Ecological Role of Adult and Juvenile Anadromous Forage Fish in Maine Estuaries: Sea-Run Alewife and Groundfish Predators

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Abstract

Historically, river herring (composed of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) were an extremely abundant seasonal resource in the nearshore Gulf of Maine, originally as a subsistence food and trade item for both Native Americans and European settlers, and later as a commercial commodity. River herring link marine and freshwater systems through the transfer of marine- and freshwater-derived nutrients up and downstream. Historical evidence suggests that river herring were an important forage fish for nearshore groundfish stocks; we contend that without prey fish restoration, the rebuilding of commercial fish stocks will be an incomplete, and likely unsuccessful process. This project addresses what we think is a key component of this system– the role of river herring in estuarine food webs before, during and after spawning runs. Our objectives were to (a) assess the ecological role of river herring as prey in Maine estuarine food webs, and (b) to assess the relationship between spatial distribution, seasonal timing and densities of river herring in estuaries relative to their movement between freshwater and saltwater habitats. Ultimately we sampled 4 estuaries in with low and high river herring returns and quantified predation on alewife by nearshore groundfish caught using hook and line. We analyzed diets from cod, pollock, sculpin and mackerel, developing a somewhat unique nearshore record of diets of these species. The most important results of this work were that (1) that few to any large fish predators were present inshore during the time in which adult river herring would be moving up rivers to spawn (May/June), in contrast to historical reports, and (2) young-of-year (YOY) river herring were readily consumed by a variety of fish species and sizes when YOY river herring were present in the system in late summer or fall. We conclude that that

river herring have the potential to provide important late summer forage for juvenile groundfish and other predators, and that, until large groundfish recover in the nearshore region, the most important predators of adult river herring are humans, seals and waterbirds.

Final Technical Report to the Northeast Consortium: Ecological Role of Adult and Juvenile Anadromous Forage Fish in Maine Estuaries: Sea-Run Alewife and Groundfish Predators

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Introduction

Historically, river herring (alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis)*) were an extremely abundant seasonal resource in the nearshore Gulf of Maine (GOM), functioning originally as a subsistence food and trade item for both Native Americans and European settlers, and later as a commercial commodity. Prior to 1825 hundreds of tons of river herring were harvested from the St. Croix River, Washington County, Maine, salted and barreled for export to southern New England and the West India market (Perley 1852). The availability and importance of river herring as a commercial and ecological resource plummeted coast-wide in the late 1800s, first as a result of the damming of rivers and streams (Baird 1883), and later with the introduction of more efficient open water fishing gear. The connection between loss of spawning habitat and decrease in alewife numbers was often obvious within a few years of dam installation; for example, on the St. Croix River, local residents wrote letters of protest to the Maine state government as early as 1821 describing the loss of food and revenue and imploring that fish ladders be installed (Maine State Archives 1821). More recent east coast landings of alewife have decreased since the 1970s, dropping from 40-65 million pounds to 1.4 million pounds by 1996 (U.S. Department of Commerce 1999).

Today, river herring are a resource whose diminished numbers have substantial ramifications for the ecology of the GOM and associated rivers and lakes in which they spawn. River herring link marine and freshwater systems by transferring marine-derived nutrients upstream in the form of eggs, excretion and the approximate 50% of adults who die during the spawning run. In oligotrophic freshwater systems these nutrients may have bolstered benthic productivity (e.g., Durbin et al. 1979), possibly augmenting prey availability for other anadromous fishes such as Atlantic salmon. In addition, alewife young-of-year (YOY) can have a transitory effect on zooplankton community composition in lakes (Durbin et al. 1979; Yako et al. 2000) and are prey for freshwater fish species (e.g., large- and smallmouth bass, Yako et al. 2000; Hanson and Curry 2005). River herring YOY export freshwater nutrients to marine systems where they are consumed by a variety of predators. In the nearshore marine environment, commercially important predatory fishes would have benefited from both the spawning run and YOY escapement, as well as seabirds and marine mammals. Adult stripped bass are voracious predators of both adult and YOY alewife in estuaries and rivers (Walter et al. 2003) and cod commonly eat clupeids in the GOM (Link and Garrison 2002). In 1883, a report by the U.S. Commissioner of Fish and Fisheries describe the co-migration of spawning cod and alewife along the coast, and implicates the loss of alewife runs as the cause for the loss of cod spawning aggregations near rivers (Baird 1883; Ames 2004). Remaining populations of nearshore cod and other predators now compete with commercial fisheries for a shrinking resource.

