Cobbosseecontee Watershed, Maine. Fish History, Water Quality, Hydrology and Aquatic Restoration Overview

-- WORKING DRAFT 2/1/2012 --

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for Kennebec Reborn, Inc.
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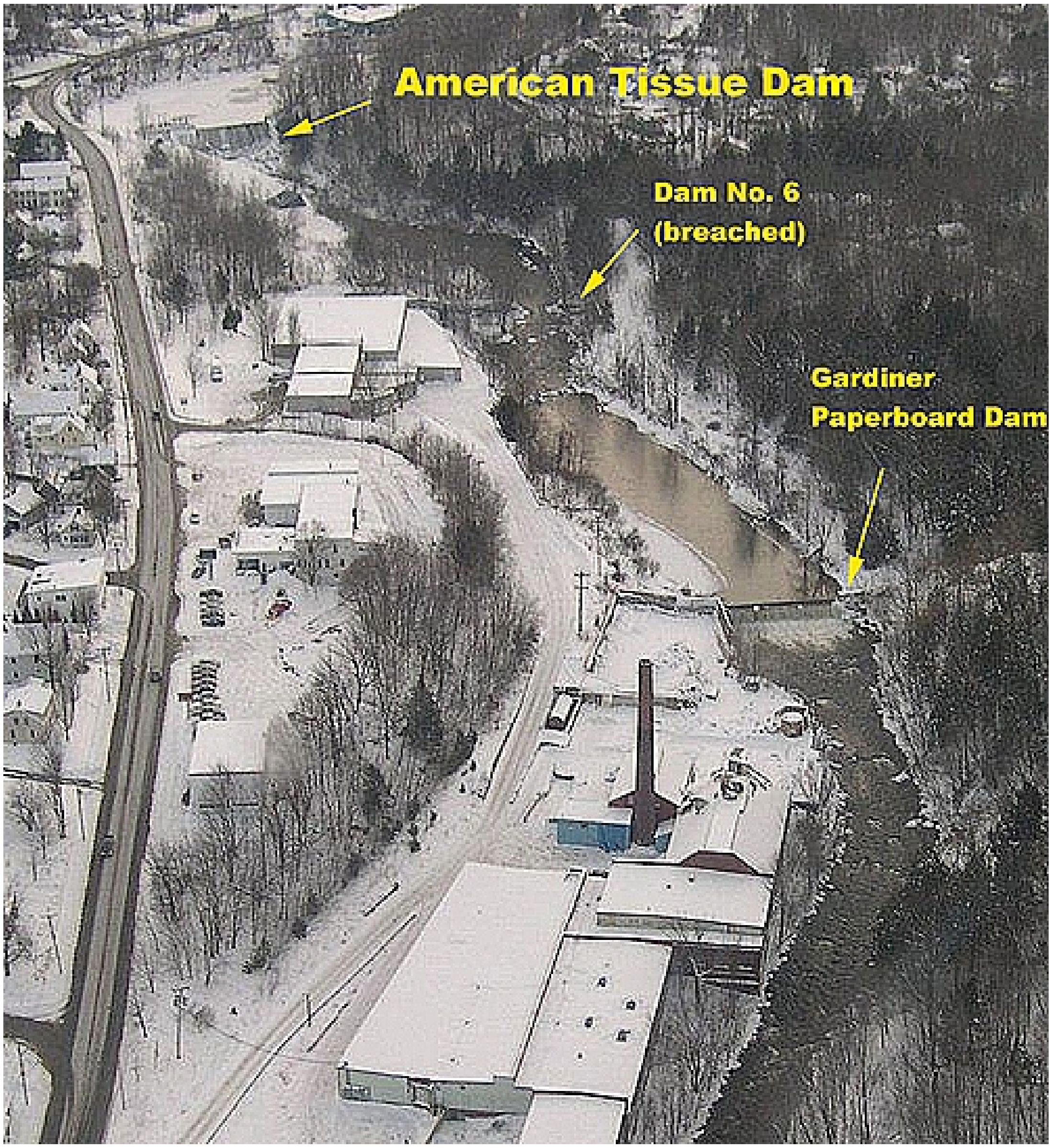
Executive Summary:

Dammed at its head of tide in 1761, Cobbosseecontee Stream is the largest coastal watershed in Maine which still remains impassable to native migratory fish. A tributary of upper Merrymeeting Bay, the Cobbosseecontee watershed includes the communities of Gardiner, West Gardiner, Litchfield, Richmond, Winthrop, Manchester, Monmouth, Readfield and Hallowell. It contains 20.3 square miles of lakes and ponds, the largest being Cobbosseecontee (Gumscook), Maranacook and Annabessacook.

