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RESEARCH PAPER

The use (and misuse) of archaeological salmon data to infer historical abundance in North America with a focus on New England

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Abstract Information about historical animal or plant abundance often either explicitly or implicitly informs current conservation practice. If it can be shown that an organism was not historically abundant in a region, its conservation importance may be downgraded. In contrast to abundant archaeological support for historic importance of salmon in the Pacific Northwest, historic abundance of Atlantic salmon in New England has been called into question based on the rarity of salmon bones in archaeological sites. These data have been used to argue that the importance of salmon to the region has been exaggerated and that expensive restoration efforts in some rivers should be reconsidered. Here, we argue that lack of archaeological bone fragment abundance does not make a convincing case against historical Atlantic salmon abundance in New England for three primary reasons. First, salmon bones were rare or absent at sites that still have large salmon runs. Second, the lack of salmonid bones in general at archaeological sites suggests poor preservation and/or recovery of bone for these species relative to bones of other fishes. Third, given the presence of large numbers of non-salmonid anadromous fish in the site areas where people fished and deposited fish bones, power to detect salmon bones in studies to date may have been generally low. We present reliable historical accounts that help build a convincing case that salmon were historically abundant in New England rivers. We suggest that rarity of salmon bones in the existing archaeological data should not have unwarranted influence on present-day conservation decision-making in New England.

Keywords Archaeological · Calcined · Middens · Bone · Conservation decision making · Historical abundance · Pacific salmon · Atlantic salmon

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Introduction

In 1799 a local Connecticut newspaper covered the launch of the U. S. S. Connecticut upon the waters of the Connecticut River. The article contained the following verse…

> While shad and salmon feel the patriot glow,
> And throng in numerous shoals the watery way,
> And sturdy sturgeon from the depths below,
> Leap up her matchless beauty to survey (Barber 1836)

From early American times, New England's largest river has been associated with migratory fishes. While greatly reduced numbers of shad (*Alosa sapidissima*), sturgeon (*Acipenser oxyrhynchus, Acipenser brevirostrum*), and striped bass (*Morone saxatilis*) may still be found returning to the river's waters from the ocean, naturally occurring populations of Atlantic salmon (*Salmo salar;* hereafter salmon) disappeared from the river 200 years ago. This decline has been mirrored in other rivers throughout New England so that in contemporary times, only a few rivers in Maine have remnant populations. However, even these populations have declined to the point that they have been listed as endangered (United States et al. 2005). Modern efforts to restore salmon to the Connecticut and other rivers have been driven by the assumption that salmon were at one time abundant in these rivers. Without reliable quantification of salmon run sizes prior to European contact, there is a large degree of uncertainty surrounding this issue (Carlson 1992). Carlson challenged the assumption that salmon were historically abundant based on (1) bone data from archaeological sites and (2) a reinterpretation of historical accounts. Her interpretations have been widely discussed by those interested in New England salmon conservation and have the potential to influence management decisions. We are concerned that the conclusions drawn from Carlson's research will unduly influence salmon conservation throughout New England. The recent decision by the US Fish and Wildlife Service to discontinue funding Connecticut River salmon restoration illustrates the need to operate from an accurate assessment of historical abundances. In addition, the disappearance of salmon from New England rivers represents a warning to other regions that still maintain salmon runs and should not be dismissed based on potentially incorrect interpretations of archaeological data. Here we critically examine these challenges and argue that they do not provide a convincing argument on which to base conservation decisions. First, we examine arguments based on archaeological data from the region. Second, we provide additional reliable historical accounts that are consistent with historically abundant runs of salmon in the Connecticut River.

We note that in the context of this paper, the words abundant and abundance imply no inference on our part about absolute numbers of fish. Unless otherwise stated, these words are used to indicate that salmon were widely distributed throughout New England both along the length of the coast and along the length of individual river systems. Populations extended from Maine to the Connecticut River, and within individual rivers, they occurred in tributaries close to river mouths and those extending well inland. In addition, the numbers of fish this habitat produced were sufficient to provide historic communities with economically important fisheries that came under legal protection. However, reconstructing historical numbers of salmon in New England is not the intention of this paper.

This assessment of abundance is taken from historical documents that date from the mid-1600s to the late 1700s. Many of these are legal documents dealing with regulation of fisheries and can be considered reliable accounts. We also discuss archaeological data dating from 8,000 B. P. to the nineteenth century. We argue that though these archaeological data demonstrate that salmon were present prior to European contact, they are insufficient to form conclusions about abundance during this period.

Brief biology of salmon, shad, and alewives

Because we refer frequently to Atlantic salmon, shad, and alewives in this paper, a brief biology of each of these species follows.

