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How Policy, Politics, and Science Shaped a 25-Year Conflict over Alewife in the St. Croix River, New Brunswick–Maine

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Abstract.—Consensus-based research uses scientific inquiry as an unbiased tool to contrast opposing positions in resource conflicts. However, when applied inappropriately, science is more likely to polarize opposing parties. Opposing parties also may use a consensus-based research process to delay actions not in their interest. The recreational smallmouth bass (SMB) *Micropterus dolomieu* fishery in the St. Croix River, New Brunswick–Maine is an example of how consensus-based research failed to bring opposing sides in a natural resource conflict to a mutually agreeable resolution. Recreational fishing guides blamed high alewife *Alosa pseudoharengus* returns for the crash of a naturalized SMB fishery in the upper watershed and proposed an exclusion law in response. In 1995, Maine legislated that all fishways in the St. Croix River be closed to alewives, with a resulting decline from 2.6 million alewives in 1987 to 900 by 2002. Claims of insufficient data to describe alewife ecological impacts on SMB led to formation of a local, state, provincial, U.S., and Canadian stakeholders science committee charged with developing a study that would describe SMB and alewife interactions. The committee identified the question, has alewife presence contributed to poor SMB population performance, as of primary importance to moving forward to a resolution. To test this hypothesis, SMB condition and growth, and the diet habits and diet overlap of alewives and SMB, were used as indicators of competition. Results, presented here, indicate that growth did not decline in the presence of alewives, age-0 SMB condition did not decline when alewives were present, and diet overlap between the two species was low in three of four lakes examined. Thus, the available data did not indicate that alewives caused poor SMB population performance. The project results helped break down institutional barriers between Maine natural resource agencies. However, local recreational fishermen were not satisfied with the project process or results, claiming that their interests, as represented by the state freshwater fish and game agency, were not seriously considered. They opposed~~,~~ and nearly defeated~~,~~ a bill to reintroduce alewives to the St. Croix River in 2008, again citing insufficient data to justify the action.

Introduction

Natural resource conflicts may be based in a variety of misunderstandings or opposing viewpoints concerning the use of a resource (Odell et al. 2005). The perception that an institution failed to manage a resource fairly and efficiently is often the trigger for conflict among stakeholders (Bennett et al. 2001). Feelings of inequity or injustice by parties involved in an issue are likely to develop into conflict. Decisions that marginalize local stakeholders, under the assumption that communities are an obstacle to efficient or rational management, are often met with resistance (Agrawal and Gibson 1999). ~~And c~~ommunities that are not involved in the active management of natural resources may choose to use those resources destructively. More often, stakeholders who feel slighted by the management process will enter into a lengthy and costly appeal process, delaying implementation of management decisions (Germain et al. 2001). Allocation of natural resources ~~between opposing groups or activities may not be mutually exclusive,~~ but ~~any~~ perception to the contrary can further polarize a conflict, making

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trade-offs and resolution harder to reach (Grimble and Wellard 1997). Many interventions in natural resource management issues have failed because not enough attention was paid to the economic interests and objectives of stakeholders.

This manuscript describes a natural resource management conflict over alewife *Alosa pseudoharengus*, an anadromous herring that is native to the eastern seaboard of North America. The case study specifically deals with a northern population that spawns in the St. Croix River watershed, Passamaquoddy Bay, Gulf of Maine and the interaction of that population with a naturalized sport fish, smallmouth bass Micropterus dolomieu. The St. Croix River defines the border between New Brunswick, Canada and Maine, USA. Consequently, all conflicts that occur in the St. Croix are international by definition, even if local by nature. Stakeholders in this 20-year impasse include marine and freshwater resource management agencies from the state of Maine, the province of New Brunswick, the U.S. Fish and Wildlife Service, the Department of Fisheries and Oceans Canada, local fishing guides, and conservation groups. The fisheries issue also has relevance to the National Marine Fisheries Service because the alewife is a marine species that falls under the authority of the Magnuson-Stevens Fishery Conservation and Management Act. The International Joint Commission has jurisdiction over border disputes between the United States and Canada.

Despite the prevalence of international stakeholders, the fisheries issue in the St. Croix River region is specific to 21,945 ha of lake habitat and two Maine counties. The original complainants about alewives were made by eastern Maine freshwater fishing guides (EMFFG), who suspected that alewives were the cause behind a downturn in smallmouth bass (SMB) fishing in one upper watershed lake. The EMFFG successfully lobbied the Maine state legislature and pushed through a law in 1995, which excluded alewives from most of the St. Croix River drainage. The conflict today is between EMFFG, backed by the 1995 law that requires state of Maine natural resource agencies to prevent alewife from ascending fish ladders in the St. Croix River, and opposing local, national, and international conservation groups; state and national management agencies; and marine resource users.

What was essentially a local issue in 1995 is now seen as a contributing factor in the range-wide decline of the U.S. river herring fishery (including alewife and blueback herring *A. aestivalis*). Legislative decisions made in 1995 accounted for the economic needs of Washington County, Maine, where the median income is less than $26,000 per year. Little consideration was given to species, ecological, and geographic considerations surrounding the loss of more than 1.5 million pounds in alewife biomass. In 2006, river herring were declared a "species of concern" by the National Marine Fisheries Service (USDOC 2006), a status that focuses research and conservation efforts to prevent a species from declining to the point where Endangered Species Act protection is needed. In 2007, the Atlantic States Marine Fisheries Commission started an amendment process to determine if closing the U.S. river herring fishery was warranted, based on declines in commercial landings since the 1990s (ASMFC 2007). Several Atlantic states, through their own management review processes, concluded that emergency closures of river herring fisheries were warranted (i.e., in Connecticut [2002], Massachusetts [2006], Rhode Island [2006], and North Carolina [2007]). The St. Croix fishery issue existed in a vacuum in 1995 but is very relevant to conservation of the species in 2008.

Alewife Management Issues in St. Croix River

Management actions that led to the St. Croix River impasse started almost two centuries earlier. The first dams were constructed on the St. Croix River around 1790; however, not until construction of the Union Dam in 1836 was there a drastic and long-term decline in anadromous fish returns (Perley 1852; Goode 1887). At about the same time, SMB were introduced to the upper St. Croix River watershed, where they have supported a significant recreational fishery since the mid-1900s (Warner 2005). A century of increasing industrialization and restricted fish passage followed the completion of Union Dam (Marshall 1976). In 1960, reliable fish passage was installed at Milltown Dam, the first dam without fish passage. Within a few years, alewife escapement numbers were around 10,000 (Marshall 1976). Pollution abatement in the 1970s and improvements to the Milltown fish passage facilities in 1981 likely led to the alewife population explosion of the late 1980s.

Alewife spawning escapement prior to 1981 was likely between 100,000 and 200,000 individuals. Between 1985 and 1988, the number of alewives returning to spawn increased exponentially to 2,624,700 fish (Figure 1). Beginning in 1988, parts of the St. Croix watershed were closed to alewives in response to EMFFG concern over the coincident decline of SMB in Spednic Lake. These closures, requested by Maine inland fisheries officials for research and management, were in effect permanent reductions in alewife spawning habitat, codified by passage of the 1995 legislation. A precipitous decline in the St. Croix alewife population resulted, with the population reaching a low of just 900 fish in 2002 (Figure 2).