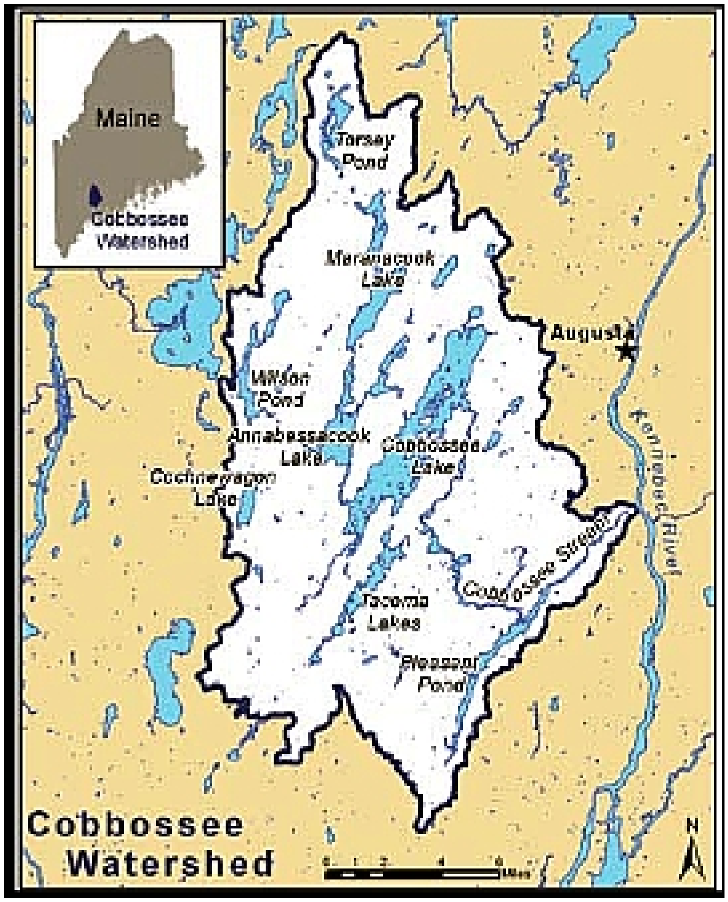
Working from 1998-2004, a consortium of local citizens, citizen conservation groups, and state and federal agencies secured $125,000 in funding for the necessary engineering studies, legal permits and construction contracts to breach and remove the first dam on the watershed, the 180-year-old Gardiner Paperboard dam in downtown Gardiner, Maine.[1] After the hired contractor failed to perform the dam removal project in autumn 2004, the dam and adjoining property were subsequently sold to several entities, the most recent of which has declined interest in re-inititiating the dam removal project. Options available for securing passage for native fish on Cobbosseecontee Stream include cooperative public/private efforts by willing dam owners to provide fish passage; invocation of the State of Maine's fishway law; and use of the U.S. Endangered Species Act (ESA) for endangered anadromous Atlantic salmon (*Salmo salar*) native to the watershed.

In 2011, Kennebec Reborn, Inc., a non-profit Maine corporation, asked Douglas H. Watts, the project leader for the 2004 Gardiner Paperboard dam removal project, to compile for all interested parties an historic and scientific baseline of information regarding the condition of the aquatic resources of the watershed. This report relies on publicly available documents from a wide variety of sources dating from the mid 1700s to the present. Included also are photographs and direct observations collected by Mr. Watts from Cobbosseecontee Stream from 1994 to present. The purpose of this Report is to provide all stakeholders with a comprehensive overview of the natural and cultural history of the watershed to guide and inform decisions regarding its future.

1 2004 dam removal consortium members included Maine Dept. of Marine Resources, Maine Atlantic Salmon Authority, U.S. Fish & Wildlife Service, National Marine Fisheries Service, USFWS/NMFS Gulf of Maine Project, Atlantic Salmon Federation, Trout Unlimited, Newark Paper Group, Inc. Regulatory entities supporting and approving the project included Maine Dept. of Environmental Protection, U.S. Army Corps of Engineers, City of Gardiner, Maine, State of Maine Historic Preservation Commission.



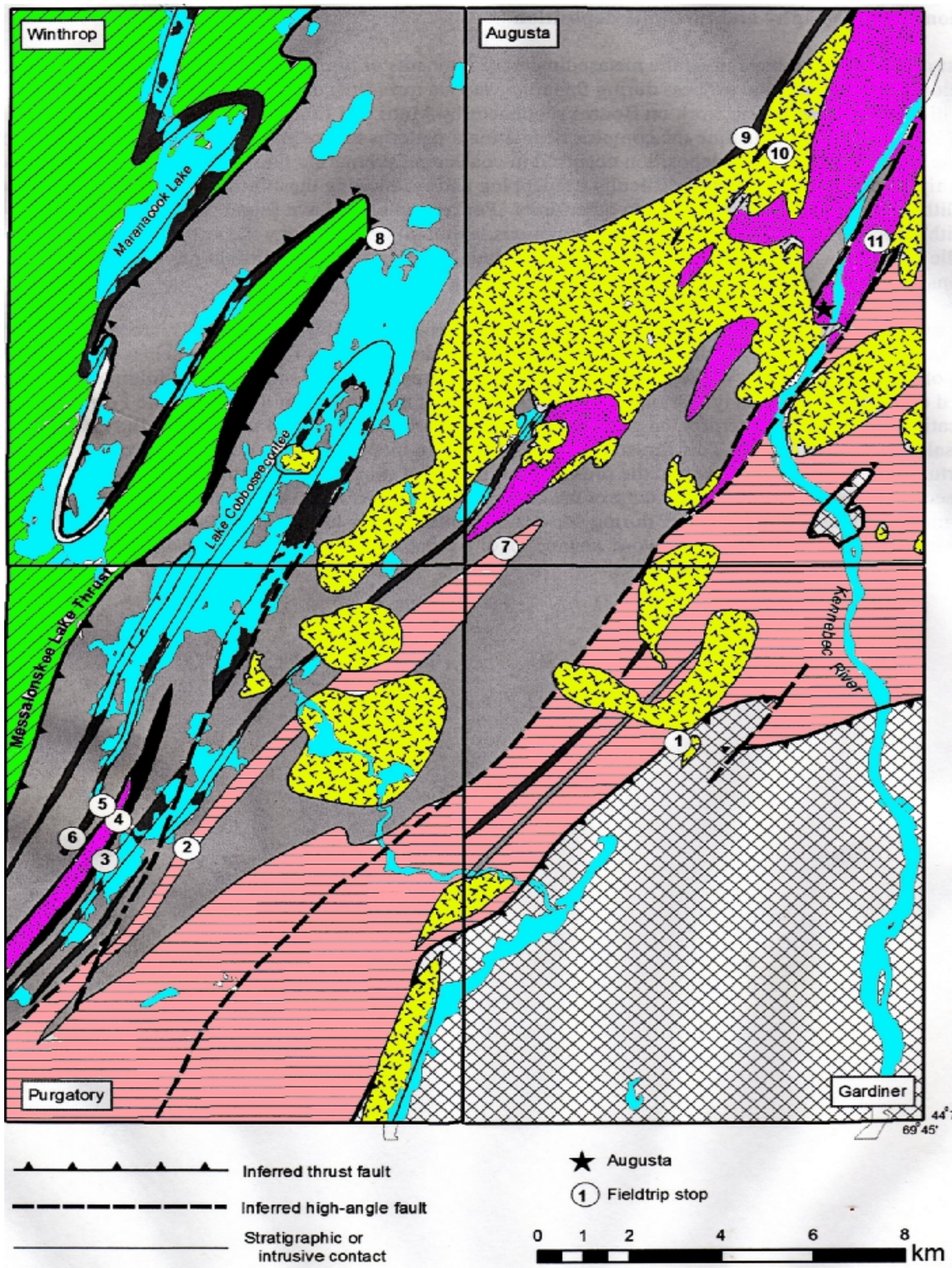
This December 2011 image shows Cobbosseecontee Stream in downtown Gardiner, Maine approx. 1 mile above its confluence with the Kennebec River. There used to be four stone dams below the Gardiner Paperboard Dam, called Dam No. 1, No. 2, No. 3 and No. 4. These dams breached in the early 20th century and are now reduced to stone abutments along the river channel. The Gardiner Paperboard Dam (Dam No. 5) is now the lowermost dam on Cobbosseecontee Stream. The next dam is the American Tissue Dam, the only hydro-electric dam on the stream. About 1/4 mile above the American Tissue Dam (around the corner in the upper part of the photo) is the New Mills Dam, which is non-hydro and owned by the City of Gardiner and the towns of Litchfield, Richmond and West Gardiner. Photo by Ed Friedman, Point of View Helicopter Service, Bowdoinham, Maine.