Currently, river herring are taken by several fisheries that operate both in rivers and offshore in the GOM. Spawning river herring are harvested by municipalities and fishermen in early spring as an inexpensive commercial and recreational fishing bait. For example, the alewife fishery at Damariscotta Mills generated revenues of $16,000 for the towns of Newcastle/ Nobleborro, Maine, in 2004 from license fees and bushel sales of alewife to lobster fisherman (D. Wright, pers. comm.). The local nature of river herring runs can also reduce bait costs of fishers by eliminating middle-men, fuel, and handling charges. River herring are also taken offshore by gillnet, purse-seine and trawl during yearly migrations to and from spawning rivers. Competition for river herring may become more fierce with recent amendments to the Atlantic States Marine Fisheries Commissions (ASMFC) Fisheries Management Plan by tightening regulations on the American shad, river herring (alewife and blueback herring) and the Atlantic herring fisheries. The ASMFC recognizes the duel commercial and ecological roles of river herring, but lacks the data required to make management suggestions that would ensure the sustainability of river herring resources (U.S. Department of Commerce 1999).

We have chosen to work with river herring because alewife, at least, respond quickly to habitat restoration efforts and therefore have the potential to meet the demands of commercial harvesters while fulfilling the ecological needs of freshwater and estuarine systems. For example, when the head-of-tide fishway was improved on the St. Croix River, New Brunswick, alewife spawning escapement climbed from 170,000 in 1981 to 2 million by 1986 (St. Croix International Waterway Commission, unpublished data). Closing fishways had the reverse effect. Restoration efforts in the Kennebec watershed, including removal of the Edwards Dam and initial stocking of alewife, resulted in estimated returns between one and two million alewife by 2004 which have been maintained since (Maine Department of Marine Resources). Both state and federal agencies have demonstrated the political and financial will to pursue localized habitat restoration for anadromous fishes (i.e., by supplying funds for fish passage improvements). Increases in sheer numbers appear to be a real possibility for alewife and likely blueback herring.

This project attempted to address what we contend is a key component in understanding consequences of reestablishing links between freshwater and marine ecosystems of the GOM through the restoration of alewife spawning runs: the ecological role of alewife in estuarine food webs, both as predators and prey and densities and spatial distribution of alewife in estuaries before, during and after spawning runs. This information will assist in quantifying the transfer of nutrients and materials from the ocean to the uplands in the form of adult excretion, adult mortality, and egg production, and the return of some of those materials to the estuaries as YOY escapement. In concentrating on estuaries, we highlight river herring interactions with many juvenile fishes that use the estuaries as nursery grounds, increase our ability to relate river herring density and location to spawning activities, and compliment existing large-scale data on alewife distribution along the coast of Maine collected by Maine Department of Marine Resources survey trawls. We feel a better understanding of the freshwater – marine connection will help inform public discussions and decisions in a way that will be broadly beneficial for the people of the state.

Project objectives and scientific hypotheses
Our original objectives were to compare the diets of potential predators in one high alewife estuary to one low alewife estuary per summer, with a total of four estuaries in the experimental design. After near zero catches of potential alewife predators in Denny's Bay (Cobscook/Passamaquoddy Bay)in 2006 and no available means to count alewives in the Denny's River that same spring, in 2007 we added two midcoast Maine estuaries with larger, monitored alewife runs and larger potential predator populations. This effectively increased the chance of observing alewife predation in the nearshore marine environment and we maintained this sample regime in 2008 (Table 1).