The nature of interspecific interactions between alewives and SMB was central to the debate regarding what should be done about the alewife decline. Those opposed to reintroducing alewives claimed that the scientific data describing the interaction of alewives with organisms in the freshwater ecosystem was insufficient to justify the "experiment" of reintroducing alewives to the St. Croix watershed. The Maine legislature supported the alewife opposition in 2001 when conservation groups first attempted to repeal the 1995 law. It became apparent that intervention from organizations outside the state government would be necessary when a five-agency (Maine, New Brunswick, Canada, and U.S. federal) proposal to conduct staged alewife releases into St. Croix waters and study the effects on resident SMB populations failed shortly thereafter. The 1995 law prevented Maine fisheries agencies from participating in any release. A working group, with representatives from many of the ~~afore-mentioned~~ stakeholders, acted to fill the data gap by agreeing

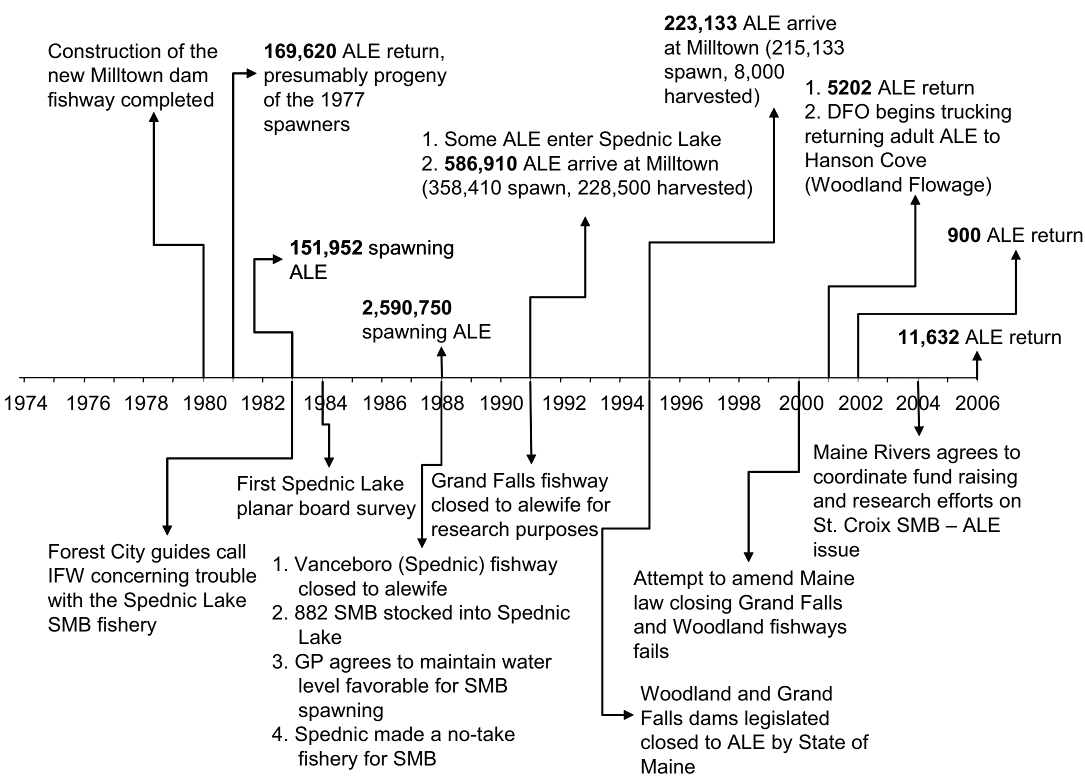

Figure 1.—Timeline of events in the management of alewives and alewife returns on the St. Croix River. Spawner escapement in any year consists mostly of fish spawned 4–5 years previous (SCIWC 2000). ALE = anadromous (sea-run) alewife, IFW = Maine Department of Inland Fisheries and Wildlife, SMB = smallmouth bass, GP = Georgia-Pacific Corporation, and DFO = Fisheries and Oceans Canada.

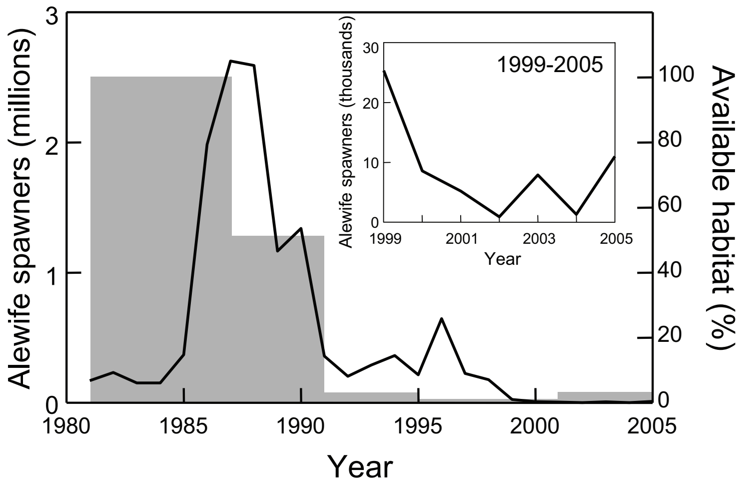

Figure 2.—Alewife spawning escapement (left axis, solid line) and available spawning habitat (right axis, shading) graphed against year in the St. Croix River system. The inset shows spawning escapement in number of alewives between 1999 and 2005. Spawning alewives were counted at Milltown Dam fishway by the St. Croix International Waterway Commission. The maximum spawning area was equal to Woodland Flowage, Grand Falls Flowage, Big Lake, and Spednic Lake. The minimum spawning area was equal to waters between Milltown Dam and Woodland Dam.

to support an independent research project organized by nongovernmental organizations. The role of science in the political landscape of the St. Croix issue became addressing how alewives and SMB interacted in freshwater.

Ecological studies of alewives in their native range, under natural conditions, are rare compared to investigation of the invasive land-locked form. Many of the concerns regarding anadromous alewife effects in freshwater ecosystems are derived from information about landlocked alewives in the Laurentian Great Lakes. Alewife opponents have cited early mortality syndrome (Fisher et al. 1996), water quality concerns (Brooks and Dodson 1965), competition, and predation (Bunnell et al. 2006) as evidence for keeping the St. Croix River fishways closed. Similarities between the two life histories do exist. However, a cohort of anadromous alewives are present in freshwater for 4–5 months in their first year of life, then for several weeks 4–6 years later when they return to spawn. Conversely, landlocked alewives are permanent freshwater residents.

The working group project was designed to investigate the potential negative impacts of anadromous alewives on SMB. The working group evolved into a science advisory committee that consisted of the U.S. Fish & Wildlife Service (USFWS), Maine Department of Inland Fisheries & Wildlife (MEIFW), Maine Department of Marine Resources (MEDMR), Fisheries and Oceans Canada (DFO), New Brunswick Department of Natural Resource (NBDNR), St. Croix International Waterway Commission (SCIWC), and Maine Rivers (MR). Each member of the working group represented a constituency of stake holders. USFWS represented U.S. national conservation interest, particularly those encompassed by the Anadromous Fish Act of 1965. MEDMR and DFO represented marine commercial and conservation interests; MEDMR and NBDNR represented local freshwater fishing interests. The role of MR and SCIWC was neutral and could be best described as facilitatory as far as securing funding and administering project activities (i.e., meetings, research, and publication). Focal questions researched by the project were chosen through the consensus process by the science advisory committee. Questions chosen in part reflected MEIFW SMB and alewife data that was available and had not been analyzed. The two primary questions were: (1) do adult alewives eat age-0 SMB and/or compete with age-0 SMB for food, and (2) do age-0 alewives compete with age-0 SMB for food.