Cobbosseecontee Watershed Description

The Cobbosseecontee watershed is approx. 217 square miles in area. It contains three ponds greater than 1,000 acres, 16 greater than 100 acres, and 24 greater than 10 acres (Table 1). Approx. 10 percent of the watershed is occupied by lakes and ponds.

The principal river in the watershed is Cobbosseecontee Stream, which begins at the outlet of Cobbosseecontee Lake in Manchester, flows for approx. 20 miles in a "U" shape and enters the Kennebec River at Gardiner, Maine. The topography of the watershed is mostly rolling, low elevation hills and valleys, with the highest relief in the northwestern section (Readfield, Monmouth), and the lowest relief in the southeastern section (West Gardiner, Richmond). Water flow is generally from northwest to southeast, except for the southernmost portion, where water flows abruptly northeast from a topographical low near the outlet of Pleasant Pond to a short and abrupt drop in downtown Gardiner. The configuration of surface lakes, ponds and streams in the watershed suggest a young, glacially deranged system controlled by a northeasterly trending Paleozoic bedrock fabric.



A bedrock map overlay of the Cobbosseecontee watershed shows a close correlation between lake and pond location and the northeasterly trend of Paleozoic thrust faults and folded beds of highly erodable limestone within the late Silurian Central Maine Sequence. Map key: green = Sangerville formation, red = Vassalboro formation, grey = Waterville formation, purple = Mayflower Hill formation, cross-hatch = Nehumkeag Pond formation, black = sulfidic and/or impure marble sections of Waterville Formation. Yellow areas are Devonian to Permian granitic plutons. Map adapted from Marvinney, West, Grover and Berry *in* NEIGC (2010).

Table I: Major Lakes and Ponds of the Cobbosseecontee Watershed

Lake	Acreage	Mean/Max Depth (ft.)
Cobbosseecontee Lake	5,238 acres	37/100
Maranacook Lake	1,844 acres	30/128
Annabessacook Lake	1,415 acres	21/49
Pleasant Pond	800 acres	10/26
Torsey Pond	679 acres	15/45
Woodbury Pond	513 acres	21/62
Cochnewagon Lake	394 acres	22/28
Dexter/Berry Ponds	288 acres	13/25
Sand Pond	279 acres	31/82
Upper Narrows Pond	239 acres	25/54
Lower Narrows Pond	223 acres	31/106
Carlton Pond	223 acres	25/57
Hutchinson Pond	105 acres	10/24
Jimmie Pond	99 acres	34/75
Little Cobbossee	91 acres	17/33
Horseshoe Pond	74 acres	10/10
Total	13,092 acres	

Source: Maine DEP at www.lakesofmaine.org

Primary bedrock types in the watershed are Silurian marine sand and mud sediments that were deeply buried, intensely folded and metamorphosed into granofels, schists and impure marble during the Devonian. Several medium to large intrusions of fine-grained Devonian granite ('Hallowell Granite') form the eastern edge of the watershed. All bedrock younger than Devonian has been scoured away. The broad and flat topographic low in Litchfield at the "Horseshoe Pond" section of Cobbosseecontee Stream is the result of glacial scouring of a unique nepheline syenite pluton that can only be observed via glacial erratics, ie. 'Litchfieldite,' scattered nearby (Marvinney et al. 2010; West and Ellenberger 2010; Barker 1965; Bayley 1892).