Atlantic salmon (*S. salar*) display a wide degree of variation in terms of life history, having both anadromous populations and freshwater resident populations (Scott and Scott 1988). Anadromous Atlantic salmon typically migrate to the ocean after spending 1–3 years in natal streams (Klemetsen et al. 2003). In North America, salmon will spend between 1–3 years in the ocean before returning to their natal streams to spawn, though some European fish may remain at sea up to 5 or more years before spawning (Klemetsen et al. 2003; Chaput 2012). This contributes to a large degree of variation in size among adult salmon, ranging from 1.5 to >20 kg (Klemetsen et al. 2003; Chaput 2012). Adult salmon will generally return to natal streams with enough fidelity that different tributaries within a river system may have genetically discrete populations (Hansen and Quinn 1998). Though spawning occurs in October and November, salmon may return to the river beginning as early as April. This is especially true in more southern parts of the range where summer temperatures at river mouths may exceed tolerable levels for salmon (Scott and Scott 1988; Juanes et al. 2004). Though widely distributed on both sides of the North Atlantic, salmon are a cold water species whose southern range is limited by warm water temperatures (Elliott and Elliott 2010). In North America, the southern limit of their historic range is Connecticut coastal drainages, though remaining wild populations reach only to Maine (Parrish et al. 1998).

American shad (*A. sapidissima*) range along the Atlantic coast of North America from northern Florida to the St. Lawrence River in Canada, though they are most abundant between North Carolina and Connecticut (Facey et al. 1986; Limburg et al. 2003). Like Atlantic salmon, they undergo extensive ocean migrations, with fish from Florida to Maine migrating to summer feeding grounds in the Bay of Fundy (Leggett 1976; Limburg et al. 2003). As with salmon, shad spawn in freshwater natal rivers (Leggett 1976). Spawning does not appear to have a required distance above brackish water, although historical documents indicate that in some river systems, shad may have migrated over 1,000 km upstream (Leggett 1976; Limburg et al. 2003). The timing of the spawning migrations varies with latitude, beginning earlier in southern populations and lasting 2–3 months (Leggett 1976; Limburg et al. 2003). In New Brunswick and Quebec, migrations peak in May and June (Leggett 1976). Shad are North America's largest herring and adult females reach about 50 cm (Limburg et al. 2003).

Alewives (*Alosa pseudoharengus*) are related to shad, but are smaller, commonly reaching lengths of 25–30 cm (Scott and Scott 1988). Like shad, they are anadromous and will use river and stream corridors to access ponds for spawning, though they will also spawn within rivers and streams (Scott and Scott 1988; Mather et al. 2012). In New England, spawning may extend from late March to early June (Durbin et al. 1979). Individuals mature at age 3–6 (Mather et al. 2012). They are found in the Northwest Atlantic from Newfoundland to North Carolina (Scott and Scott 1988). The geographic distribution of alewives overlaps with the closely related blueback herring (*Alosa aestivalis*) which ranges further south (Loesch 1987). Because of their similar appearance and indiscriminate use by fisheries, the two species are commonly referred to collectively as river herring (Loesch 1987).

Argument against historical salmon abundance in New England

Unlike the Pacific Northwest, where the historical abundance and importance of salmon (*Oncorhynchus* spp.) has not been questioned (Table 1), a number of questions have been raised about the historical importance of salmon in the Connecticut and other New England rivers. Carlson reviewed records of the remains of fish bones at 75 archaeological sites throughout the northeast region, including parts of New York and Canada. She found little evidence for the presence of salmon (Carlson 1992). Out of all of these sites, only two New England sites yielded definitive identifications of Atlantic salmon bone fragments. One fragment came from Penobscot Bay in Maine (Fig. 1), and one came from Strawberry Bank in Portsmouth, N.H. Carlson examined records from one site located in the Connecticut River Basin. This site at Turners Falls, Massachusetts (Fig. 1) contained only the remains of shad (*A. sapidissima*) and alewife (*A. pseudoharengus*) (Carlson 1992). Carlson also argued that the literature accounts of abundant salmon in New England rivers were largely exaggerated second hand accounts (Carlson 1988). She argued that salmon, though present, had never been abundant in New England rivers, particularly those at the southern limit of the historical range, such as the Connecticut River (Carlson 1992). In addition, Carlson (1992) hypothesized that salmon did not begin to colonize New England waters in substantial numbers until a relatively recent period of climatic cooling known as the Little Ice Age (AD 1550–1800).

