifes	$2.80	Maine lobstermen Association bait-price data (MLA, 2011)

The relative magnitudes of the bait savings under the various scenarios are similar to relative magnitudes of the total discounted revenue. Furthermore, as expected, the more alewife that is substituted for frozen bait, the higher the bait savings.

FIGURE 9: PRESENT VALUE OF BAIT SAVINGS

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$1,238,572	$2,111,333
Management Alternatives		
Low-Harvest Rate, 5 Year Regrowth	$911,296	$1,553,442
Low-Harvest Rate, 10 Year Regrowth	$1,051,895	$1,793,115
High-Harvest Rate, 5 Year Regrowth	$143,015	$243,790
High-Harvest Rate, 10 Year Regrowth	$354,082	$603,586

Finally, we address the fact that alewife may be more effective than frozen bait. Some interviewees indicated that fewer pounds of alewife are required when baiting a trap relative to baiting a trap with frozen bait. We explore the scenario where 1.5 pounds of frozen bait can be replaced by 1 pound of alewife. This increases the total bait savings (Figure 9 versus Figure 10). Finally, we also provide estimates of yearly revenue from bait savings. Figures 11 and 12 provide estimates of the bait savings that would exist if the optimal harvest strategy had been implemented 30 years ago.

Unlike the direct benefits, the bait savings will likely not be contained within Washington County, although a large portion of the bait savings may occur in

bait use to be much larger than this amount currently. Therefore, it is reasonable to explore the possibility that alewife mostly replaces frozen bait.

Washington County because lobstermen typically use alewife from alewife runs relatively close to them. We do not attempt to estimate the monetary value of bait saving expected to accrue to Washington County because we do not have information on bait usage in Washington County and the demand for alewife in place of frozen bait in the area.

FIGURE 10: PRESENT VALUE OF BAIT SAVINGS WITH EFFICIENCY GAINS

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$2,253,913	$4,040,481
Management Alternatives		
Low-Harvest Rate, 5 Year Regrowth	$1,658,347	$2,972,839
Low-Harvest Rate, 10 Year Regrowth	$1,914,205	$3,431,503
High-Harvest Rate, 5 Year Regrowth	$260,253	$466,544
High-Harvest Rate, 10 Year Regrowth	$644,346	$1,155,088

FIGURE 11: YEARLY REVENUE FROM BAIT SAVINGS IF LADDERS REMAINED OPEN SINCE 1980, NO EFFICIENCY GAINS

Scenario	Nominal Bait Savings (Estimated Harvest * Savings/Bushel in $2011)	
	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$156,862	$267,395

FIGURE 12: YEARLY REVENUE FROM BAIT SAVINGS IF LADDERS REMAINED OPEN SINCE 1980, WITH EFFICIENCY GAINS

Scenario	Nominal Bait Savings (Estimated Harvest * Savings/Bushel in $2011)	
	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$285,452	$511,716

Total Benefits

In this section we present the estimated total benefits, (the sum of the direct and indirect benefits). The net present value of benefits ranged from $3.1 million to $5.9 million, assuming optimal management of the fishery. The annual benefits from the fishery this year, if the fish ladders had been opened in 1980 and the fishery had been optimally managed, ranges from $388,000 to $743,000.

FIGURE 13: TOTAL BENEFITS, NO EFFICIENCY GAINS

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$3,065,706	$3,938,467
Management Alternatives		
Low Harvest Rate, 5 Year Regrowth	$2,255,635	$2,897,780
Low Harvest Rate, 10 Year Regrowth	$2,603,645	$3,344,864
High Harvest Rate, 5 Year Regrowth	$353,989	$454,764
High Harvest Rate, 10 Year Regrowth	$876,421	$1,125,925

FIGURE 14: TOTAL BENEFITS WITH EFFICIENCY GAINS

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$4,081,047	$5,867,615
Management Alternatives		
Low Harvest Rate, 5 Year Regrowth	$3,002,685	$4,317,177
Low Harvest Rate, 10 Year Regrowth	$3,465,954	$4,983,252
High Harvest Rate, 5 Year Regrowth	$471,228	$677,518
High Harvest Rate, 10 Year Regrowth	$1,166,685	$1,677,427