Our second original objective was to quantify the distribution of river herring in estuaries before, during and after spawning runs; we were unable to pursue this objective because (1) fisherman were unable, or unwilling, to tow nets in the nearshore region (Passamaquoddy Bay) because of currents or obstructions, (2), in the midcoast estuaries (Damariscotta & St. George) the proliferation of fixed gear (i.e., lobster gear) made trawling or purse seining impossible, not to mention the difficulties we encountered using hook and line, and (3) it was difficult to schedule days at sea when river herring out-migrations are unpredictable in advance.

Participants
David Turner (2006, 2007, 2008), South Meadow Road, Perry, Maine
Mike Myrick (2007), P.O. Box 36, Cushing, Maine
John Stotz (2007), P.O. Box 131, Round Pond, Maine
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Six undergraduate or recently graduated students from the University of Southern Maine, University of Maine and McGill University have assisted in diet analyses, data entry and fieldwork (Kyle Moulton, Shannon Prescott, Mike Rautenberg, Abby Pearson, Spencer Blair-Glantz, Robin Tiller).

We received additional help from The Maine Department of Marine Resources, Damariscotta/Newcastle Fish (Alewife) Committee, the Warren (St. George River) Fish

Committee and Town of Warren, The Passamaquoddy Tribe (Pleasant Point), and Maine SeaGrant.

Methods

Sampling sites

Need maps of sampling sites!! At a minimum, a list of sample sites with GPS coordinates and inner, middle, and outer designations and dates sampled.

Based on the near absence of predatory fishes in Denny's Bay and an inability to quantify river herring runs in the system, we added two southern estuaries with larger alewife runs and more potential predators in 2007.

Table 1: Sampling design 2006-2008. In 2007 we dropped Denny's Bay and Sites were sampled in early summer, mid summer and late summer; actual dates varied by year.

	High alewife numbers	**Low alewife numbers**
2006	Denny's Bay	Gleason Cove
2007 (using remaining funds from 2006)	Damariscotta Estuary, St. George Estuary	Gleason Cove/western passage of Passamaquoddy Bay
2008 (no cost extension from 2007)	Damariscotta Estuary, St. George Estuary	Gleason Cove/ western passage of Passamaquoddy Bay

In general we targeted underwater structure that was either a known historical fishing spot (Passamaquoddy) or where our collaborating fishermen observed fish aggregations on sonar (Table 2). We re-visited these sampling sites during most sampling periods.

Table 2. List of sites fished during 2006, 2007 and 2008.

Fish diet collections

Fish were collected using primarily hook and line due to strong tides in the Passamaquoddy Bay site, and the prevalence of lobster gear in the midcoast sites. Hook types (e.g., unbaited jigs such as bucktails, Sabiki rigs, etc, or baited hooks) varied depending upon target species (cod, mackerel, pollock, sculpin), site, and fishing conditions. We tracked the number of hooks in the water and the time these hooks were fished in order to estimate catch rates. In 2007 we used baited tub trawls at several St. George River and Damariscotta River sites to augment our catch, but found that most hooks were stripped of bait within the 3-hour soak period by small non-target fish and crustaceans (see results). We also tried using several lobster pots as fish traps (based on the common occurrence of fish being caught in lobster pots) but without much success. In 2007 and 2008 we shifted our sampling dates to later in the summer and into the fall to better capture out-migrating young-of-year (YOY) river herring.