Carlson (1992) argued that statements by modern biologists that salmon runs in New England once rivaled those of the Pacific Northwest are erroneous. On this point, we agree. Modern estimates of salmon numbers for Pacific and Atlantic salmon indicate that Pacific salmon are much more abundant. Pacific salmon include a group of five different species that run into rivers at different times of the year whereas Atlantic salmon consist of only one species that runs in spring and summer (Robinson et al. 2009). Among the Pacific salmon, certain species may enter rivers in massive numbers. For example, runs of sockeye salmon (*Oncorhynchus nerka*) in the Fraser River alone have been recorded in numbers as high as 23.6 million individuals (Rensel et al. 2010). This number for one species in one river exceeds the entire global

Table 1 A brief overview of archaeological salmon remains in the Pacific Northwest

Salmon remains in Pacific Northwest archaeological sites
The harvesting and storage of salmon has long been recognized as the economic underpinning of aboriginal cultures in the Pacific Northwest. Vast quantities of salmon are considered the resource base that allowed for the development of complex societies demonstrating evidence of ascribed status, elaborate art, permanent dwellings, large villages, and land ownership (Matson 1992). Unlike New England, the remains of salmon bones are a ubiquitous feature of archaeological sites in the Pacific Northwest. The same questioning of the historical importance of salmon has therefore never occurred in the Pacific Northwest
The Pacific Northwest has an extensive history of archaeological study. Early excavations in the 1930s revealed fish bones, but predated comparative collections of fish bones needed for the purpose of species identification (Carlson 1998). By the 1960s and 70s, faunal analysis of sites to determine diet, subsistence, and cultural adaptation became an important part of the regions archaeological studies (Carlson 1998). Butler and Campbell (2004) reviewed 13 sites with faunal assemblages predating 7,000 BP and so many studies of a later date that the authors considered this to be more published data than could be reviewed in detail in a single manuscript. They focused on 38 coastal and 33 interior sites from the South-Central Northwest Coast (surrounding Puget Sound) and the Northern Columbia Plateau (central Washington) subregions. These sites yielded a total of 220,000 vertebrate specimens. Salmonid bones were present at every coastal site and were the most abundant fish at most sites. Bone preservation was not as good in the interior sites, but salmonid bones made up the most abundant fish genus in all but 6 of 51 assemblages at these 33 sites. Though their analysis was done at the family level, those bones that could be identified to species were predominantly *Oncorhynchus tshawytscha* (chinook salmon). Some Pacific Northwest sites have turned up massive numbers of salmon vertebrae. At the Dalles site on the Columbia River, Cressman et al. (1960) removed in excess of 125,000 salmon vertebrae
Quality of bone preservation varies with site. Coastal Pacific Northwest shell middens generally have very good bone preservation due to their acid neutralizing effects (Cannon 2000). Calcined bone is bone that has been chemically altered through burning at the high temperatures found in maintained fires, a process that renders the bone more resistant to degradation (Maymon and Bolian 1992). As a result, calcined bone is often associated with poor preservation conditions. There are some cases where calcined bone was found in Pacific Northwest sites. At the Namu site on the central coast of British Columbia one of the earliest deposits, dated to 7620 BP, is noted to produce a small number of fish remains, including calcined salmon vertebrae. These remains were recovered after being washed through 1/16 inch mesh screen (Cannon 1996). Fine screen sifting has been used at many Pacific Northwest sites. In Butler and Campbell's 2004 review, most of the selected sites included fine screen samples of 1/8 inch or less
Fine screen sifting and water screening techniques can be important for proper recovery of fish bone. At the Namu site, water screening was noted to significantly increase the visibility and recovery of faunal remains, particularly smaller remains such as fish (Cannon 1991). In Japan, as in New England, historical writings exist referencing abundant salmon. Also as in New England, scarce evidence for salmon remains in archaeological sites led many to conclude that salmon had not played as important a role as suggested by these writings (Matsui 1996). More recent work with fine sifting and water screening techniques has turned up numerous salmon remains, supporting the historical accounts (Matsui 1996). In New England, 1/4 inch screens have generally been used in archaeological excavations (Carlson 1992). Some more recent investigations using fine screening have turned up additional salmon remains (Robinson et al. 2009)

run of wild Atlantic salmon returning to rivers (Naylor et al. 2005; Chaput 2012). Abundance of adult size anadromous Atlantic salmon is currently less than 10 million fish annually (Chaput 2012). Harvests for Columbia River anadromous salmonids (including steelhead, *Oncorhynchus mykiss*) have declined dramatically in recent decades, however, historically have been measured in tens of millions of tons (Levin and Schiewe 2001). For this reason it seems unrealistic to expect the archaeological importance of salmon in the Northeast to rival that in the Pacific Northwest. However, this does not mean that Atlantic salmon were any less abundant in New England than other parts of the species range.