Methods

Alewife Effects on Smallmouth Bass Condition and Growth

Between 1989 and 2005, MEIFW collected scale samples and/or length–weight data from SMB in the lower St. Croix drainage, as well as from seven other lakes in eastern Maine (Figure 3). Alewives were absent from four lakes, and the alewife status of lakes in the St. Croix drainage changed through time (Table 1). Density data were not available for alewives or SMB in most study lakes. The exception was Woodland Flowage where alewife counts had been conducted at the Milltown Fishway since 1981. Densities ranged from an average high of 639 alewives/ha (259/acre; 1991–1994) to 0 (1995–2000) to a current average of 8 alewives/ha (3/acre; 2001–2005). All lakes were located in MEIFW resource management region C, including Washington County, Hancock County, and part of Penobscot County. Lakes ranged in size from 5 to 13 km^2. Six lakes were mesotrophic (http://pearl.maine.edu/), and the remainder were oligotrophic.

The condition analysis assessed the correlation between a low length–weight ratio for SMB at the end of their first year of growth and the presence of alewives. Condition data were collected by electrofishing (backpack or boat) of up to 50 age-0 SMB per year in early fall after growth for the year had ceased. One day of effort was expended per lake in a variety of locations; thus, 50 fish were not always caught. Fish were returned to the laboratory alive, sacrificed, measured, and weighed (0.01 g). Large fish (>85 mm) suspected of being age 1+ were aged by scale and excluded from the data set if found to be older than 0+. Condition of age-0 SMB was expressed as Fulton's condition factor (K_b) (Anderson and Neumann 1996) and percent of relative weight (W_r) (Murphy et al. 1990, 1991). Wr is a better than Kb for between-lake comparisons, although the calculation of W_r is more complicated (Murphy et al. 1991). Statistical analysis of condition data consisted of *t*-tests of alewife versus no alewife lakes and one-way analysis of variance (ANOVA) on the average annual condition of age-0 SMB in a lake (Systat 12). Wr was square root transformed and K_b was log $(x + 1)$ transformed to approximate a normal distribution.

Woodland Flowage was omitted from the condition ANOVA and treated separately in its own analysis because it neither fell into the "alewife" nor the "no alewife" category. Differences in K_b associated with alewife spawning escapement were explored with a one-way ANOVA. Spawning escapement (i.e., the number of alewives either allowed to pass Woodland Dam or stocked into Woodland Flowage at Hanson Cove by DFO) and K_b were log$(x + 1)$ transformed.

The growth analysis looked for a correlation between low SMB growth, between ages 1–3, and the presence of alewives. Growth data (i.e., back-calculated length from scales) were collected from age 1+ SMB in the spring before growth commenced for that year. Approximately 100 SMB were angled from each lake (Big Lake, Grand Falls Flowage and Woodland Flowage; see Table 1 for years of available data). One day of effort was expended per lake in a variety of locations; 100 fish were not always caught. Scales were aged, and distance between annuli and scale radius measured for fish up to age 5 only, in accordance with MEIFW protocols.

Statistical analysis of SMB growth data were performed on estimated length-at-age. Length-at-age was calculated using the scale back-calculation formula:

$$L_{ij} = 21 + \left(\frac{A_{ij}}{r_j}\right) \times (L_j - 21) \quad , \tag{1}$$

where L_{ij} is the length-at-annuli (length-at-age) of fish j at annulus i, A_{ij} is the distance between annuli i and the focus of fish scale j, r_j is the radius length of fish scale j, and L_j is the length at capture of fish j. Growth was calculated by

$$G_{ji} = L_{ji} + 1 - L_{ji}, \tag{2}$$

where G_{ij} is the growth of fish j at annuli i and L_{ji} is the estimated length of fish j at annuli i. Using this method, growth data were available as far back as 1984 for 5-year-old fish caught in Grand Falls Flowage in 1989, 1985 for fish caught in Woodland Flowage in 1990, and 1986 for fish caught in Big Lake in 1991.

Big Lake and Grand Falls and Woodland

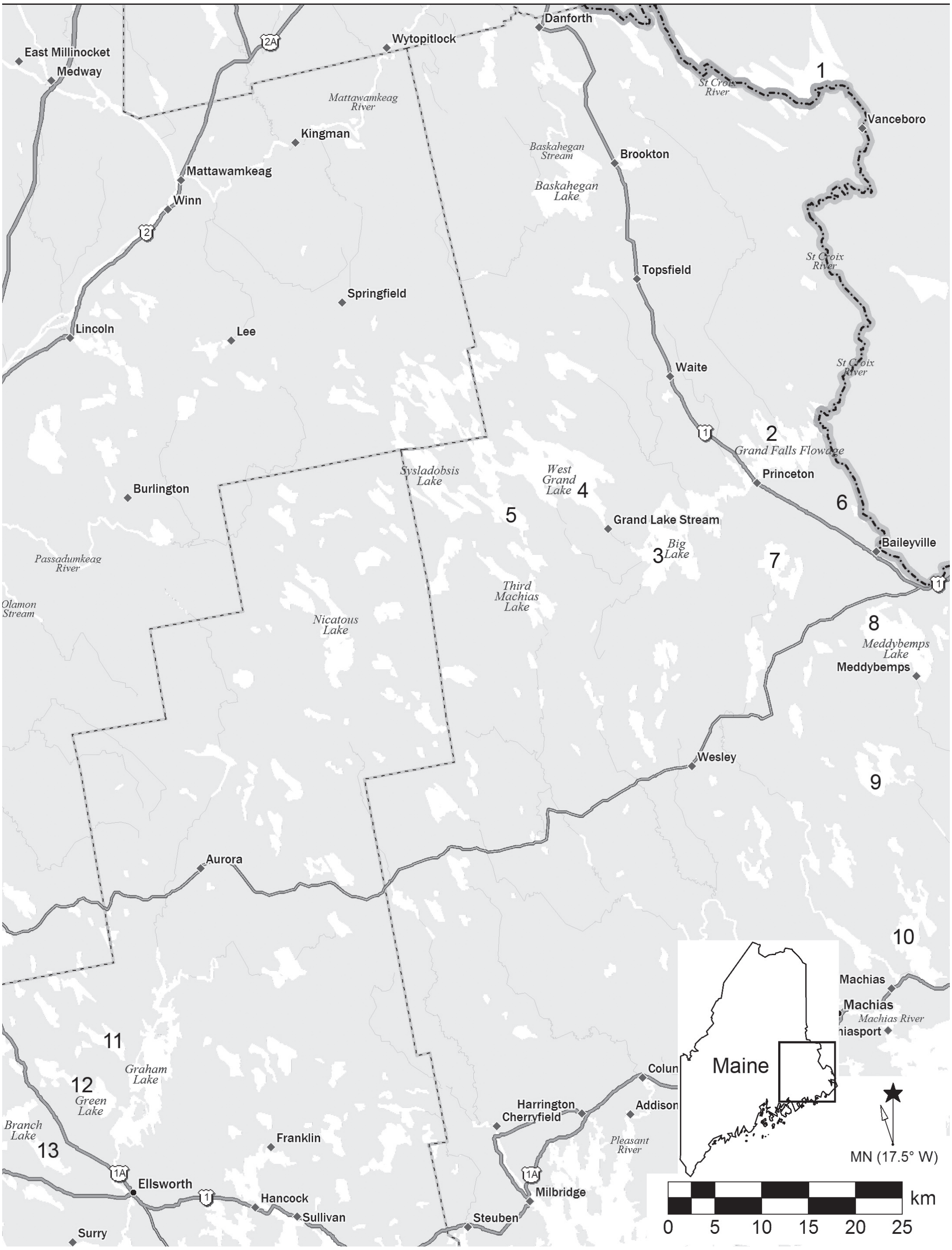

Figure 3.—Map of region with lakes sampled. 1. Spednic, 2. Grand Falls, 3. Big, 4. West Grand, 5. Pocumcus, 6. Woodland, 7. Pocomoonshine, 8. Meddybemps, 9. Cathance, 10. Gardner, 11. Beech Hill, 12. Green, 13. Branch.