FIGURE 15: YEARLY TOTAL BENEFITS IF LADDERS REMAINED OPEN SINCE 1980, NO EFFICIENCY GAINS

	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$388,264	$498.796

FIGURE 16: YEARLY TOTAL BENEFITS IF LADDERS REMAINED OPEN SINCE 1980, WITH EFFICIENCY GAINS

	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth	$516,854	$743,118

Conclusion

The opening of the alewife ladders on the St. Croix River has the potential to increase economic activity in Washington County, Maine, the most economically depressed county in Maine. The magnitude of direct and indirect (lobster bait savings) benefits depend on the recovery of the alewife population as well as economic factors. To address uncertainty in these biological and economic parameters, we have explored multiple inputs and developed multiple scenarios.

Estimates of total benefits using our preferred parameter estimates for the discount rate, population growth rate, and carrying capacity, highlight the importance of management decisions. In particular, the total economic value achieved under the optimal management scenario is significantly higher than the other scenarios considered. Therefore, when choosing the length of time to allow the fishery to recover without harvest and the harvest rate, managers should consider the implications of these choices on total economic value.

Under the optimal management scenario direct benefits were estimated to be $1.8 million. Lobster savings benefits ranged from $1.2 to $4 million based on assumptions about relative bait efficiencies and the percentage of frozen bait alewife is likely to replace. Estimated total benefits (the sum of direct and indirect benefits), range from $3.1 million to $5.9 million.

Comparing these values to measures of current economic activity in Washington County, suggests a functioning alewife fishery could make a significant contribution to the local economy.

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Appendix 1: Population Growth and Harvest Model

The results in this report are based on a density dependent logistic growth model following. We assume logistic growth occurs during the course of one year, and then an instantaneous harvest occurs, the population grows again (logistically) for one year, followed by another instantaneous harvest, and so on. Finally, we do not incorporate uncertainty, autocorrelation, or other complexities.

Appendix 2: Sensitivity to Carrying Capacity Assumption

Our carrying capacity estimate is from Dill et al. (2010) and based on data from Gibson and Myers (2003). The estimate may be conservative because while the Gibson and Myers (2003) paper presents data on observed biomass production per square kilometer of habitat, the data do not come from unharvested alewife populations and are therefore below the true carrying capacity for those rivers. However, it is difficult to know to whether the alewife populations will be similar to observed alewife populations.

Additionally we use the habitat area considered (24,638 acres opened to alewife) in the Dill et al. (2010) report. As the carrying capacity of a population depends on the habitat area, our estimates of the future alewife population are dependent on the future available alewife habitat.

Lotze and Milewski (2004) use a carrying capacity estimate of 31.7 million. To demonstrate the sensitivity of the results Figure 17 replicates the analysis done to arrive at the Figure 6 estimates, but with the larger carrying capacity. As expected, the total present value of expected revenues is higher with the larger carrying capacity.

FIGURE 17: PRESENT VALUE OF ALEWIFE HARVEST REVENUE, CURRENT ALEWIFE PRICES, HIGH K

Scenario	Total Revenue
Optimal Management	
Optimal Harvest Rate, Optimal Regrowth	$2,362,869
Management Alternatives	
Low-Harvest Rate, 5 Year Regrowth	$1,698,546
Low-Harvest Rate, 10 Year Regrowth	$1,964,611
High-Harvest Rate, 5 Year Regrowth	$233,231
High-Harvest Rate, 10 Year Regrowth	$594,888

Harvest is incorporated into the model by making the simplifying assumption that a constant percentage of the alewife population is harvested each year. This is reasonable assumption because management of runs typically involves closure to allow escapement on certain days of the week (ASFMC, 2010). This differs from the proposed rule in Dill et al., which relies on evaluations of the small-mouth bass population.

Appendix 3: Sensitivity to Growth Rate Assumption

In this Appendix we explore the impact of the assumed population growth rate on the economic benefits. We examine the results using a low population growth rate of 0.25, and a high population growth rate of 0.5. We find that the total economic benefits are very sensitive to the growth rate assumed. Furthermore, a low growth rate and high-harvest rate can drive the population to extinction.