The topography and controlling hydrologic features of the Cobbosseecontee watershed represent the long-term erosional flattening of the Paleozoic bedrock of Central Maine into an extensive peneplain which was deeply incised by the channel of the Kennebec River much later. This topography is diagnostic of the lower Kennebec River valley from Waterville to Richmond, where tributary streams have little or no gradient until 1-2 miles before they reach the Kennebec and then suddenly plunge 100 feet or more down to the river in the span of a mile, e.g. Town Farm Brook, Sidney; Goff Brook, Sidney; Seven Mile Stream, Vassalboro; Riggs Brook, Augusta; Fisher Brook, Augusta; Whitney Brook, Augusta; Bond Brook, Augusta; Vaughan Brook, Hallowell; Worromontogus Stream, Randolph; Eastern River, Pittston.

Hydrology: Natural v. Present Day

The Cobbosseecontee watershed is today deranged in both a geological and anthropomorphic sense. In the geologic sense the watershed is dominated by numerous natural lakes and ponds connected by short sections of streams; in the anthropomorphic sense those few sections of natural stream between the lakes and ponds are now almost wholly dammed and impounded. The natural lakes and ponds are elevated above their natural height by dams; the stream thoroughfares connecting them are impounded and flooded; and the natural wetlands around the lakes and streams are unnaturally elevated. While there is just as much *water* in the Cobbossee watershed today compared to the 18th century, the aquatic species which depend on this water cannot get from one part of the watershed to the other when they need to. This is called watershed disconnectivity.

Watershed connectivity is a key parameter of watershed health. Cobbosseecontee is a type example of a watershed which was naturally highly interconnected and has in historic times become extremely fragmented. Watershed fragmentation, even at minor (100 yard) scales, can have profound impacts on aquatic ecology, species diversity and richness. Fragmentation in the Cobbosseecontee watershed, due to 19th century and ongoing anthropogenic impacts, occurs at the small, medium, large and regional scales. The Cobbossee watershed is completely cut-off from communication with the Kennebec River; and each successively smaller segment of the watershed is cut-off from communication with the segment above and below.

In 2009, the Maine State Planning Office, Maine Stream Connectivity Work Group, stated:

> "Centuries of land and water resource development in Maine, while supporting historical economic and social goals, have impaired chemical, physical, and biological linkages within and among Maine's estuaries, streams, lakes, and other aquatic systems. A notable source of this impairment is the loss of in-stream, or longitudinal connectivity. Construction of dams and road crossings that were not designed with ecological needs in

> mind limit connectivity by blocking access to habitat that is critical to the survival of Atlantic salmon, alewife, native brook trout, freshwater mussels and other organisms requiring unimpeded movements throughout watersheds during some or all of their life cycle. Along with ecological impacts, impaired connectivity also has considerable economic and social costs, including the loss of income and jobs historically supported by thriving commercial and recreational fisheries. Likewise, the population-suppressing effects of lost connectivity on certain riverine species has led to increasingly restrictive, costly and complex environmental regulatory processes created to protect these imperiled organisms from further harm." [2]

Cobbosseecontee Stream drops approx. 125 vertical feet in less than two miles in downtown Gardiner to its mouth with the Kennebec.[3] The 18 miles of stream above Gardiner is flat, wide and sinuous with large expanses of open, seasonally wetted meadow. The late 1800s construction of the New Mills Dam in Gardiner raised the natural stream level at the dam by approx. 11 feet and the impounding effect of the New Mills dam is observable for more than 12 miles upstream to a set of rapids below the Collins Mills Dam in West Gardiner. This indicates that the natural gradient of the stream from Collins Mills to downtown Gardiner, ie about 80 percent of the stream's length, was originally less than one foot per mile.

Aerial photographs near and above the "Horseshoe Pond" segment of the stream in Litchfield and West Gardiner show the submerged contours of the original channel several feet below the contemporary water surface. The stream's natural topographic character is quite similar to that of the Sebasticook River between Newport and Benton Falls, ie. long and nearly still 'deadwater' areas separated by short reaches of 1-2 foot vertical drops over glacially formed lag boulder deposits. This topography is confirmed by 1700s and 1800s historic records, which contain no mention of any mill dam sites or privileges on the stream between Collins Mills and New Mills.

The two most substantial artificial alterations to the hydrology of the Cobbossecontee watershed occurred in the late 1800s with the construction of the New Mills Dam in Gardiner and the outlet dam at Cobbosseecontee Lake. According to an October 28, 1882 article in the *Kennebec Reporter*, the Cobbosseecontee Stream dam owners formed in 1879 an organization called the "Gardiner Water Power Company" to secure greater water storage and reliable stream flows at the various ponds and lakes that feed into Cobbosseecontee Stream. The article states:

2 Sourced at: http://www.maine.gov/spo/coastal/coastal-habitat-restoration.htm

3 Historic records show that Cobbossee Stream had a large cove at its confluence with the Kennebec with tidal influence extending up to the Rt. 201 bridge (much like what still exists at Togus Stream in Randolph). In the early 20th century, the cove was in-filled with demolition debris creating the Gardiner municipal parking lot on the south side of the stream and the Hannaford supermarket parking lot on the north side of the stream. The channel of Cobbosseecontee Stream below the Rt. 201 bridge is artificial and made primarily of in-filled demolition debris and glacial till.