Table 1.—Background information on lakes included in the smallmouth bass (SMB) condition, growth, and diet habit analyses (http://pearl.maine.edu). Adult SMB data were used for the growth analysis; age-0 SMB data were used in the condition analysis. Diet habit data were collected in 2005 from Big, Grand Falls, Pocumcus, without alewives, and Cathance, Gardner, Meddybemps, Woodland with alewives. Trophic index is based on Secchi depth; the Chlorophyll-*a* trophic index is reported for Pocomoonshine Lake. ALE = alewife, age-0 = young-of-year; oligo = oligotrophic, and mes = mesotrophic.

Lake	Watershed	ALE present	Area (km^2)	Mean depth (m)	Trophic state	Years adult SMB sampled	Years adult SMB sampled
Beech Hill	Union	No	5.47	13.4	oligo	–	1999–2002
Big	St. Croix	Until 1990	41.7	3.7	meso	1991, 1993, 1995, 1997, 1999, 2001, 2003	1994–2005
Branch	Union	No	10.94	11.9	oligo	–	1995–2002
Cathance	Dennys	Yes	11.76	7.3	oligo	–	1995–2003
Gardner	East Machias	Yes	15.05	12.2	–	–	–
Grand Falls	St. Croix	Until 1990	27.08	3.0	meso	1989, 1993, 1995, 1997, 1999, 2001, 2003	1994–2005
Green	Union	No	12.1	13.4	oligo	–	1994–1998, 2000–2003
Meddybemps	Dennys	Yes	27.38	4.3	meso	–	1992, 1995–2003
Pocomoonshine	East Machias	Yes	9.97	4.3	meso	–	1992, 1995–2003
Pocumcus	St. Croix	No	8.95	7.6	–	–	–
West Grand	St. Croix	No	58.03	11.3	meso	–	1994–2005
Woodland	St. Croix	Yes (to 1994; 2001 to 2005), No (1995–2000)	4.75	4.6	–	1990, 1994, 1997, 2000–2004	1994–1995, 1997, 1999, 2001–2005

flowages underwent a series of sequential closures in the late 1980s and early 1990s so that each lake had scale samples collected from fish grown in the presence and the absence of alewives. Age-1 through age-3 SMB from each lake were tested separately to quantify variability in growth between alewife and no alewife years. Nonparametric methods were used because growth at age *t* was autocorrelated with growth at age $t - 1$. Statistical analysis was performed on Big Lake and Grand Falls using the Mann–Whitney U-test (Sokal and Rohlf 1995). Woodland Flowage had four distinct periods of alewife access between 1985 and 2005 (Table 1). Each time period was analyzed as a separate treatment in a 4×1 Kruskal-Wallis one-way nonparametric ANOVA for ages 1–3.

Comparison of Smallmouth Bass and Alewife Diet Habits

Seven lakes were chosen to conduct the diet analysis portion of the project. Four lakes with alewives and three lakes without were matched for size, average depth, productivity, and other limnological characteristics (Table 1). Alewives have free access to Cathance, Meddybemps, and Gardner lakes via Denil (Gardner and Meddybemps) or Alaskan steep-pass (Cathance and Meddybemps) fish ladders. Alewives were stocked into Woodland Flowage up to a density of 15 fish/ha (~7,100 alewives) by DFO, starting in 2001.

Adult alewife diets.—Adult alewife diets were collected to estimate what percentage of the diet consisted of fish, especially members of the family Centrarchidae. Adult alewives were targeted in Cathance, Meddybemps, and Gardner lakes and Woodland Flowage using nocturnal sets of stationary gear between June 25 and July 26, 2005. Trammel nets (1.8 m tall, 30.5 m long, 2.5-cm interior mesh, 30.4-cm outer mesh) were set three times between dusk and dawn for 30 min on at least four nights in each lake. Captured alewives were measured (mm) and weighed (g) on site. Diet samples were collected via gastric lavage (Hartleb and Moring 1995), flushing the gut contents into an 80-μm brass sieve. Diet contents were then washed into a 236.5-mL (8 oz.) plastic cup and preserved in a solution of 80% alcohol, 15% water ,and 5% polyethylene glycol (F13) (Warmington et al. 2000). In 24–36-h samples were concentrated into a 90-mL plastic vial with 70% ethanol for long- term storage. Fifteen alewives were sacrificed and their stomachs removed to verify the effectiveness of gastric lavage. In all cases, gastric lavage cleared the foregut but left the contents of the hind gut largely intact. Hind gut contents were usually a single concentrated pellet of mostly digested material. Most of this material was not identifiable, so the gastric lavage protocol was considered effective with the stipulation that only the foregut was being sampled.

Diet contents were identified to family when possible, and in most cases, all organisms were counted. In cases where zooplankton were too numerous to count individually, three 2-mL subsamples were taken, all organisms of the focal taxa were counted, and the results averaged. Number of organisms was estimated by scaling the average number of organisms per 2-mL subsample up to the volume of fluid in the container prior to subsampling. Five representative diet items per fish from each category of diet items identified were measured to the nearest 0.01 mm with a stereo dissecting scope equipped with a 10× optical micrometer. Lengths of diet items were used to calculate an average length of prey ingested for each category of diet item identified. Diet item dry mass was calculated from length measurements using published formulas and conversions (Dumont et al. 1975; Rosen 1981; Culver et al. 1985; Yan and Mackie 1987; Benke et al. 1999; Johnston and Cunjak 1999; Nicol and Mackauer 1999; Dole-Olivier et al. 2000; Sabates et al. 2003).

Age-0 alewife and smallmouth bass diets.—Age-0 alewife and age-0 SMB bass diets were collected to assess degree of food resource overlap between the two species. Alewife and SMB age-0 were fished using a beach seine (1.2 m tall, 15.25 m long, 6.4-mm mesh). Lakes were sampled every 2 to 3 weeks between July 27 and September 9 during daylight hours (Table 2). Cathance Lake samples were analyzed in two periods, August 23 and September 8. All Gardner lake samples were combined; only five age-0 SMB were collected on September 7, so this date was combined with August 1. Age-0 SMB collected on August 18 were significantly longer than those collected on July 27 and August 3, which did not differ from each other; thus, the two earlier samples were combined. All Woodland dates were combined because length of SMB collected on three dates did not differ significantly.