Salmon bones absent where salmon present

We find the bone fragment data an unconvincing argument against historically abundant Atlantic salmon for three primary reasons. First, salmon bones were rare or absent at sites that still have large salmon runs. Of two sites located on the Miramichi River in New Brunswick, Canada, only one bone fragment was definitively identified as salmon (Carlson 1992). The Miramichi River currently has the largest run of Atlantic salmon in eastern North America (Department of Fisheries and Oceans Canada 2010). Run numbers have declined in recent years, but data indicate that some years see returns of over 100,000

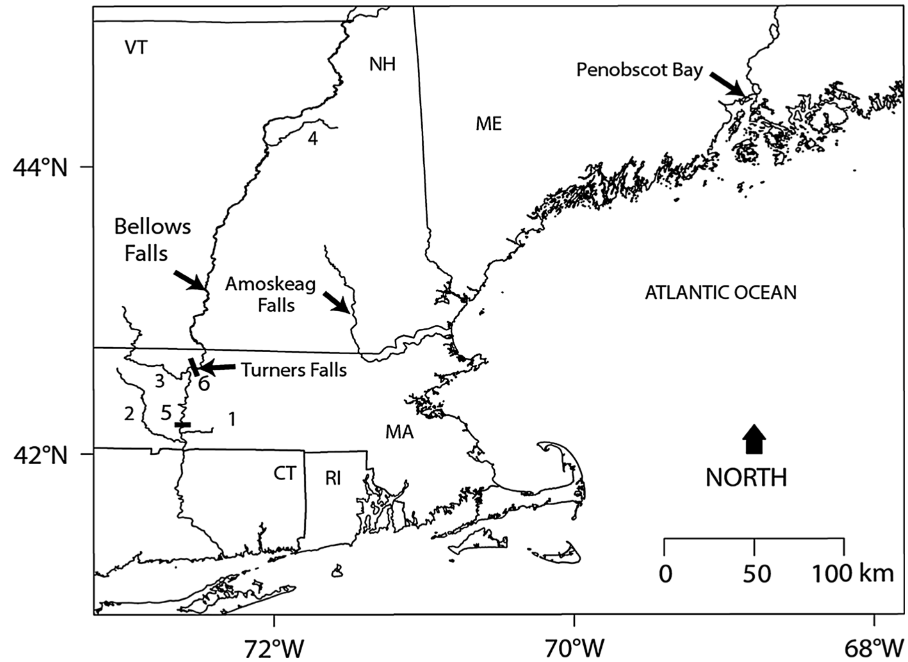

Fig. 1 Connecticut River tributaries with references to salmon populations in historical literature include (*1*) Chicopee River (*2*) Westfield River (*3*) Deerfield River and (*4*) Ammonoosuc River. Bellows Falls appears as the upstream limit to shad migration, while Atlantic salmon are noted to pass upstream. The first dams on the mainstem of the Connecticut River went up at (*5*) Holyoke, MA and (*6*) Turners Falls, MA. Three locations of the archaeological sites reviewed by Carlson include Turners Falls, MA, Amoskeag Falls, NH, and Penobscot Bay, ME, of which, only one site in Penobscot Bay yielded salmon bones

individuals (Chaput 1995). There is no reason to doubt that this river had large historical runs as well. For a system with such a large number of salmon to yield only one positively identified salmon bone suggests there are alternative explanations for the lack of salmon bone fragments in the middens (waste heaps). Other sites from Nova Scotia and New Brunswick, regions in which salmon runs still occur, did not contain any salmon bones (Carlson 1992).

Low general recovery of salmonid bones

Second, the lack of salmonid bones in general at these sites suggests either poor preservation or poor recovery of bone for these species relative to other fishes. For example, out of all sites located within New England, only one site was found to contain the remains of brook trout (*Salvelinus fontinalis*) (Carlson 1992). Brook trout are currently common throughout New England, despite widespread degradation of habitat (Hudy et al. 2008). Brook trout require clean cold water and are often harvested for food. Brook trout appear to be common throughout the state of Maine (Hudy et al. 2005). Yet, at 38 sites from throughout Maine, not one bone fragment was positively identified as brook trout (Carlson 1992). Even if bone fragments identified only to the family salmonidae (trout, salmon, charr) were brook trout, using Carlson's reasoning, we could conclude that brook trout were not historically abundant in New England. However, it is a reasonable assumption that brook trout were historically abundant and it seems likely that they would have appeared in the diet of the region's early inhabitants. We suggest that the lack of observed brook trout bone fragments should not be considered evidence that brook trout occurred historically at low abundance throughout New England. Further, plausible alternative explanations for the bone fragment data exist and must be ruled out before Carlson's interpretations are used to guide conservation decisions in New England rivers. These include species-specific decomposition rates in acidic soils, alternative deposition sites for some fish species, improper recovery techniques, or study sites biased towards marine based fisheries. For example, Carlson states that 'bone does not preserve well in inland sites due to the acidic soils of New England' (Carlson 1992), but does not provide or refer to data on species-specific degradation rates.