"Until within three years, the power has been unreliable in the summer months. The mills had to shut down, more or less of the time in July and August, on account of a water shortage. The saw mills were run by turns. The day and night were divided into sections of so many hours, each, and one of these was assigned to each mill. This sort of thing has been obviated by the company's purchases of increased flowage rights and raising the reservoir dam. The company purchased a few weeks ago, at an expense of $12,000 the Whitman mill privilege, on Anabessacook Pond, in Winthrop, for the sake of flowage right. The company now owns seven ponds for storage uses as follows: Pleasant Pond, three Purgatory ponds, Great Pond, Anabessacook Pond and Horseshoe Pond. There is an unfailing supply of water, every dry season in the year."

Table III: Cobbossee Watershed
Selected Lake and Impoundment Elevations (present day)

Maranacook Lake	211 msl
Tacoma Lakes	175 msl
Jimmie Pond	173 msl
Narrows Ponds	172 msl
Annabessacook Lake	171 msl
Hutchinson Pond	169 msl
Cobbosseecontee Lake	166 msl
Collins Mills impoundment	142 msl
Horseshoe/Pleasant Pond	135 msl
Amer. Tissue dam impoundment	125 msl
Confluence w/Kennebec River	tidal

Water Quality

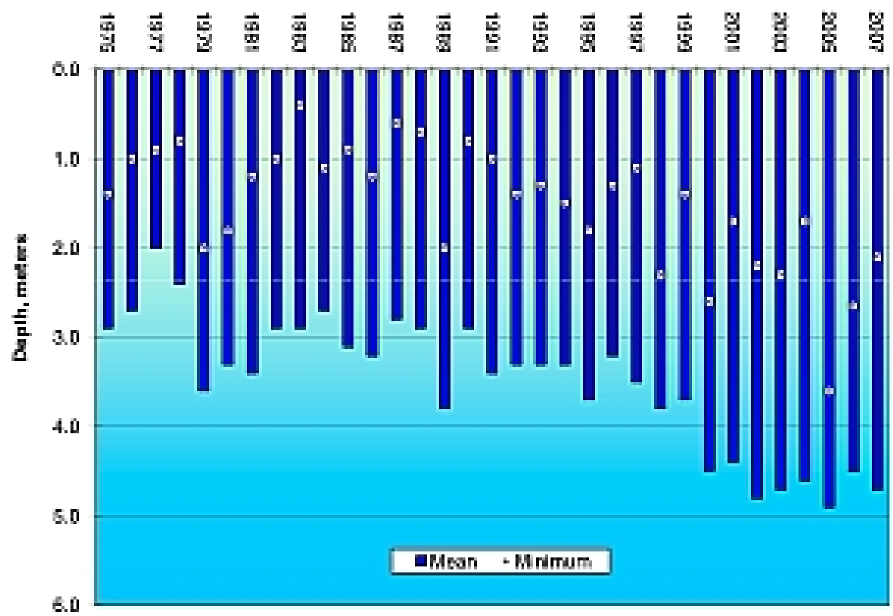
In his 1925 *History of Winthrop*, Everett Stackpole reviewed the late 1700s efforts by earliest citizens of the Town of Winthrop to secure fish passage for alewives at the Gardiner dams, and wrote: "Had the people foreseen the sawdust and chemicals now poured annually into the running waters of Maine, they might not have contested so long for fishways."

Eighty years later, William Monagle wrote:

"Restoring a severely degraded lake, particularly after decades of abuse, requires significant resources, dedication and cooperation among all stakeholders, and, of course patience and perseverance. It has been said, in fact, that it may take as much time to rehabilitate a lake impacted by human related activities as it took to degrade it in the first place. That certainly seems to have been the case with 5,238 acre Cobbosseecontee Lake ... The first documented report of the severe algae blooms in lakes of the

Cobbosseecontee Stream watershed occurred in 1939 in Annabessacook Lake, which had been on the receiving end of municipal and industrial discharges since the early 1900s. The algal blooms were so severe that a local resident reminisced that one could visit the shore of Annabessacook Lake on a calm morning in the 1950s, write one's name in the algal surface scum, and return that afternoon and find it still legible."

Dennis (1982) and Monagle (2007) review the history of severe water pollution in the Cobbosseecontee watershed during the 20th century, primarily from the long-term direct discharge of municipal and industrial pollutants into Annabessacook Lake and heavy phosphorus and nitrogen inputs from cow manure spread at nearby farms. These historic discharges also intensely affected Cobbosseecontee Lake and Pleasant Pond, which lie directly downstream from Annabessacook. The legislature's creation of the Cobbossee Watershed District in 1971, the only district of its kind in Maine, was intended to identify and eliminate historic and ongoing water quality threats throughout the watershed.



Secchi disk readings for Annabessacook Lake, Winthrop, 1975-2007.
Data from Cobbossee Watershed District (Monagle 2007).

With the cessation of direct discharge of pollutants to the watershed in the 1970s, the CWD's focus shifted to controlling non-point source pollution inputs emanating from area farms and lakefront residential development. Long-term monitoring of water quality by the CWD has shown substantial improvement from 1960s conditions at Annabessacook Lake. Recent (2009) CWD data shows Cobbosseecontee and Anabessacook Lakes and Cochnewagon, Wilson, Woodbury and Torsey Ponds remain profoundly debilitated by past and ongoing cultural pollution, as shown below:

Table IV:
Late Summer Thermocline and Dissolved Oxygen Depths at Cobbosseecontee Watershed Lakes and Ponds