FIGURE 18: ALEWIFE POPULATION BY YEAR AND HARVEST SCENARIO: GROWTH RATE = 0.25

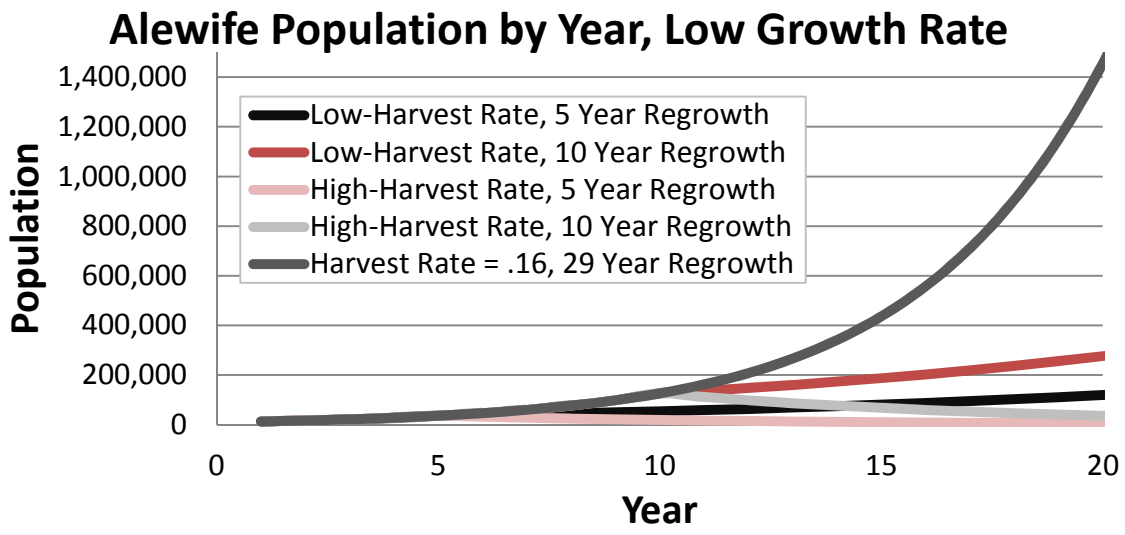

FIGURE 19: ALEWIFE HARVEST (IN FISH) BY YEAR AND HARVEST SCENARIO: GROWTH RATE =0 .25

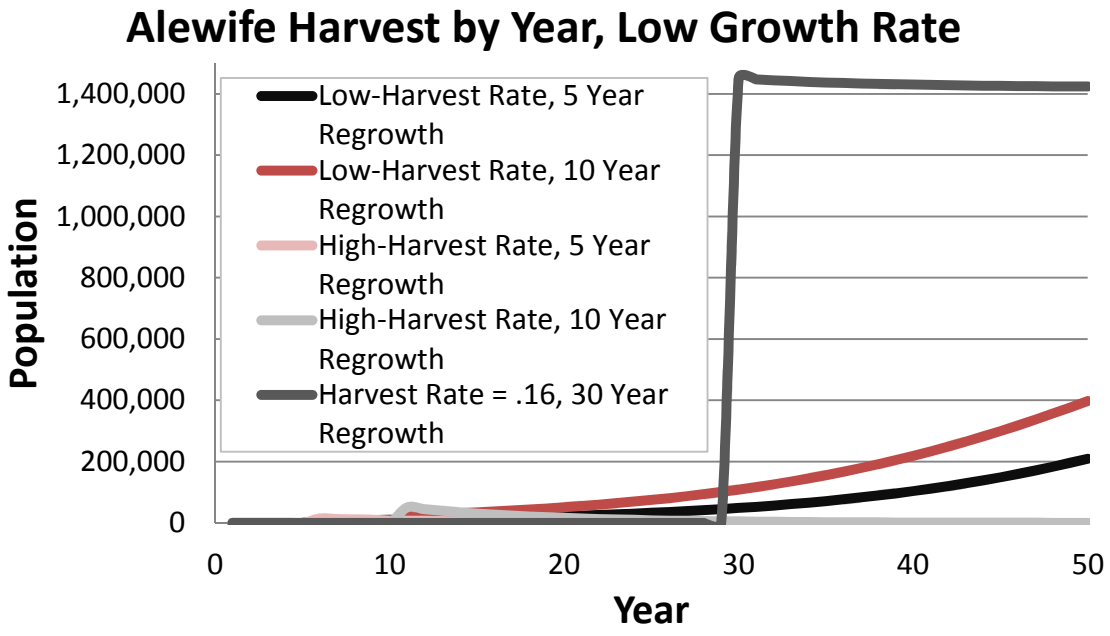

FIGURE 20: ALEWIFE POPULATION BY YEAR AND HARVEST SCENARIO: GROWTH RATE = 0.5

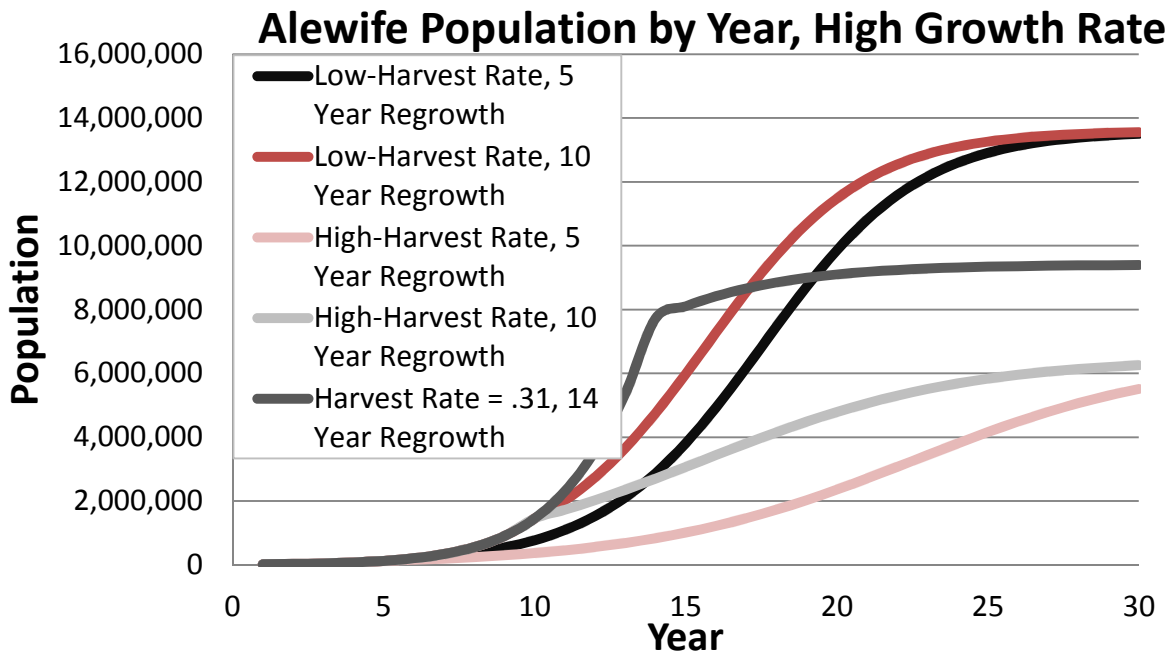

FIGURE 21: ALEWIFE HARVEST (IN FISH) BY YEAR AND HARVEST SCENARIO: GROWTH RATE = 0.5

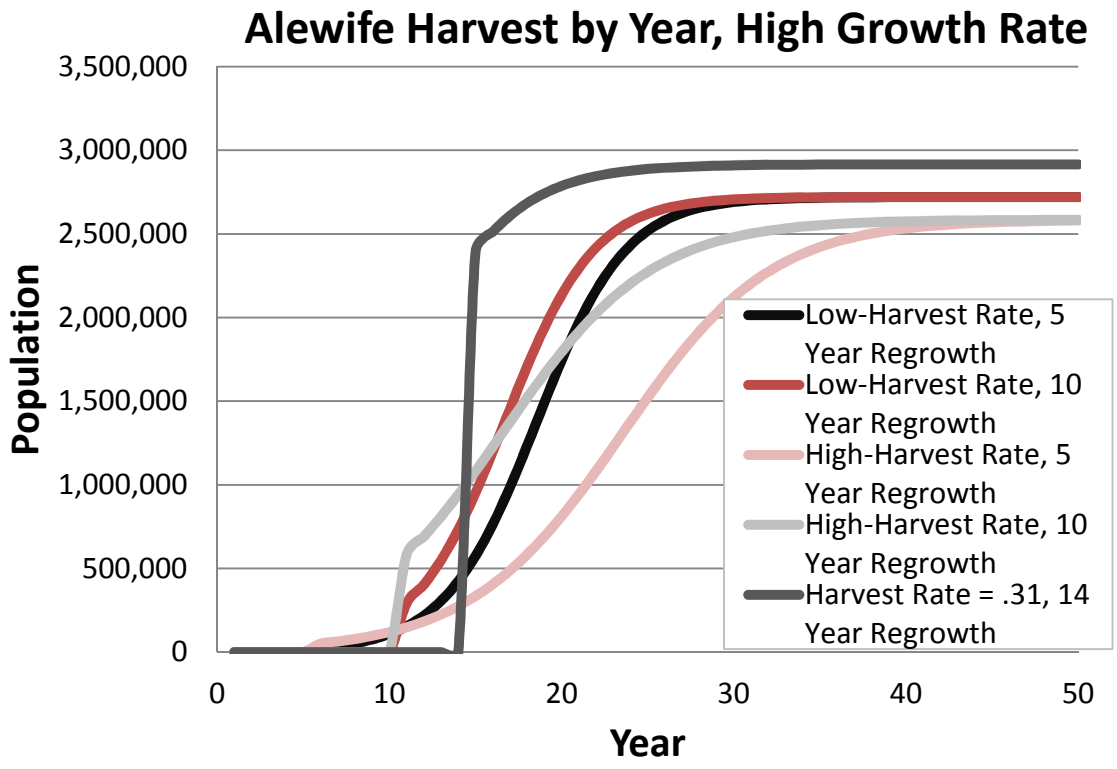

FIGURE 22: PRESENT VALUE OF ALEWIFE HARVEST REVENUE, CURRENT ALEWIFE PRICES: LOW AND HIGH GROWTH RATES

Scenario	Total Revenue
Optimal Management	
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$734,786
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$3,019,175
Management Alternatives	
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$158,946
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$247,946
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$2,458,591
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$2,646,344
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$1,914,373
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$2,502,980

FIGURE 23: YEARLY REVENUE FROM ALEWIFE HARVEST IF LADDERS REMAINED OPEN SINCE 1980: LOW AND HIGH GROWTH RATES

Scenario	Estimated Harvest (Bushels)	Nominal Revenue (Estimated Harvest * 2011 Price)
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.25	8,059	$153,360
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.5	16,168	$307,681