Fish processing included lethal sampling of alewife and SMB age-0 in the field; subsequent data collection occurred in the laboratory. Fish caught in the field were immediately preserved in F13 preservative solution. Before diets were transferred to 70% ethanol for long-term storage, fish were removed from the preservative, measured to the nearest mm, and weighed to the nearest 0.1 g. The body cavity of the fish was opened and the stomach excised and rinsed into a 2-mL vial containing 70% ethanol. The goal was to excise the stomach of 25 fish from each species for each sampling date. In some cases, the total catch of age-0 SMB or age-0 alewife was haphazardly sub-

Table 2.—Dates and location (lakes) of adult alewife, age-0 smallmouth bass and age-0 alewife diet habit data collection.

Lake	Sample dates (2005)
Cathance	6/24, 7/6, 7/19, 7/26, 8/23, 8/8
Gardner	6/27, 7/11, 7/14, 7/18, 7/28, 8/17, 9/7
Meddybemps	6/23, 6/28, 7/8, 7/13, 7/20, 7/27, 8/3, 8/18, 9/6
Woodland	6/29, 6/30, 7/7, 7/12, 7/21, 8/1, 8/10, 8/19, 8/24, 9/9
Big	8/4, 8/24
Grand Falls	8/8, 8/9, 8/12, 8/30
Pocumcus	8/5, 8/31

sampled to arrive at 25 diet samples. When less than 25 fish were available, diets were processed from all the fish collected. Diet processing, including estimating item dry mass, was the same as adult alewives.

Comparisons of diet habits were facilitated by calculating the index of relative importance (%IRI) for each species and then calculating Schoener's index for each sampling period. The IRI combines frequency of occurrence as percent occurrence (%O), diet category weight as percent weight (%W) and diet category numerical occurrence as percent of number (%N) (from Liao et al. 2002). Competition potential for the same food resources between age-0 alewife and age-0 SMB was assessed using Schoener's index (Schoener 1970). Schoener's index compares differences in the proportions of prey comparison units and sums across all units to arrive at an index value that is a measure of diet overlap between two species or groups of organisms. Schoener's index is calculated as

$$\alpha = 1 - 0.5 \times \left(\sum_{i=1}^{n} \left| P_{xi} - P_{yi} \right| \right), \quad (3)$$

where P_{xi} is the proportion of food item (taxa) i in the diet of age-0 alewives, P_{yi} is the proportion of food item i in the diet of age-0 SMB, and n is the number of prey categories (Kahilainen and Ostbye 2006). Here, Schoener's index is expressed as a percentage (i.e., $\alpha \times 100 = \%\alpha$) and IRI values were substituted for P. A value of 0% indicates no diet overlap, and a value of 100% indicates complete diet overlap. It is assumed that fish diet overlap must be greater than or equal to 60% in order to be biologically significant, a value that has been widely accepted in scientific literature (Zaret and Rand 1971; Wallace 1981; Willis et al. 2002; Kahilainen and Ostbye 2006; Kahl and Radke 2006).

Results

Alewife Effects on Smallmouth Bass Condition and Growth

There was no difference in age-0 SMB condition between the groups of lakes with alewives present or alewives absent and no indication that high or low condition values from a subset of lakes affected the analysis for either W_r or K_b. Condition was significantly different between lakes for both W_r ($p <$ 0.001, $F = 6.26$, $n = 85$) and K_b ($p < 0.001$, $F = 5.87$, $n = 85$). SMB from Grand Falls Flowage had the highest condition, followed by Cathance and Meddybemps lakes. Green Lake SMB had the fourth highest condition; SMB from West Grand Lake had the lowest condition.

Stocking rate (i.e., spawning escapement) did not correlate with increased or decreased SMB condition in Woodland Flowage. Linear regression of SMB log (K_b + 1) against alewife stocking rate was not statistically significant ($p = 0.1$, $F = 2.8$, $n = 9$). K_b was lowest in 1994, at a stocking level of 796 alewives/ha, followed by 2003, at a stocking level of 14 alewives/ha. K_b was highest in 2002, at 2 alewives/ha, followed by 2005 at 15 alewives/ha.

There was no evidence that the presence of alewives retarded SMB growth between the ages of 1 and 3. In Big Lake (age 2) and Grand Falls (age 1 and age 3) SMB growth was significantly higher (p < 0.05), coincident with years when alewives were allowed passage into the lake (Figure 4; Table 3). In Woodland Flowage, there was no statistically significant difference in growth between periods when the St. Croix River was open, when access to spawning area was reduced, when the river was closed to alewives, or when DFO ~~truck~~ stocked alewives. Age-1 SMB did have a higher average growth in Woodland for 2001–2005, during DFO stocking, but this was not statistically significant (Figure 4; Table 3).

Comparison of Smallmouth Bass and Alewife Diet Habits

Adult alewife diets.—Fish made up a very small proportion of the diet of the adult alewives collected, less than 0.28% of the diet. Out of 70 adult alewives sampled from three lakes, 10% had fish in their guts. Most fish prey that were found in alewife stomachs had the general body characteristics of either larval stage rainbow smelt *Osmerus mordax* or larval stage alewives. Adult alewives consumed a range of diet items once in freshwater, including pelagic plankton (Daphnidae, Polyphemidae, and Copepoda) (Table 4). Adult alewives also ate dipteran pupae and trichopteran larvae. Most adult alewives were caught in the cove nearest the lake outlet, presumably the point of access to the lake.

Age-0 alewife and smallmouth bass diets.—Zooplankton were the most frequently found diet item for both species for all lakes, but there was con-

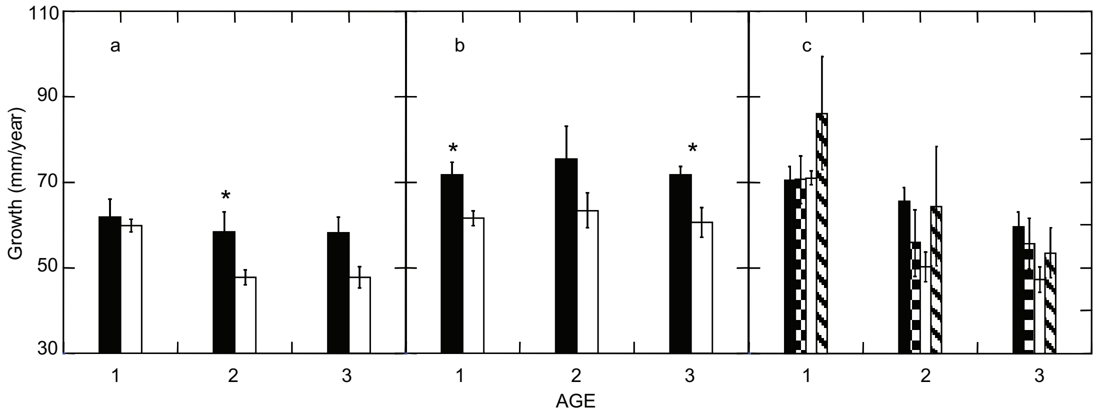

Figure 4.—Smallmouth bass growth (mm/year) for (A) Big Lake, (B) Grand Falls Flowage, and (C) Woodland Flowage. Black bars represent years in which alewives were present; white bars represent years when alewives were excluded. Error bars are 1 SE. Additional categories for Woodland included alewives reduced (block), when alewife spawning habitat was reduced to Woodland only, and alewives stocked (hash), Fisheries and Oceans Canada ~~trucking of alewife~~ around Woodland Dam. * = $p < 0.05$.

siderable variation in age-0 diet by lake. Both age-0 alewives and SMB were caught in mixed schools, presumably feeding alongside each other. However, age-0 SMB, more than alewives, diversified their diets with other invertebrates (e.g., mayfly larvae, midge larvae, and adults of these invertebrates; Table 5). Of the four lakes sampled with sympatric populations of SMB and alewives, biologically significant diet overlap (Schoener's index > 60%) was detected only in Meddybemps Lake, on the first sample date (Table 6). Meddybemps Lake age-0 alewives foraged almost exclusively on cladocerans (Family Sididae) at the time of the first (98%) and second (93%) sampling. Age-0 SMB also ate Sididae (69%), along with other cladocerans (28%). By the second sampling, age-0 SMB in Meddybemps Lake were still eating Sididae (40%) and another zooplankter (Family Moinidae, 17%), but were also eating fish (41%).