In fact, interior New England archaeological sites suffer from very poor preservation of faunal assemblages, which allows for limited interpretation of results (Robinson et al. 2009). At most such sites, only heavily calcined bones have survived the effects of acidic soils and fragmentation (Sanger 2003). Calcination occurs chiefly when bone is burned at high temperatures in maintained fires, resulting in chemical alteration (Maymon and Bolian 1992). Calcination renders bone more susceptible to fragmentation as a result of pressure and most calcined bone recovered from archaeological sites is smaller than unburned bone (Stiner et al. 1995). The types of salmon bones that are recovered from NewEngland archaeological sites are what would be expected under poor preservation conditions. Differential bone densities of salmon skeletal elements suggest that under intensive degradative processes, density mediated destruction should result in a prevalence of vertebral elements (Butler and Chatters 1994). In New England sites, salmon remains appear to be almost exclusively vertebrae (Carlson 1992; Spiess et al. 2001; Robinson et al. 2009). Some references maintain that skeletons of salmonids are more friable than those of other teleosts, which has contributed to poor recovery of salmonid remains at many archaeological sites (Casteel 1976; Matsui 1996; Cannon 2000). Though Robinson et al. (2009) agree that salmonid skeletal remains in interior New England sites are limited to small, fragmented pieces, they note that these fragments preserve as well as other fish bones. They maintain that poor recovery is due rather to the use of improper recovery and identification methods (Robinson et al. 2009).

The studies examined in Carlson's (1992) review generally employed 1/4 inch screen to sift samples. 1/4 inch screen size appears to be adequate for recovering salmon remains when they are large, uncalcined, and mostly complete. However, in situations where remains are largely small fragments of calcined bone, smaller screen sizes are required (Matsui 1996; Partlow 2006). More recent studies using finer mesh screens have turned up additional salmon remains in New England sites. There are currently seven sites in Maine with documented occurrences of archaeological salmon (Robinson et al. 2009). Robinson et al. (2009) analyzed a 0.025 m^3 soil sample from the Sharrow site on the Piscataquis River that had previously yielded 2 salmon vertebrae from the entire site (Spiess 1992). After processing this material through 1/16th inch screen they recovered 3,737 fragments of fish bone. Robinson et al. (2009) identified 123 of these fragments, noting at least 6 species. Though American eel (*Anguilla rostrata*) was the most abundantly identified fish, Robinson et al. (2009) recovered 21 fragments of large salmonid vertebrae from this sample. They cite another example of calcined bone that yielded no salmon fragments using 1/4 inch screen, 15 fragments with 1/8th inch screen, and 50 fragments with 1/16th inch screen (Robinson et al. 2009). Two salmon vertebrae dating from 4,500 to 3,800 B.P. have been recovered from the Turner Farm site in Penobscot Bay while the large salmonid remains taken from the Sharrow site on the Piscataquis River date to the Middle Archaic Period (6,000 B.P.–7,500 B.P.) (Petersen et al. 1991; Spiess et al. 2001).

Additional non-salmonid anadromous fishes

Third, localized relative abundance of the anadromous species present in the Connecticut River at the time of bone fragment deposition creates sampling problems that must be addressed. Numerical dominance of anadromous shad relative to Atlantic salmon leads to the expectation that salmon bones should be rare relative to shad bones. Inadequate sample sizes of bone fragments have low power to detect relatively rare salmon bones. In 1992, 721,000 shad were lifted over the dam at Holyoke on the Connecticut (Fig. 1). More shad than this likely entered the river, because they are able to spawn at locations downstream from the dam (Freeman 2003). It is likely that the historical numbers were many times larger than this as contemporary populations have access to only a fraction of their historic spawning habitat. Currently, only the Connecticut River mainstem below Holyoke remains barrier free, and despite the presence of fish passage facilities, dams still limit passage for shad (Zimmerman et al. 2010; Marschall et al. 2011; Haro and Castro-Santos 2012). Potentially, even a substantial salmon run of 40,000 individuals would be small relative to the numbers of shad. The Turners Falls midden site on the Connecticut River contained only the remains of shad and alewives, but we certainly cannot conclude that no other species were present. Other diadromous species such as American eel (*A. rostrata*), as well as resident species such as sturgeon (*A. brevirostrum*), maintain extant populations in the Connecticut River. That none of these species show up in the fish remains at this site suggests that this bone data should not be used to preclude the presence of salmon.