FIGURE 24: PRESENT VALUE OF BAIT SAVINGS: LOW AND HIGH GROWTH RATES

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$498,095	$849,078
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$2,046,629	$3,488,789
Management Alternatives		
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$107,746	$183,669
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$168,077	$286,512
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$1,666,623	$2,841,010
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$1,793,896	$3,057,967
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$1,508,964	$1,508,964
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$1,696,713	$2,892,303

FIGURE 25: PRESENT VALUE OF BAIT SAVINGS WITH EFFICIENCY GAINS: LOW AND HIGH GROWTH RATES

Scenario	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$906,417	$1,624,890
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$3,724,389	$6,676,533
Management Alternatives		
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$196,072	$351,489
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$305,861	$548,302
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$3,032,866	$5,436,872
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$3,264,474	$5,852,065
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$1,508,964	$1,508,964
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$3,087,622	$5,535,031

FIGURE 26: YEARLY REVENUE FROM BAIT SAVINGS IF LADDERS REMAINED OPEN SINCE 1980, NO EFFICIENCY GAINS: LOW AND HIGH GROWTH RATES

Scenario	Nominal Bait Savings (Estimated Harvest * Savings/Bushel in $2011)	
	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.25	$103,958	$177,214
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.5	$208,570	$355,539

FIGURE 27: YEARLY REVENUE FROM BAIT SAVINGS IF LADDERS REMAINED OPEN SINCE 1980, WITH EFFICIENCY GAINS: LOW AND HIGH GROWTH RATES

Scenario	Nominal Bait Savings (Estimated Harvest * Savings/Bushel in $2011)	
	50% of Alewife Replaces Frozen Bait	95% of Alewife Replaces Frozen Bait
Optimal Management		
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.25	$189,181	$339,137
Optimal Harvest Rate, Optimal Regrowth: Growth Rate = 0.5	$379,549	$680,340

Appendix 4: Sensitivity to Price Assumption

The total direct benefits from an alewife fishery will depend on the price of alewife. We consider three different prices; a price lower than what is currently observed ($15/bushel), the current average price ($19/bushel), and a price higher than the currently observed price of alewife ($30/bushel). Figure 28 shows the benefits for all three price levels. Regardless of the harvest and growth scenarios, benefits to the fishery will be 57.6% higher if the price of alewife increases to $30/bushel (a 57.6% price increase) and they will be 21.1% lower if the price of alewife is $15/bushel (a 21.1% price decrease). The table below shows the magnitude of these differences.