Table 3.—Results of Kruskal-Wallis tests of smallmouth bass (SMB) growth in years with alewives present and years with alewives absent for SMB of ages 1–3. Data were collected by Maine Department of Inland Fisheries & Wildlife between 1981 and 2004. Sample sizes, as number of years in which SMB scales were collected, appear below the p values. ALE reduced (1988-1994) and ALE stocked (2001-2005) refers to alewife management periods in Table 1. See Figure 1 for detailed explanation. ALE = alewife; * = significant test.

Lake	Age 1	Age 2	Age 3
Big	$p = 0.5$	$p = 0.02$*	$p = 0.06$
ALE present	5	4	3
ALE absent	11	12	12
Grand Falls	$p = 0.01$*	$p = 0.2$	$p = 0.03$*
ALE present	7	6	4
ALE absent	10	11	12
Woodland	$p = 0.2$	$p = 0.15$	$p = 0.14$
ALE present	6	5	3
ALE reduced	4	4	4
ALE absent	6	6	6
ALE stocked	3	3	3

Table 4.—Major diet items based on the %IRI (index of relative importance) method for adult alewives, sorted by lake. Diets were collected from alewives in the lake during the 2005 alewife spawning season. *n* = sample size.

Diet taxa	Gardner	Meddybemps	Woodland
Daphnidae	1.6	82.9	0.8
Polyphemidae	2.1	[illegible]	56.7
Diptera pupae	43.9	0.2	4.7
Trichoptera	10.6	0.1	26.7
Copepoda	13.6	5.2	0.1
Bosminidae	5.6		2.6
Sididae	5.6	0.9	
other	17.1	10.6	8.3
n	38	21	11

The diet of allopatric age-0 SMB was similar to the diets of SMB that occurred with alewives. In all lakes, zooplankton made up a large proportion of the diet. Benthic invertebrates became more important in subsequent samples, as did fish prey (Table 7).

Discussion

Alewife Effects on Smallmouth Bass Condition and Growth

Analyses completed for this project did not indicate that a systematic decline occurred in SMB popu-

Table 5.—Major diet items, based on the %IRI (index of relative importance) method, for age-0 alewives and age-0 smallmouth bass in lakes with sympatric populations. Diets were collected from alewives in the lakes during the 2005 growing season. CA = Cathance, GA = Gardner, ME = Meddybemps, WO = Woodland. A = alewife, S = smallmouth bass. Numbers following A or S refer to sampling period. n = samples size.

Diet taxa	CA A1	CA A2	CA S1	CA S2	GA A	GA S	ME A1	ME A2	ME S1	ME S2	WO A1	WO S1
Sididae	0	0	1.2	24.1	0.3	53.1	97.8	93.0	69.3	40.0	0	1.0
Chaoborus	62.8	76.9	0	0.4	0.2	0	0	0	0	0	0	0
Chydoridae	0.6	0.1	68.8	0.1	36.8	2.6	0.1	0.6	0	0	0	0
Diptera adult	0.4	0	0.4	4.9	1.4	0.1	0	0	0	0	22.0	49.0
Bosminidae	2.3	0.5	0	0	56.9	0	0	0	0	0	0	0
Ephemeroptera	0.1	0.3	2.6	0.5	0	37.6	0	0	0	0.5	0	17.0
Fish	0	0	1.5	8.5	0	1.1	0	0	0	40.6	0	3.9
Polyphemidae	0	13.0	5.0	32.9	0.1	0	0	0.1	0	0	0	0
Simulidae	0	0	0	0	0	0	0	0	0	0	48.7	2.2
Trichoptera	0	0	0.2	0	0	0.1	0.1	0.1	0	0.5	21.7	17.1
Daphnidae	29.6	0.2	7.2	0.4	0	0	0	0	0	0	0	0.2
Zygoptera	0	0	0	27.9	0	0.1	0	0	0	0	0	0.3
Cladocera	0	0	0	0	0	0	0	0	27.6	0.5	0	0
Chironomidae	0.3	0	0.4	0	1.3	2.1	0.2	2.7	2.8	0.2	5.4	5.3
Moinidae	0	0	0	0	0	1.6	0	0	0	17.1	0	0
Holopedidae	0.2	8.1	0	0	1.3	0	0	0	0	0	0	0
Terrestrial insect	0	0	5.9	0	0	0	0	0	0	0.1	0	0
Plecoptera adult	0	0	5.4	0	0	0	0	0	0	0	0	0.3
Other	3.7	0.8	1.5	0.3	1.7	1.5	1.6	3.5	0.2	0.4	2.3	3.8
n	25	25	9	10	35	17	50	8	7	28	7	36

Table 6.—Schoener's index of diet overlap values for age-0 alewives and age-0 smallmouth bass (SMB) and average length of fish sampled (SD). Data are presented as percent diet overlap between alewives and bass by sample period and lake. Values greater than 60% are considered biologically relevant. ALE = alewife.

Lake	First sampling	Species data	Second sampling	Species data
Cathance	8.7%	ALE: 58.7 mm (9.8) SMB: 49.4 mm (4.8)	14.1 %	ALE: 63.9 mm (12.1) SMB: 60.2 mm (3.7)
Gardner	4.3%	ALE: 44.1 mm (8.4) SMB: 52.6 mm (6.0)		
Meddybemps	69.8%	ALE: 33.9 mm (3.5) SMB: 40.1 mm (5.0)	40.4%	ALE: 35.6 mm (1.3) SMB: 62.6 mm (10.5)
Woodland	46.8%	ALE: 79.4 mm (8.4) SMB: 59.0 mm (7.4)		
Big		SMB: 45.0 mm (4.0)		SMB: 52.2 mm (5.1)
Grand Falls		SMB: 46.9 mm (10.7)		SMB: 54.7 mm (5.8)
Pocumcus		SMB: 42.6 mm (5.4)		SMB: 56.0 mm (7.3)

lation performance in the presence of anadromous alewives. The project predicted that size-structured interactions would inhibit age-0 SMB feeding, as reflected in growth, condition, and diet overlap measures (i.e., adult alewives would eat age-0 SMB and/or compete with age-0 SMB for food and age-0 alewives would compete with age-0 SMB for food. Interspecific competition between predator and prey fish can lead to a size-structured interaction (Bystrom et al. 1998; Olson et al. 1995) when prey impedes the growth of predator. Size-structured interactions are an acute problem for piscivorous fishes in northern latitudes, like St. Croix River SMB, because a minimum growth threshold (~60 mm) is required for overwinter survival (Shuter et al. 1980; Shuter and Post 1990; Curry et al. 2005). Reaching the minimum overwinter size is often associated with an ontogenetic shift to piscivory (Ludsin and DeVries 1997; Olson et al. 1998), which may in turn depend on the availability of smaller high-quality

Table 7.—Major diet items, based on the %IRI (index of relative importance) method, for age-0 smallmouth bass (SMB) in lakes without alewives. Diets were collected from SMB in the lakes during the 2005 growing season. GF = Grand Falls; Pocu = Pocumcus. Number following lake name refers to sampling period. *n* = samples size.