Lake	Mean/Max Depth	Depth of DO Depletion	Depth of Thermocline*	Deepwater Habitat**
Maranacook Lake	30/128	100	~25	+75 ft.
Lower Narrows Pond	31/106	75	~20	+55 ft.
Jimmie Pond	34/75	60	~12	+48 ft.
Sand Pond	31/82	50-55	~20	+30 ft.
Upper Narrows Pond	25/54	30	~18	+12 ft.
Carlton Pond	25/57	25-27	~15	+10 ft.
Cochnewagon Lake	22/28	20-25	~20	0
Annabessacook Lake	21/49	15-20	~27	0
Cobbosseecontee Lake	37/100	25-30	~30	0
Wilson Pond	23/42	20	~20	0
Woodbury Pond	21/62	18-20	~18	0
Torsey Pond	15/45	18-20	~18	0

Notes: * Depth at thermocline is where water temperature profiles show a sharp (~5 F) change. ** Deepwater habitat is defined as below the late summer thermocline and above the depth of dissolved oxygen depletion. A score of zero means the depth of dissolved oxygen depletion is near, at or above the observed thermocline in the same profile. *Source*: CWD, Maine VLMP (2011).

The above table shows a clear distinction in the lakes and ponds in the Cobbosseecontee watershed. The first group (Maranacook, Sand, Upper and Lower Narrows, Jimmie and Carlton Ponds) have high to moderate late summer dissolved oxygen levels at and below the thermocline. The second group are noticeably devoid of dissolved oxygen below the late summer thermocline. In Group Two lakes the correlation between depth of thermocline and the onset of anoxic conditions are so close they can be used as a proxy for one another.

Of note is that the depth of the late summer thermocline of the 12 lakes roughly correlates with surface acreage, with the more sheltered and smaller headwater ponds having a shallower thermocline than the larger, more wind-swept lakes. In contrast, no positive correlation exists between late summer thermocline depth and mean and maximum pond depth.

These data are disturbing since they show that half of the 12 major lakes and ponds in the Cobbosseee watershed are virtually anoxic below the late summer thermocline.

This difference is most profoundly seen at Maranacook and Cobbosseecontee Lakes. They are the two largest lakes in the watershed and are about 100 feet deep (Cobb max. = 100 ft.; Maranacook max. = 128 feet). Both have similar late summer thermocline depths: 25-30 feet. Late summer oxygen depletion at Maranacook does not start until 100 ft, ie. 75 feet *below* the late summer thermocline. At Cobbosseecontee Lake, DO levels drop to near zero *at* the thermocline; in late summer the entire lake volume below 30 feet deep is virtually anoxic. The severe DO depletions at Annabessacook and Cobbossee Lakes are consistent with their history of recent (20th century) pollution. However, an equally troubling situation is seen at three ponds which lack such a documented historic period of severe cultural pollution, ie. Torsey Pond, Woodbury Pond and Wilson Pond. In all three, DO levels consistently drop to near zero just below the late summer thermocline, just as they do at Annabessacook and Cobboseecontee.

Woodbury Pond is a unique outlier in that it has a similar mean, max. and late summer thermocline depth as its next door neighbor, Sand Pond: (62 vs. 82 feet max. depth; 21 vs. 31 ft. mean depth). But at Woodbury Pond dissolved oxygen depletion begins almost exactly at the late summer thermocline (~20 feet), while at Sand Pond dissolved oxygen levels are quite high (above 5 ppm) all the way down to 55 feet, ie. 35 feet below its late summer thermocline.

Differences between Jimmie (Jamies) Pond in Hallowell and Carlton Pond in East Winthrop are interesting because both ponds have been highly protected public water supplies for much of the 20th century. Carlton Pond has twice the surface acreage as Jimmy Pond (223 v. 99 acres); is shallower by mean and max. depths (25/35 vs. 57/75); and both have very shallow (12-15 ft.) late summer thermoclines. But at Jimmie Pond the hypolimnion is well-oxygenated in late summer almost down to its bottom (~60 feet) while at Carlton Pond the hypolimnion becomes oxygen depleted at 27 feet.

Cochnewagon Pond in Monmouth is perhaps the most useful index lake to assess the impacts of cultural eutrophication in the Cobbossee watershed. The mean and maximum depths at Cochnewagon are nearly identical (24 ft. vs. 28 feet). It is 'flat-bottomed' -- like a baking tin. At 28 feet max. depth and 394 surface acres, Cochnewagon is the shallowest of the natural ponds in the Cobbossee watershed larger than 100 acres. The next shallowest ponds are Torsey Pond at 45 feet deep and Annabessacook at 49 feet. But we know from Atkins & Foster (1867) that despite its very shallow depth, Cochnewagon hosted a native population of rainbow smelt which spawned in its tributaries. Like Annabessacook and Cobbosseecontee, Cochnewagon has been subjected to severe pollution in the 20th century. Cochnewagon and Annabessacook are the only two ponds in the watershed which have been treated with alum (aluminum sulphate) to sequester anthropogenic phosphorus in their bottom sediments. Despite an alum treatment to the lake in 1986, CWD data show a steady decline in mean water clarity since 1992, with 2005-2010 Secchi clarity approx. 2 meters less than in the early 1990s and the period 2005-2009 showing the lowest clarity measurements as yet recorded.

Water quality data at depth in the Cobbossee watershed lakes and ponds show a disturbing division between lakes which have dissolved oxygen below their thermoclines in late summer and those which have none. This difference suggests a cultural cause, since there is no natural reason why adjacent and interconnected ponds of similar depth and size (ie. Maranacook and Cobbossee; Sand Pond and Woodbury Pond) should have such wildly divergent DO levels below their respective late summer thermoclines.