FIGURE 28: NET PRESENT VALUE OF REVENUE ACROSS PRICE ASSUMPTIONS (WITH A 5% DISCOUNT RATE)

Scenario	Low	Preferred	High
Optimal Management			
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$579,180	$734,786	$1,158,360
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$2,379,802	$3,019,175	$4,759,603
Management Alternatives			
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$125,286	$158,946	$250,572
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$195,438	$247,946	$390,876
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$1,937,933	$2,458,591	$3,875,867
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$2,085,926	$2,646,344	$4,171,851
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$1,508,964	$1,914,373	$3,017,929
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$1,972,922	$2,502,980	$3,945,843

Appendix 5: Sensitivity to Discount Rate Assumption

In this Appendix we examine the sensitivity of our results to the chosen discount rate. In particular, we replicate prior tables from the report using a 3% and 7% discount rate, rather than a 5% discount rate.

FIGURE 29: PRESENT VALUE OF ALEWIFE HARVEST REVENUE: 3% AND 7% DISCOUNT RATES

Scenario	3% Discount Rate	7% Discount Rate
Optimal Management		
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$2,140,671	$306,690
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$6,664,730	$1,642,019
Management Alternatives		
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$673,252	$54,575
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$902,467	$94,032
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$5,687,327	$1,281,973
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$5,955,292	$1,414,723
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$4,740,647	$945,392
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$5,615,962	$1,348,405

FIGURE 30: PRESENT VALUE OF BAIT SAVINGS, NO EFFICIENCY GAINS: 3% AND 7% DISCOUNT RATES

	50% of Alewife Replaces Frozen Bait		95% of Alewife Replaces Frozen Bait	
Scenario	Discount Rate = 3%	Discount Rate = 7%	Discount Rate = 3%	Discount Rate = 7%
Optimal Management				
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$1,451,111	$207,898	$2,473,639	$354,394
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$4,517,868	$1,113,087	$7,701,388	$1,897,425
Management Alternatives				
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$456,382	$36,995	$777,972	$63,063
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$611,762	$63,742	$1,042,840	$108,658
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$3,855,309	$869,020	$6,571,956	$1,481,376
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$4,036,956	$959,008	$6,881,602	$1,634,774
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$3,213,576	$640,860	$5,478,025	$1,092,442
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$3,806,932	$914,053	$6,489,491	$1,558,141

FIGURE 31: PRESENT VALUE OF BAIT SAVINGS WITH EFFICIENCY GAINS: 3% AND 7% DISCOUNT RATES

	50% of Alewife Replaces Frozen Bait		95% of Alewife Replaces Frozen Bait	
Scenario	Discount Rate = 3%	Discount Rate = 7%	Discount Rate = 3%	Discount Rate = 7%
Optimal Management				
Low Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$2,640,685	$378,326	$4,733,829	$678,207
High Growth Rate, Optimal Harvest Rate, Optimal Regrowth	$8,221,468	$2,025,560	$14,738,230	$3,631,123
Management Alternatives				
Low Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$830,509	$67,322	$1,488,814	$120,685
Low Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$1,113,264	$115,996	$1,995,694	$207,940
High Growth Rate, Low-Harvest Rate, 5 Year Regrowth	$7,015,765	$1,581,415	$12,576,823	$2,834,926
High Growth Rate, Low-Harvest Rate, 10 Year Regrowth	$7,346,321	$1,745,172	$13,169,395	$3,128,485
High Growth Rate, High-Harvest Rate, 5 Year Regrowth	$5,847,960	$1,166,215	$10,483,356	$2,090,618
High Growth Rate, High-Harvest Rate, 10 Year Regrowth	$6,927,731	$1,663,363	$12,419,009	$2,981,831