Diet processing

Captured fish were held in a flow-through live well until processing. We obtained diet samples from fish >150mm in length using gastric lavage to flush the fish's stomach; diet items were captured on a 500 μm sieve. Fish were fin-clipped, allowed to recover in the live well, then released alive. Gastric lavage produced a high quality diet sample as it stops the digestive process, and allowed us to minimize the number of fish we killed. The effectiveness of gastric levage on commonly caught species ranged from 85-100% (Table 1). We found that harder and larger items, e.g., whole urchins or large crabs, could be felt in the stomach and we could flush these items out with additional effort. The presence of these items was also evident from crab legs and urchin spines that flushed out more easily. We concluded that this method is effective in flushing fish stomachs of the species tested. Diets were preserved in a solution of 70% ethanol, 10 % methanol, 5% PEG-300, and 15 % distilled water.

Table 1. Effectiveness of gastric lavage (stomach flush). To test the efficacy of the stomach flush methods, fish stomachs were flushed according to our normal procedure, and the fish were killed by an overdose of sedative. We then examined the dissected stomach to determine if the flush was effective. Residual food items were found in 8 of 87 fish sampled.

Dissected stomachs				
Fish species	**Total fish sampled**	**Empty after flushing**	**Not empty after flushing**	**% Effectiveness**
sculpin	21	18	3	86
mackerel	23	21	2	91
dogfish	3	3	0	100
cod	20	17	3	85
pollock	20	20	0	100

Diet items were identified to the lowest taxonomic level possible (usually family), counted and total wet weight for each type of diet item was recorded. Because digestion levels varied from fish to fish, most major diet items were collapsed into large categories (e.g., crab, amphiphod, etc).

River herring spawning run numbers

River herring spawning run numbers for each estuary were estimated in a variety of ways. Our assumption was that, at a minimum, these numbers of fish must pass through the estuary on their way to spawn in the spring. Available spawning and harvest numbers are presented in the results section.

a. Damariscotta Dr. Willis installed video counting equipment at the Damariscotta Mills fish ladder in 2007 as part of a separate project to estimate spawning escapement into the lake. Video numbers were compared with 10 minute on the hour hand counts (conducted by the dam owners) and found to be greater than, but within the error estimate of the hand count data so we used the hand counts. When combined with harvest data, these data give a relatively complete account of how many alewives reached the harvest point at Damariscotta Mills, and therefore traversed the estuary during their migration.

b. St. George River In 2007 and 2008, Dr. Willis led a NOAA-funded project that constructed and installed an experimental counting weir in the St. George River as part of a project to assess alewife movement over a rehabilitated dam site at the inlet of Sennebec Pond (7 miles upstream). We assume that Sennebec Pond receives a small proportion of the total run because considerable spawning habitat exists downstream, but the data do give a relative sense of the run escapement in 2007 and 2008. The majority of adult river herring data from the St. George River comes from harvest records at the harvest point at head of tide in Warren. The weir used in the Sennebec Pond Project was an attempt to field test counting weir designs appropriate for mainstem coastal rivers without fishways, as a way to address the need for harvest-independent counts of alewife runs. The design used in 2007 and 2008, a floating panel weir, was sound and should be able to withstand the higher flows in the lower portion of the river should full river counts be attempted in the future.

c. Little River (Passamaquoddy) Counting alewives on the Little River proved to be more difficult than anticipated, primarily because the town of Perry and the Passamaquoddy Tribe had conflicting interests regarding the alewife run, and there was a history of poor cooperation and trust between the two parties.

d. Dennys River We were not able to obtain counts of river herring in the Dennys River for the 2006 season when we fished Dennys Bay. However, in 2008, the Atlantic Salmon Commission modified its salmon counting weir to allow river herring counts, demonstrating that there is a viable (though small) run in the Dennys River.

Results

Diets

We caught approximately 3000 fish in 2007 and 2008 (Table 2), most of which were sampled for diets. Up to 25 diets from each target species (mackerel, cod, sculpin) have been processed, with diet items identified to lowest taxonomic level possible, counted and weighted (wet weight). Data is currently being analyzed.

Table 2: 2007 and 2008 catches from Damariscotta, Passamaquoddy Bay (Little River, Perry) and St. George Estuaries. The Passamaquoddy site was not fished in the spring of 2007 as a result of insurance issues for our collaborating fisherman.