Diet taxa	Big 1	Big 2	GF 1	GF 2	Pocu 1	Pocu 2
Sididae	0	21.8	1.7	35.2	43.7	60.7
Ephemeroptera	0.1	20.2	5.6	58.6	0.1	1.7
Diptera pupae	62.2	0.2	0	0.8	3.1	0
Fish	1.1	0.9	0	1.4	37.4	19.3
Polyphemidae	0	5.4	40.7	0	7.3	1.9
Diptera adult	2.3	28.0	13.3	0.1	0	0.1
Daphnidae	29.0	0	0.5	0	0	0.1
Chironomidae	0	6.7	0.4	0.9	3.3	5.3
Hymenoptera	2.1	0.1	13.3	0	0	0
Trichoptera	0.1	0.5	11.3	1.1	0.1	1.0
Chydoridae	0	4.9	1.5	0.1	2.6	2.7
Hemiptera	0	0	8.9	0	0	1.5
Other	2.9	11.1	2.7	1.8	2.5	5.6
n	25	24	8	25	9	25

prey (Galarowicz and Wahl 2005). The results presented here do not suggest that alewives negatively affect age-0 SMB across the region as a whole or in a lake where alewives were intermittently introduced and removed.

There were, however, some limitations to the study. Existing data from MEIFW came from a variety of sampling efforts that were started in the late 1980s and early 1990s. In many cases, the sampling programs were a response to a previously identified problem. The methodology used reflected what was known in the fisheries field at the time. The depth of sampling also reflected the resources (hours and dollars) available to contribute to any one sampling need in light of regular management duties. Ancillary data that would have been useful in 2005 was often not available from years when samples were collected (e.g., annual spawning escapement, diet habits, prey abundance). For that part of the project executed in 2005, the number of sampling activities limited the depth of information that could be collected from any one water body, and the number of lakes sampled dictated how much time could be committed to collecting fish in different parts of the lake. For example, alewife spawning escapement numbers were not available for any specific water body other than Woodland Flowage, and compromises had to be made in sampling for adult alewife versus age-0 alewife versus age-0 SMB. The decision to cover a wide temporal and spatial breadth of lakes ~~meant~~ that this study cannot suggest threshold stocking or escapement levels at which alewives and SMB interactions change or address the implications of diet overlap that might occur at the larval or black fry stage of development.

Despite these caveats, the available data yielded some insights into how the presence of alewives affected SMB population performance. Condition between groups of lakes with and without alewives was not significant, possibly due to significant differences in condition between lakes within groups. The lake with the highest condition was a no-alewife lake, followed by two alewife lakes. Individual lake characteristics appeared to be better determinants of condition than alewife presence or absence. Within the same lake, Woodland Flowage, annual variation was a stronger determinant of bass condition than alewife stocking rates. Negative effects of alewives on the growth of SMB for ages 1–3 were not apparent; there was no difference in bass growth whether alewives were present or absent. Conversely, growth was equal or greater for SMB in the presence of alewives in Big Lake and Grand Falls Flowage. Results of the current analysis do not support the presumed negative impacts of alewives on SMB population performance.

Comparison of Smallmouth Bass and Alewife Diet Habits

The adult and age-0 alewife diet analyses did not identify direct (predation) and/or indirect (size structured) interactions between alewife and SMB populations. Observations from Spednic Lake were the genesis for this research question. MEIFW and NBDNR observed low SMB survival between the black fry and fall age-0 stage, concurrent with increasing alewife returns and high age-0 alewife production (R. Jordan, Maine Inland Fisheries and Wildlife, personal communication). Diets of adult alewives indicated that fish prey made up an extremely small percentage of the diet. These results agreed with earlier results from Maine lakes (Jordan 1989). Based on the available data, one would conclude that adult alewives are not a significant predator of age-0 SMB.

Age-0 alewives and age-0 SMB diet data were examined for biologically significant diet overlap that might be indicative of a competitive interaction. The extent of diet overlap did not support this hypothesis for the lakes sampled. Schoener's index was less than 60% in most lakes, below the threshold for biologically significant interaction. The late June sampling of Meddybemps Lake produced the only biologically significant diet overlap of the study (69%). Zooplankton in the family Sididae were a common diet item of both specie. Ironically, SMB and alewives have coexisted in Meddybemps Lake since 1877 (Warner 2005). Given the long history of sympatry between these two species, it is likely that Sididae were a shared diet item because they were the most prevalent food resource in the lake.

Late summer may represent the most obvious window for age-0 alewife and age-0 SMB to compete for food resources. In late summer, the decline in planktonic prey drives alewives into the littoral zone. Benthic food items (e.g., chironimids, ostracods, benthic zooplankton) become more prevalent in the guts of age-0 anadromous alewives (Vigerstad and Cobb 1978; Gregory et al. 1983; Jessop 1990;

Hanson and Curry 2005). However, overlap of bass and alewives in the littoral zone may be relatively short and not entirely detrimental. Some research indicates that the decline in planktonic prey is a cue for age-0 alewives to begin moving towards the ocean (Vigerstad and Cobb 1978; Yako et al. 2002). Although interactions between age-0 alewives and age-0 SMB could reduce bass growth if alewives out-compete bass for important intermediate prey resources, it is also possible for alewives spawned late in the season to become a prey resource themselves (Hanson and Curry 2005).

Alewife Management Issues in St. Croix River

The expectation of science in a dispute is that investigation will result in proof and an immediate resolution of the conflict. However, when science is brought in before the political process has identified the most important commonalities and objections, science can delay action on an issue (Oreskes 2004). Using scientific inquiry to help shape policy is considered, in some circles, a gross misrepresentation of how science and policy should intersect (Oreskes 2004). Two entities (people, scientists, agencies, etc.) interpreting the same set of results with incongruent a priori objectives will inevitably arrive at different conclusions (Oreskes 2004; Sarewitz 2004). Clarifying value disputes, reflected in study objectives agreed upon by the stakeholders, is considered a more appropriate, constructive, and less inflammatory use of scientific inquiry (Sarewitz 2004).

This project was not the first study to address the effects of alewives on freshwater ecosystems, but rather represented a second round of inquiry focused on anadromous alewife interactions with freshwater ecosystems. A 10-year study by MEIFW and MEDMR found that anadromous alewives had no statistically significant negative effects on freshwater game fish, forage fish, or water quality at a stocking rate of six fish per acre (14/ha; Kircheis et al. 2002). MEIFW studies conducted after the closure found that Spednic Lake adult alewives could have competed with age-0 SMB for prey when they were sympatric (Jordan 1988) and that excluding alewives from Spednic Lake resulted in recovery of the bass population (Figure 5; Smith 1988, 1998). Alewife proponents and opponents maintained that evidence contrary to their position lacked credibility. Neither of the two Spednic Lake studies nor Kircheis et al. (2002) addressed a widely agreed upon set of objectives. Supporting and opposing positions taken by the groups, and their associated actions, were based in strong commitments to collective goals and values (Sarewitz 2004). The alewife opposition claimed that no "adequate biological data about the impact on other species" was available, an argument that convinced the Maine legislators to maintain fishway closures in 2001. In response, DFO demonstrated their commitment to reestablishing alewives in the St. Croix River by commencing "trap & truck" operations to stock alewives in the first closed section of the river, Woodland Flowage.