Hypothesis of Little Ice Age population expansion

Based on some literary evidence for the presence of salmon in historical times and the general lack of evidence for salmon at archaeological sites, Carlson (1992) developed a hypothesis that a period of climatic cooling from 1550 to 1800 (the Little Ice Age) resulted in expansion of New England salmon numbers. Though this is an interesting conjecture, we believe that the archaeological evidence is not sufficient to either support or reject this hypothesis. We base this belief largely on the preceding arguments that suggest the data reviewed by Carlson has flaws that cannot be ignored. However, another problem with this hypothesis is that several of the sites reviewed by Carlson date to the Little Ice Age, yet none of these sites contained salmon remains. These sites include the Fort Pentagoet site in Penobscot Bay, a French Fort that dates to 1635–1674. The Damariscove Island site off the coast of Maine dates to the seventeenth century and was an English fishing station. The Simons House located on Cape Cod is a Native American domestic site dating from the late seventeenth through the nineteenth centuries (Carlson 1992). We believe it is inconsistent to draw conclusions about changes in abundance through time based on these data when all sites, regardless of when they date to, are similar in regards to their general lack of salmon remains.

Given the questions raised above, should we base conservation decisions on the data currently in hand? We argue that additional archaeological data would be required to address the uncertainties we raise. However, conservation decisions will be made in the absence of such data. In the remainder of this paper, we turn to reliable historical accounts not mentioned by Carlson that build a convincing case that salmon were historically abundant (at least dating back to the mid-1600s) in the Connecticut River prior to construction of mainstem dams, and absent thereafter. We chose to focus on accounts relating to one river system, the Connecticut River, because it represents the southern limit of the historic range of salmon in New England. Because salmon are a cold-water species, establishing the historical importance of salmon at this extreme southern limit of their range strengthens the argument that they were well distributed throughout other regions of New England. A summary of the historical accounts we use appears in Table 2.

Table 2 Accounts of salmon in the Connecticut River and its tributaries from the historical literature. Decade represents the decade that the material is referencing, if known. Some sources such as the New Hampshire Gazetteer, are compilations for which this information is not available. Entries appear as near as possible in chronological order from top to bottom

Summary of account	Source	Pub year	Decade
Fishing licenses granted by town of Springfield, MA	Springfield: 1636–1886	1888	1670
Law preserving land for public salmon fishing	Court of Massachusetts	1905	1740
Account of salmon as economically important fish	History of Connecticut	1781	1770
Account of salmon passing Bellows Falls, NH	New Hampshire Gazetteer	1817	NA
Law protecting salmon in Westfield River, MA	Court of Massachusetts	1783	1780
Fishing banned at mouth of Westfield River, MA	Court of Massachusetts	1786	1780
Fishing limitations in Connecticut River	Court of Massachusetts	1788	1780
Massachusetts requests other states to protect salmon	Court of Massachusetts	1790	1790
Law preserving salmon in Ammonoosuc River, NH	State Laws of New Hampshire	1797	1790
Salmon said to have deserted Connecticut River	Connecticut and Rhode Island Gazetteer	1819	NA
Northampton, MA citizens request dam removal	Hampshire Gazette	1844	1840

Historical presence of salmon in the Connecticut River

Samuel Peters, writing in the eighteenth century, includes the following passage regarding the importance of migratory fishes to the early economy of Connecticut…

> The shad, bass, and salmon, more than half support the province. The sturgeon is made no use of. From the number of seans employed to catch the fish passing up to the lakes, one might be led to suppose the whole must be stopped; yet, in six months time they return to the sea with such multitudes of young ones as fill Connecticut river for many days, and no finite being can number them (Peters 1782).

According to Peters more than half of the province of Connecticut's income derived from migratory fishes, including salmon. Though this passage doesn't explicitly state the proportion of salmon to other fishes, the author does go on to say, 'The salmon, large and small, are exported both pickled and dried,' (Peters 1782) indicating that they were plentiful enough to be an export of Connecticut.

Salmon are referred to in historic documents indicating that several tributaries of the Connecticut River had economically important fisheries as well. In 1677, Springfield, MA voted to grant a license to several persons to set up fishing operations on the Chicopee River (Fig. 1). The document fixed prices for both salmon and shad (Green and Springfield (Mass.) 1888). State laws passed in New Hampshire in 1786 included laws aimed at preventing the destruction of salmon in the Ammonoosuc River (Fig. 1) within a certain distance of the mouth of the Connecticut River because the salmon 'in said river might be of great use to the public, if properly preserved' (New Hampshire and United States 1797). It is worth noting that the Ammonoosuc River, flowing out of the White Mountains, enters the Connecticut River 362 km upstream from where it empties into Long Island Sound (Jones 2008).