	Damariscotta						Passamaquoddy						St. George					
	2007			2008			2007			2008			2007			2008		
Fish Species	spring	summer	fall	spring	summer	fall	spring	summer	fall	spring	summer	fall	spring	summer	fall	Spring	summer	fall
cod	3	22	46	3	43	76	.	1	14			3	1	17	18		17	56
cunner	8	4	10	3	6	51	.							7	7		8	18
cusk	3						.											
dogfish							.	1	1		5							
herring							.	4		2		1		1				4
longhorn sculpin	2	4	14		13	18	.	34	17	35	55	86	1	6	3	2	2	8
mackerel		15	75		54	152	.	63	80		68	219		40	83		51	229
mackerel large					4	1	.				63	18					4	15
mackerel small			31			2	.				69				54		2	
pollock		30	60	14	23	147	.	1	4		1	27		13	20		33	78
redfish	3	15	5	3	19	21	.				1			10	6		6	3
sea raven				1	1	6	.	7	1		4	15		1	1		1	5
shorthorn sculpin	2	10	4	7	3	2	.	35	20	45	20	97	1	6	2			7
silver hake							.	1	1						1			
rainbow smelt							.	1				1						

River herring in diets

Despite considerable fishing effort (Table 6), and adding sampling sites in midcoast estuaries, we encountered relatively few large predatory groundfish in our spring sampling. However, catches of target species increased significantly in the summer and fall sampling periods, suggesting that groundfish are rare inshore in the spring, and that groundfish large enough to prey upon spawning alewife (≥20 cm total length) are absent in nearshore waters. Our observations and inquiries lead us to conclude that birds, marine mammals, and humans are the major predators of spawning alewife.

Table 6: Fishing effort expended in the St. George and Damariscotta River Estuaries in May 2007. Catch rates were very low.

Damariscotta Estuary May 2007		
Gear	**Total set time (hours)**	**Effort per fish (hours)**
Handlines	149.88	21.41
Groundlines	1911.88	637.29
Traps	75.00	9.38

St. George Estuary May 2007		
Handlines	122.43	no fish caught
Groundlines	1419.87	1419.87
Traps	69.37	34.69

However, October 2007 samples demonstrated the fact that, in the right place at the right time, young of year (YOY) river herring are a preferred diet item for groundfish in the nearshore region. September 2007 was a dry period, ending in early October with heavy rains on the 12th (Fig. 1). This coincided with the appearance of YOY river herring in the diets we sampled (Fig. 2), as well as in sightings of schools of YOY river herring in harbors and along the coast. The presence of YOY river herring correlated with above-water (gulls) and below-water (pollock, cod and mackerel) feeding events. River herring in these schools ranged from 54 – 94 mm (Fig. 3).The fisherman we were working with at this time reported seeing schools of river herring up to two weeks before this time period as well.