Water Flow, Level and Quantity

Under Maine Private & Special Laws, Ch. 95, sects. 2 and 14 (1971), the Cobbossee Watershed District is authorized to establish a water level policy at dams in the Cobbosseee watershed upstream from, and including, the New Mills Dam in Gardiner. The CWD water level policy was made effective on Jan. 1, 1981 and amended July 17, 1983. It establishes seasonal maximum and minimum water levels for eight dams during spring, summer, fall and winter based on elevations obtained from the 1929 National Geodetic Vertical datum. The four level periods are Spring (March 1 to May 31); Summer (June 1 to Sept. 14); Autumn (Sept. 15 to Oct. 13); Winter (Nov. 1 to Feb. 29). Spring maximum is based on the 10-year USGS flood elevation. Allowable 12-month water level variation from seasonal min. to max. is generally 2 - 3 feet.

The CWD water level policy contains no criteria for minimum flows in streams affected by dams in the watershed, in part because its targets are based on seasonal impoundment water level targets, ie. the amount of water above the dam, not the amount flowing over or through it into the stream below. The only in-stream flow regulation in the watershed exists at the American Tissue hydroelectric project in downtown Gardiner, which has a minimum instantaneous flow requirement of 51 cfs or inflow to the dam, whichever is less. Up until the early 2000s, dramatic reductions in streamflow in the free-flowing section of the stream in Gardiner were seasonally commonplace (Lewis Flagg, MDMR, pers. comm. 1997), and caused the dessication of the eggs of native Atlantic salmon, white sucker and blueback herring. The legally required minimum flow at the American Tissue Dam is approx. 50 percent lower than the USFWS recommended aquatic base flow of 0.5 cfs per square mile of watershed area for Northeast U.S. watersheds. At Gardiner, this ABF flow would be approx. 100 cfs.

Due to the size of its lake, the Cobbossee Lake outlet dam is the primary vehicle used by CWD to manage flows in the watershed, esp. in Cobbosseecontee Stream and Pleasant Pond. Abrupt reductions in outflow at the Outlet Dam are common in the late spring, when the CWD policy shifts from a 'spring' to 'summer' outflow mode. If the transition from spring and summer modes is done quickly, in-stream flows can drop by 50 percent or more in several days, resulting in the sudden de-watering of free-flowing areas downstream. At present the CWD has no explicit written policy calling for the gradual down-ramping of outlet flow/releases to allow aquatic life to make a safe transition to lower stream flows.

Table II: Dams managed by CWD for water level control

Dam	Waterbodies affected	Owner
Torsey Pond dam	Torsey Pond	Torsey Pond Assoc.
Wilson Pond dam	Berry, Dexter, Wilson Ponds	Tex-Tech Industries
Cochnewagon dam	Cochnewagon Pond	Town of Monmouth
Maranacook Lake dam	Maranacook Lake	Carleton Woolen Mills
Martin Hovey dam	Annabessacook Lake	Town of Monmouth
Cobbossee Outlet dam	Cobbossee & Little Cobbossee Lakes	Town of Manchester
Tacoma Lakes dams	Jimmy, Buker, Sand, Woodbury, Little Purgatory Ponds	Tacoma Lakes Imp. Assoc.
New Mills dam	Pleasant Pond, Cobbossee Stream	Four-Town Consortium

Aboriginal (Native) Fish Species Assemblage

The native fish species assemblage of the Cobbosseecontee and adjacent watersheds is the end result of the Wisconsinan glaciation and de-glaciation. Not only did the most recent (and previous) glacial epochs shape the drainage patterns of the region by scouring out lakes and re-arranging the direction of stream and river systems, they prevented the long-term survival of fish and aquatic fauna in these waters.

During de-glaciation, the continental crust of Maine was depressed well below modern day sea level. As the ice sheet retreated northward, the ocean met it at the glacial margin, resulting in the Atlantic Ocean intruding into Maine up to 420 feet above contemporary sea level, ie. to Bingham, Maine in the upper Kennebec River valley. The marine intrusion maxima occurred approx. 13,000 B.P. and is marked by extensive marine clay and silt deposits (Presumpscot Formation) and deltaic features along the state's major river valleys. Emergence of the modern coastline occurred by 11,500 B.P followed by sharp drop in relative sea level as crustal rebound increased faster than eustatic sea level rise to a low-stand at approx. 10,500 B.P. where sea-level was as much as 60 m below current levels. After 9,000 B.P, sea-level climbed again to a 'present' stand by approx. 5-6,000 B.P. and the coast of Maine started to approximate what it resembles today.

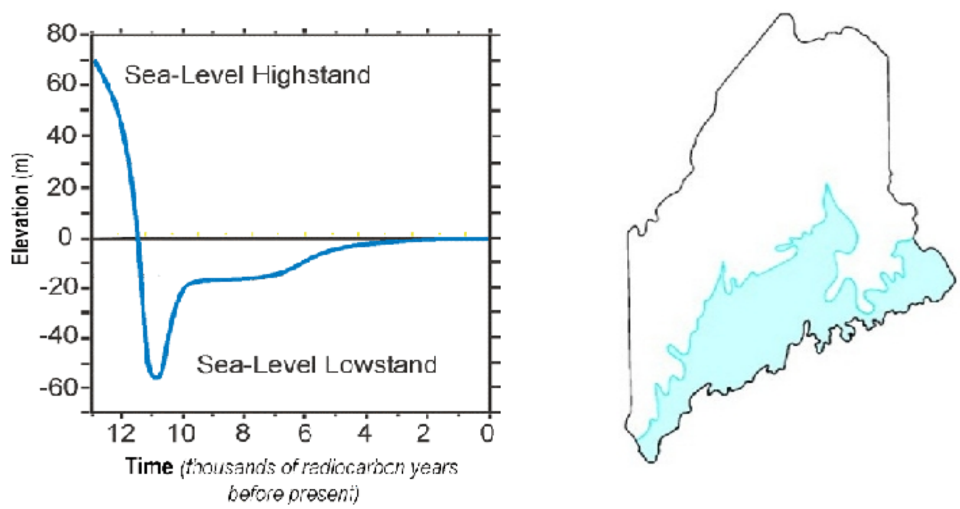


Figure on left shows post-glacial sea level change in Maine relative to current sea level. Figure on right shows maximum extent of post-glacial marine introgression in Maine, approx. 13,000 B.P. Source: Maine Geological Survey, modified from Dickson (2005).