In these upper reaches of the Connecticut system, salmon would have been particularly important to local communities because shad were absent. The Ammonoosuc River is approximately 145 river km north of Bellows Falls (Fig. 1), which appears in the literature as the northern limit of upstream migration for shad in the Connecticut River. Consistent with the biology of shad and salmon, this is noted as the stretch of river that separates salmon and shad…

> It thence passes between Walpole and the lower part of Rockingham, where the great falls commence, now known by the appellation of Bellows' Falls… Notwithstanding the violence of the current here, the salmon pass up the falls and are taken many miles above, but the shad do not pass beyond the falls (Merrill and Merrill 1817).

The records of the General Court of the Province, and later Commonwealth, of Massachusetts have many laws that point to the importance of salmon to the early residents. In the early 1740s, an act was passed to preserve an area surrounding what is modern day Shelburne Falls on the Deerfield River (Fig. 1) for fishing, stating that…

> The Salmon fishing falls in Deerfield River So Called be reserved to the use of the publick with Twenty Acres of Land Around them for Conveniency of fishing (General Court of Massachusetts 1905).

The Westfield River (Fig. 1), at the time also known as the Agawam River, also appears in the laws as a river with important salmon runs. In 1781 a committee was sent by the General Court to West Springfield and Westfield, at the cost of West Springfield, with the intent of inspecting the status of the fishery on the river. While the committee was in the process of conducting the inspection, a previous act "to prevent the destruction of Salmon and other fish in Agawam or Westfield River" was temporarily suspended (General Court of Massachusetts 1781, reprinted 1890). However, the court determined that the fishery did indeed need protecting. In 1783 an act appears in the laws extending protection "of salmon and other fish in Agawam or Westfield river" through 1785 (General Court of Massachusetts 1781, reprinted 1890). Again in 1786, a similar act appears…

> No person or persons be allowed to catch any Salmon, Shad, or Alewives with seines, nets, pots, or in any other way, in any part of said River, within two miles of the entrance thereof into Connecticut River, nor in Connecticut River, within half a mile South, or forty rods

North of the Mouth (General Court of Massachusetts 1786, reprinted 1893).

In conclusion, these historic documents, many of them legal records related to fishing regulation and conservation of fish populations, span a period of over 100 years from the mid 1600s to late 1700s. They refer to salmon populations in tributaries and the main stem of the Connecticut River. These populations span a distance of several hundred km upstream from the river mouth, demonstrating that salmon were widespread in the system, and sufficiently important to the local economies that the fishery was regulated. Based on these records, it seems reasonable to assume that salmon were originally present in most suitable tributaries of the Connecticut.

Decline and disappearance in the Connecticut River

Building the case for decline of salmon in the Connecticut River helps establish that they were once abundant. Dams began to go up on the Connecticut tributaries in the 1600s, cutting off access to spawning grounds (Gonter 2010). By the mid 1700s, major spawning tributaries such as the Salmon and Farmington Rivers in Connecticut were dammed. By the late 1700s, most tributaries in the lower portion of the watershed were dammed and returning salmon originated from rivers in the upper, less populated portion of the watershed (CRASC 1998).

These dams did not go up without protest from local people who desired the salmon runs to be unhindered. In the years prior to 1789, selectmen from the town of Winchester, NH presented petitions for sluices to be opened on dams on the Ashuelot River to allow passage of salmon. An act was passed requiring sluices to be made. The town of Keene, NH in 1790 "chose Capt. Richardson Lockhart Willard and Eli Metcalf a Committee to inspect the several milldams across Ashawolet River, agreeably to a law of this state" (Griffin et al. 1904).

By this time however, the many dams and multitudes of fishing operations on the river had taken an observable toll on the fishery. In 1788, the General Court of Massachusetts passed "An Act to Prevent the Destruction of Salmon and Shad, in Connecticut River." The act stated…

> Whereas it has been represented to this Court, in sundry petitions from the inhabitants of several towns in the County of Hampshire, that by reason of the great number of seines and nets, which are constantly used during the fishing season, in taking Salmon and Shad in Connecticut river, they have decreased for a number of years past, and that there is great danger the fishery in said river will be destroyed (General Court of Massachusetts 1788, reprinted 1894).

The act then goes on to set limits on the number of days fishing is allowed, closures of certain sections of the river, and limits on the type of equipment that can be used in catching the fish. However, it is important to note that it does state that there was a "great number of seines and nets, which are constantly used during the fishing season, in taking Salmon and Shad", indicating enough fish to attract an abundance of fishing operations.