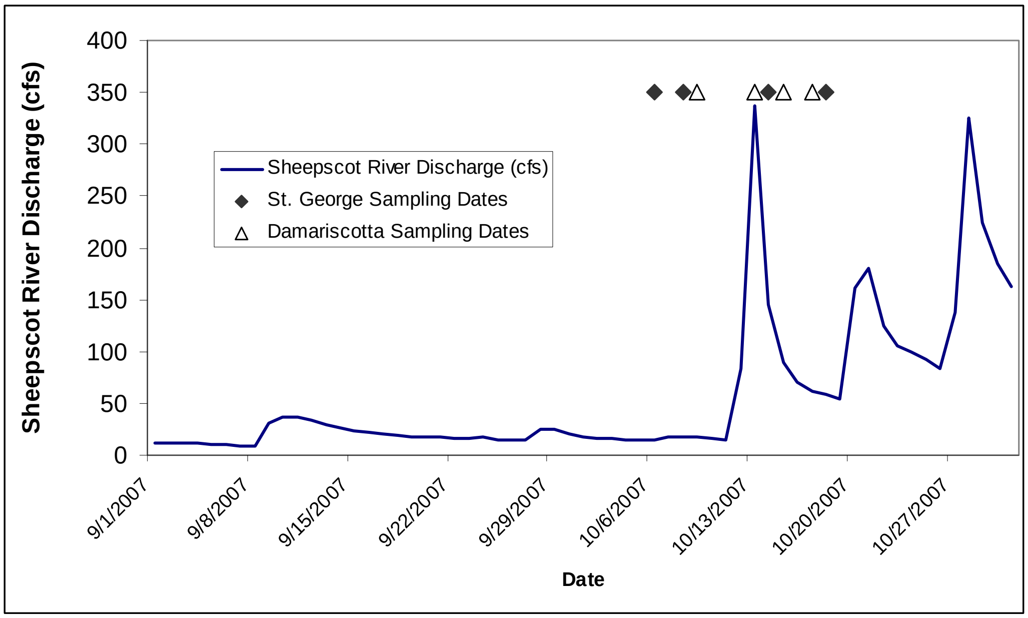

Figure 1. Sheepscot River discharge in cubic feet per second (cfs), 2007. Sampling dates for the St. George and Damariscotta estuaries are indicated. We first observed schools of YOY river herring on the 13th of October, one day after heavy rains. Discharge data from USGS.

Figure 2. Fresh YOY river herring in the diet of a mackerel caught off the mouth of the Damariscotta River. October 2007.

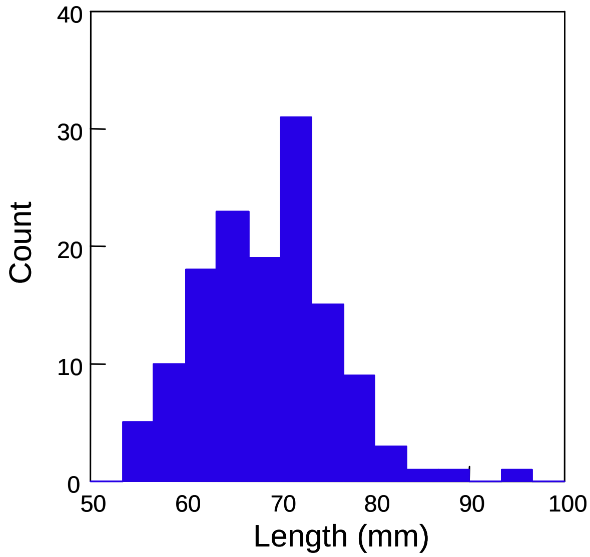

Figure 3. Length distribution of YOY river herring caught using a cast net in Damariscotta River, October, 2007. These fish were later dissected and identified as blueback herring.

River herring counts for estuaries

Counts for the Little River (Passamaquoddy Bay) alewife run were unavailable for 2007 and 2008, but were very small when compared to the midcoast estuaries (Table 3). We believe that the fish ladder on the Little River dam was nearly impassible in 2007 due to incorrect operation; commercial harvests did occur at the Little River in 2006, 2007 and 2008.

Table 3. River Herring escapement and harvest numbers. *nc* = not counted.

System		*Spawning*	*Harvested*	*Total*
Dennys[A]	*2006*	*nc*	*none*	*nc*
	2007	*nc*	*none*	*nc*
	2008	69,739	*none*	69,739
St. George[B]	*2006*	*nc*	90,000	> 90,000
	2007	7332	300,000	> 307,332
	2008	47,109	513,840	> 560,949
Damariscotta[C]	*2006*	79,230	54,360	133,590
	2007	80,142	95,640	175,782
	2008	147,834	206,400	354,234