Transparency and good faith negotiation are vital to the success of any collaborative effort, especially one as contentious as the St. Croix alewife issue. The 2001 legislative defeat forced alewife proponents to negotiate in earnest with alewife opponents. Negotiations prior to and immediately after the failure of the 2001 bill identified the most pertinent issues in the alewife–smallmouth bass debate for the St. Croix River stakeholders. Alewife proponents lead the efforts to form an ad hoc science committee to secure funding and to develop an implementation plan. Both opponents and proponents were represented on the science committee, either directly or through an agency (i.e., MEIFW represented the interests of the EMFFG). A contractor, naïve to the 20-year history of the St. Croix debate, was hired to execute the study. The implementation plan included studies of juvenile and adult SMB, anadromous alewives, landlocked alewives, and other freshwater species, along with a regional meta-analysis of data from tournament lakes where bass–alewife interactions might occur. The project, as it was originally conceived, was too big to complete in one year. The questions addressed here were deemed to be the most important and most achievable questions at the time. The study results did resolve MEDMR and MEIFW differences over alewife impacts, but focusing on SMB only, and not addressing what happened in Spednic Lake 20 years earlier, hardened the stance of the EMFFG.

The expectations from a stakeholder/science process should match the scope of the project. Unrealistic expectations will negatively affect the outcome because participants will be less willing to accept the results (Germain et al. 2001; Marshall et

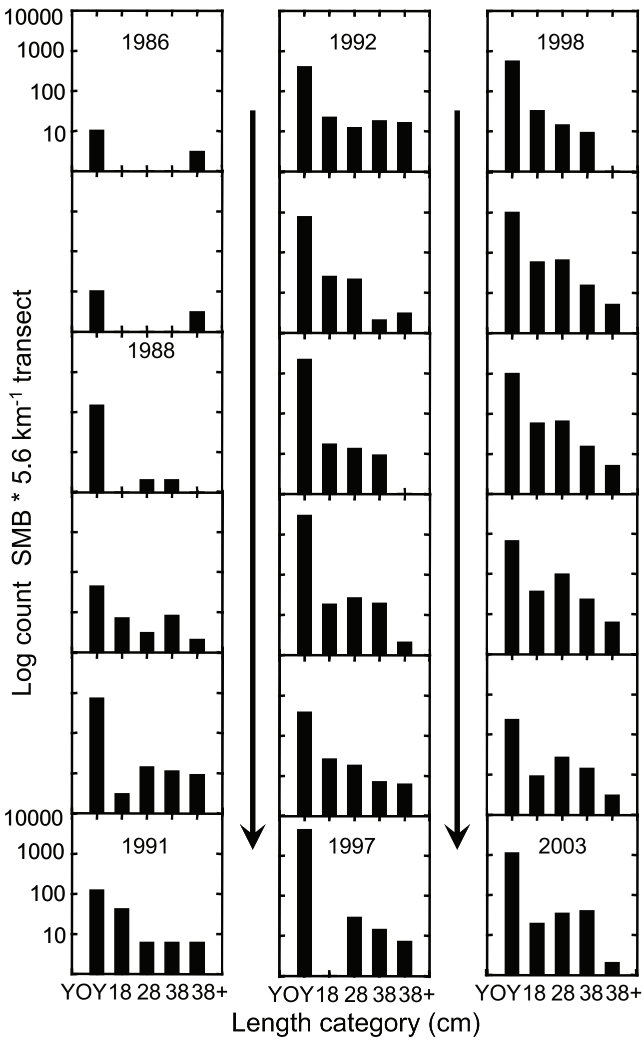

Figure 5.—Progressive time series of smallmouth bass size classes for Spednic Lake. Counts are averages per transect for at least three 5.6-km transects surveyed per year. Size-classes roughly correspond to alewife age-classes.

al. 2007). Despite what appeared to be an inclusive process, the EMFFG raised several more study objectives after data collection began in 2005. These included alewife–landlocked salmon interactions and whether alewives could negotiate the two lowest falls in the river. The EMFFG argued that these additional objectives warranted inclusion, but were ignored. Also, they claimed that the project sponsor, a conservation-focused nonprofit, biased the results towards justifying alewife reintroduction. The omitted research issues and bias claims were central to the EMFFG arguments to keep the fishways closed in 2008 when a second attempt to repeal the 1995 alewife exclusion legislation came before the Maine State Legislature. By attempting to change the terms of the St. Croix debate to include species in addition to SMB, the EMFFG may have been disingenuous in their participation. Conversely, the project organizers may have misinterpreted the EMFFG's interests in the process.

Investigation of Spednic Lake is an example of how scientific investigation can do as much to inflame a controversy as provide solutions. Even as of 2008, ~~Spendic~~ Lake was still the premiere example for alewife opponents concerning the harmful effects that alewives can have on sport fish. Year-class failures had been occurring for several years prior to 1984, when the scuba surveys began. Remediation was accomplished through stocking, alewife exclusion, new water control procedures, and changes in fishing regulations. For example, prior to 1988, water releases during bass spawning and rearing periods changed lake water levels by more than a meter in half the years between 1971 and 1986 (SCRPPT 1987), three times the threshold for negative impacts to SMB production (Neves 1975). Any of these could be credited with restoring the Spednic SMB population, but regional managers credited ~~rebuilding the SMB population to the exclusion of alewives alone~~ (Smith 1988, 1998). Spednic Lake continues to be a quandary: the EMFFG do not consider studies that occur outside of the lake to effectively address their alewife issues; there are no plans to reintroduce alewives to the lake (nor does the EMFFG want them), and therefore, it is impossible to test the EMFFG's hypotheses about alewife–SMB interactions, and not enough data are available from the 1970–1985 period to provide definitive answers. The stigma on alewives from the Spednic Lake SMB crash may prevent the two sides from reaching a mutually agreeable solution that would reintroduce alewives to the St. Croix River.

Conclusions

This project was an important step in bringing the St. Croix controversy closer to resolution. The results challenged the position of alewife opponents within Maine natural resource management agencies, removing some of the institutional barriers to reintroduction. Failing to find negative impacts in MEIFW's data were largely responsible for changing MEIFW's position. The process of negotiation around a common table also helped reduce the rhetoric and facilitate compromise between natural resource agencies. The project, however, had a much smaller effect on the surrounding politics. "An Act to Restore Diadromous Fish in the St. Croix River," as originally written, would have restored alewives to 52% or their 1987 spawning habitat if passed in 2008. Public hearings lasted 7 h. Maine Fishing Guides opposed the bill, citing the same reasons given in 2001. The Washington County, Maine legislative delegation (1of 35 senators, 5 of 153 representatives) aligned with the MEFFG before the public hearing. The Passamaquoddy Indian Nation, who have some jurisdiction over fisheries in the St. Croix River, also sided with the MEFFG. The final amended bill, brokered behind closed doors, opened the Woodland Flowage fishway in 2008, restoring alewives to 2.4% of their 1987 spawning habitat. The stipulation limiting further restoration was that the Grand Falls fishway remain closed until a study of the historical range of alewives could prove that alewives reached reservation lands above Grand Falls before Grand Falls Dam was built in 1913. Any further legislative action will be delayed until after a third round of studies is conducted on alewives in the St. Croix River.

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