The decline of the fishery concerned the General Court enough that it appealed to the Governor. The court…

> Resolved that his Exellency the Govournor be and he hereby is requested to send Copies of the Act lately passed by the Legislature of the Commonwealth for the preservation of Fish in Connecticutt River, to the Supreme Executive Power of the States of New Hampshire and Vermont and to request the said States to adopt similar measures for the preservation of Fish in the said River—The State of Connecticut having adopted similar measures for the same purpose (General Court of Massachusetts 1790, reprinted 1895).

However, the momentum in favor of industry was strong and Massachusetts passed an act in 1795 that was intended to encourage the development of mills and their associated dams. The act stated…

> Whereas the erection and support of mills to accommodate the inhabitants of the several parts of the state, ought not to be discouraged by many doubts and disputes and some special provisions are found necessary relative to flowing adjacent lands… (Massachusetts and Thomas 1799)

In 1798 a dam on the mainstem of the Connecticut was erected in Turners Falls, MA, rendering any laws in

New Hampshire and Vermont irrelevant (Greenberg 2010). A previous dam had been erected at South Hadley around 1795 (the existing structure is from a later rebuild), but it appears the dam at Turners Falls was considered a greater impediment to upstream migration (Judd and Boltwood 1863). With upstream spawning grounds cut off by mainstem dams, and downstream tributaries dammed, salmon populations declined dramatically. By 1819, one writer was able to state that although salmon were still taken from the Willimantic River, about 30 km east of the Connecticut, they had "wholly deserted Connecticut river" (Pease and Niles 1819).

Local residents of the area petitioned to have these dams removed. An article in the 1844 Hampshire Gazette outlines a petition to have the dam at South Hadley Falls removed. Written within living memory of the salmon runs, the author writes…

> Time was when salmon and shad were to be found on the table of every poor man in the valley through its whole length, with a surplus for exportation. Now, salmon have entirely deserted these waters and while below the falls, shad are taken in considerable abundance, above them, scarcely enough can be caught to pay for the tackle, boats, and labor required to run a seine. For all practical and beneficial purposes, these fisheries are destroyed (Northampton Town Meeting 1844).

However, dams were to remain on the Connecticut. The Connecticut River is currently the most dammed river of its size in the U.S. and contains 17 dams on the river mainstem and over 1,000 in the river basin (Foster 1991; Marschall et al. 2011).

Conclusion

The doubts raised by Carlson's (1992) archaeological research have served to fuel bitter criticisms of modern efforts to restore salmon to the Connecticut and other rivers (Meyer 2009). In this paper we have focused on establishing three primary points; (1) The archaeological record can be used to establish the presence of salmon in New England up to 6,000 years ago. (2) The archaeological record cannot be used to draw conclusions about salmon abundance in pre-colonial times. The poor recovery of bone in general for the region, and of salmonid bone in particular, suggests that statements about abundance based on such data should be made with caution. We argue that elimination of alternative explanations for the bone fragment data is necessary if we are to rely on interpretations drawn from these data. (3) Salmon were abundant in the Connecticut River at least from the mid-1600s until they declined concurrently with increased fishing pressure and increasing dam construction. Salmon were completely eliminated from the Connecticut River within 20 years of construction of the first mainstem dam.

What remains unclear is how abundant salmon were in the Connecticut and other New England rivers in pre-colonial times (before the mid-1600s). Future archaeological data based on methodology appropriate for small bone fragments might help to clarify this issue (Robinson et al. 2009). Carlson (1992) hypothesized that New England populations increased in abundance during the Little Ice Age (1550–1800). This hypothesis is intriguing but needs to be tested. We note that even archaeological sites included in Carlson's (1992) analysis that date to the Little Ice Age did not reveal salmon bones. Thus, her hypothesis remains unsubstantiated at this point. If there were support for her hypothesis, the appropriate baseline upon which we should base conservation decisions becomes a relevant concern. In our opinion, there are two options. The first option is that we can assume that salmon were historically abundant before and through colonial times and therefore use a state of high abundance as the historical baseline. Alternatively, the second option is that we can assume that the signal of historical abundance was due to a transient affect of the Little Ice Age and therefore a state of low abundance is the historical baseline. In the absence of pre-colonial abundance information, we suggest that caution points to the first option as the most appropriate for conservation efforts. Therefore, we recommend that a state of high abundance be used as the historical New England salmon baseline until further data are available.

We do not intend this paper as a comment on the likelihood of success of Connecticut River salmon restoration. Rather we are concerned with basing conservation decisions on potential misinterpretations of limited archaeological data. The U.S. Fish and Wildlife Service has already decided to discontinue funding the Connecticut and Merrimack River efforts, however, we are concerned that these interpretations could be misused in river systems elsewhere in New England such as with ongoing conservation efforts in Maine. Finally, the story of the decline of salmon in New England rivers serves as a warning for regions that still maintain such resources and should not be dismissed based on such interpretations.

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