[A] *Dennys River Estuary was only sampled in 2006. In 2008, the MeDMR began counting river herring for the first time at their salmon counting weir in Dennysville. The Dennys River run is currently not harvested.*
[B] *In the St. George River, estimates of spawning river herring (likely all alewives) are for those fish that moved above the rock ramp at the outlet of Sennebec Pond only. There is considerable spawning habitat downstream of Sennebec Pond.*
[C] *Damariscotta River alewives were assessed by hand counts in 2006, hand counts and video in 2007, and hand counts in 2008.*

Baited Video Observing (2007)

In 2007 we tried to increase our catch rates in all of the sampling areas by using baited tub trawls. We found that by the end of the 3-hour set time all bait had stripped from the hooks and catch rates were extremely low. In most cases, less than 10% of the hooks still had bait when retrieved. For August and October 2007 we added a Baited Video Observation Station (BVOS) to our sampling efforts. A low-cost system was constructed using the underwater video camera purchased in 2006 for conducting alewife video counts. We assessed bait retention on the hooks and identified if bait was being lost to demersal scavengers, groundfish that were not being hooked, or if the bait was simply falling off the hooks. In the midcoast (Damariscotta, St. George) we found that a baited hook was often denuded of bait within 15 minutes by lobster, crabs, or, more likely, swarms of small cunner (*Tautogolabrus adspersus*) (see published resources, below, for links to videos). We abandoned tub trawls in light of what we saw on the video.

Partnerships with fishermen

Although our collaborating fishermen were not involved with the initial design of this project, they contribute greatly to the day to day operations, helping us find historical fishing areas and imparting invaluable local knowledge. When your livelihood depends on catching fish, it is rare to have the 'luxury' of catching zeros (e.g., spring sampling for groundfish), which has spawned some interesting conversations with the captains, particularly in the spring. Through this project we were introduced to several river herring harvesters contracted to harvest river herring from Damariscotta, the St. George and the Little River, as well as the fish committees for Newcastle/Damariscotta and Warren that oversee the harvests. Over the course of this study we found a sea-change in interest in our work; initially river herring harvesters were concerned that collaboration with us would bring on more regulation and oversight- by the end of the project, independent rulings by the Atlantic States Marine Fisheries Commission made it clear that Marine harvesters would need to provide more information on their runs in order to continue harvesting. At this point attitudes relaxed and we found it easier to find collaborators on the land-side of the project.

Impacts and applications

Thus far, our largest impact on the fishing community is one of raising awareness of river herring runs and their potential impact on marine fisheries resources. The process of arranging to count river herring runs has brought us, as scientists, in contact with many members of the local community. We have worked with and conferred with fish committees from local towns, harvesters licensed by the towns to harvest and sell alewives, and local lobstermen who buy alewives for early spring bait. The river herring fishery in Maine has proven to be a foray into a politically charged fishery with many competing interests.

Alewives and blueback herring were thrust into the spotlight with the declaration of Species of Concern status in 2006 by National Marine Fisheries Commission, and the introduction of Amendment 2 to the Shad and River Herring Fisheries Management Plan by the Atlantic States Marine Fisheries Commission in January 2008. The possible action of closure of all directed fisheries took towns and harvesters by surprise.

In March, 2008, we (K. Wilson, T. Willis) organized a Maine Fisherman's Forum symposium on the Amendment 2 plan, which included a presentation by a representative of ASMFC. At this forum the four (at the time) proposed management options were discussed (see pg 19, ASMFC Shad and River Herring Public Information Document for Amendment 2, http://www.asmfc.org/), as well as two new management options, one of which was a proposal for river specific management requiring documentation of spawning escapement as well as harvest. Video and weir techniques developed and field tested in association with this project will be useful for towns interested in assessing alewife numbers in the rivers to which they have licensing rights.

The work we have been doing through this NEC project has lead to additional opportunities to work with the alewife fishery. For example, Dr. Willis is the *de facto* scientific advisor for the newly formed Alewife Harvesters of Maine. AHoM is bringing a new industry voice to alewife issues in Maine, including feedback on the proposed changes to the Shad and River Herring Management Plan and other issues, such as the St. Croix River fishway closures. We have worked with a river herring harvester in Maine to track river herring returns to his system, and we have begun work using a variety of methods to quantify river herring stock structure such that the origin of river herring caught at-sea can be ascertained.

Our second largest impact was with the fishermen we work with directly. During the June sampling both boat captains and their crew members recounted stories of fishing in the areas where we were working and catching fish. They were surprised that as far out as 6 miles from the mainland they could not catch any fish, let alone a cod or other large predator. In these same areas a decade earlier a 24 hr. tub trawl/groundline would have caught at least some desirable species.

We have also created opportunities for collaboration with municipalities in Nobleboro, Newcastle, Warren, and Waldoboro, and community groups with a resource focus (e.g., Quebec Labrador Foundation/Atlantic Center for the Environment, Trout Unlimited, Georges River Land Trust, Damariscotta River Association).

Related projects

Work on counting alewives in the St. George River was funded through a Gulf of Maine Council/NOAA habitat restoration partnership grant to Dr. Willis. Work on counting alewives in the Damariscotta River was funded through a Davis Conservation Grant to Dr.

Willis. Alewife spawning run counts in the Little River (Gleason Cove, Passamaquoddy Bay site) were attempted in spring 2007 by collaborators associated with the Passamaquoddy Tribe with advice based on our experiences in the summer of 2006. Our work on river herring in the nearshore marine environment has led to several related efforts, including several dam-removal projects, a tagging project to assess river herring returns in collaboration with a river herring harvester, and, most recently, a project focused on developing methods to assess the origin of river herring when caught at sea.

Presentations

K.A. Wilson and Theodore Willis. Alewives as Groundfish Forage in Maine Estuaries. Northeast Consortium Participants Meeting, Dec 2007. (Invited)

Workshop presentation: River Herring Management & Biology. Maine Fisherman's Forum, March 2008. Organizers: K. Wilson and T. Willis.

K. Wilson and T. Willis. River Herring in the Gulf of Maine: challenges for management and research. Invited talk as part of the Gulf of Maine Research Institute's Sea State 3.1 Public Lecture Series. April 2008.

T. Willis. River Herring in the Gulf of Maine: challenges for management and research. St. George River Land Trust. May 2008. (Invited)

K. Wilson, T. Willis and K. Robbins. Freshwater-marine linkages: the role of small coastal Maine rivers as spawning habitat for a marine forage fish. 9th Biannual River Management Society Symposium, Portland, Maine. May 2008.

K. Wilson and T. Willis. River Herring in Maine: Challenges for Management and Research. Sheepscot River Watershed Council. June 2008. (Invited)

K. Wilson and T. Willis. Freshwater – marine linkages: the role of small coastal river systems as a source of fall forage fish (river herring) in the nearshore marine environment in Maine. Maine Water Conference, Augusta, Maine. (2009)

K. Wilson and T. Willis. Freshwater – marine subsidies: The role of small coastal river systems as a source of fall forage fish (*Alosa* spp.) in the nearshore Gulf of Maine. Ecological Society of America. Aug 2008.

Published reports

Several videos were posted during the course of this project to illustrate bottom conditions around baited hooks from drop camera and alewives and their predators at the Damariscotta Fish ladder (App. 1).

Appendix 1. Videos of cunner, lobsters and pollock swarming baited hooks, and footage from the Damariscotta fish ladder video counting work posted on YouTube.

Video subject	Link
"Cunners and pollock"	http://youtube.com/watch?v=J47YXs8xyGA
"Lobster on drop camera"	http://youtube.com/watch?v=kPqH9DxvKSg
"Alewives in the Damariscotta Mills"	http://youtube.com/watch?v=PTkxoYtxkuM

"Largemouth bass eating alewives"	http://youtube.com/watch?v=VdtKc2LQ0Pg
"Cormorant eating alewives"	http://youtube.com/watch?v=EibZRfGfwjo

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