This glacial activity destroyed previous existing freshwater fauna in Maine and forced the repatriation of newly exposed, deglaciated inland waters by whatever fish species could gain access to them and survive in them. The first fish to inhabit these cold waters were marine, followed by the diadromous species, ie. those that could tolerate freshwater and saline conditions. As marine coves and embayments were uplifted and became freshwater, the truly marine species had to leave, leaving those fish species which could seasonally or wholly adapt to freshwater conditions.

One puzzle is how truly freshwater species, such as the ubiquitous native white sucker, colonized the inland waters of Maine so extensively. At sea-level lowstand, the large shallow bars of Georges and Browns Banks limited the flow of oceanic waters into the Gulf of Maine, resulting in a lower salinity nearshore coastline than today. Bourque and Weddle (1995) give this as an explanation for the common presence of oysters (*Crassostrea virginica*) along the Maine coast in the mid-Holocene and their later restriction to a few sheltered, low salinity estuaries, particularly the upper Damariscotta River in Newcastle, where they continued to be abundant until 1,000 B.P. Under this model, the warmer and less saline nearshore environment allowed a narrow but usable entryway for those native fish species which are intolerant to marine conditions. Archaeological evidence for this Early to Mid Archaic period is rare due in part to the fact that the coastline of Maine at the time was many miles further south of its present location and coastal habitation sites along the 'old' Maine coast are now submerged by 30 feet or more of water (ie. Lazy Gut Island, Deer Isle; Bourque and Weddle 1995).

The earliest glimpse of Maine's inland fish assemblage comes from the 7,000-6,500 B.P. Sharrow habitation site at the confluence of the Piscataquis and Sebec Rivers in Milo, Maine in the middle Penobscot River watershed. This deeply stratified site (3 m in depth) revealed burned bones of American eel, anadromous Atlantic salmon, brook trout, alewife, hornpout and minnow species (*Cyprinidae* sp.). This site correlates with a stick fish weir at the inlet of Sebasticook Lake in Newport used to catch American eels, with the oldest extant weir sticks yielding radio-carbon dates of 5,800 B.P. (Robinson et al. 2009). As sea-level rose toward modern day levels after 5,000 B.P., non-submerged coastal habitation sites become much more common and their faunal remains reveal a fairly modern-looking fish assemblage, including cod, sculpin, pollock, striped bass, flounder, halibut, sturgeon, Atlantic salmon, alewives, tomcod and American shad (Robinson et al. 2009; Spiess and Lewis 2001).

Faunal remains of hornpout and freshwater minnow and chub species at the 7,000 B.P. Sharrow site and in the native fish species assemblage in the Belgrade Lakes suggests that colonization of inland central Maine watersheds by non-diadromous and marine relict fish occurred early in Maine's post-glacial history, at least no later than 7,000 B.P. This is because the Belgrade Lakes are blocked to all in-migration of fish from the Kennebec River by an impassable 40-foot waterfall at Cascades Gorge in Oakland near the outlet of Messalonskee Lake yet contain nearly identical native fresh water assemblages as nearby lakes that were historically accessible via the ocean to fish. Unless this waterfall at Cascades Gorge developed very recently, the only date at which purely freshwater fish (ie. white sucker, hornpout) could gain access to the Belgrade Lakes was not long *after* the marine inundation of the Maine coast around 13,000 B.P. yet *before* the marine lowstand at 10,500 B.P. A similar pattern exists in the Androscoggin River at Great Falls in Lewiston and in the Kennebec at Caratunk Falls in Solon, which in historic times have only been passable by Atlantic salmon and American eel, but whose lakes and ponds above these falls contain the traditional native suite of freshwater fish common to the lakes and waters below these falls.[4]

This post-glacial history is shown in archaeological faunal records and in the review of native central Maine fish by Atkins and Foster (1867), both of which show a depauperate freshwater fish assemblage in central Maine compared with regions south of the Wisconsinan glacial maxima at Long Island, New York.[5] While the tribe of diadromous fish native to central Maine is fairly extensive, the number of purely freshwater native species is much more sparse:

4 The presence of native resident fish above naturally inaccessible falls in central Maine suggests several competing hypotheses: they gained access soon after marine inundation *or* these steep, impassable bedrock drops were so in-filled by glacially transported debris that they were passable and only later were scoured down to bedrock *or* there existed cross-watershed connections in earlier millenia which bypassed these falls but have now become infilled.

5 This depauperate fish assemblage is mirrored in the very low native species diversity of freshwater mussels, *Unionidae*, in Maine and New England compared with areas below the Wisconsinan glacial maxima. *See*, e.g.: Cummings, K.S and C.A. Meyer. 1992. Freshwater Mussels of the Midwest. Illinois Natural History Survey, Manual Five. Champaign, Ilinois. The dominance of diadromous fish in Maine is further shown in that many of the freshwater mussel species native to Maine require diadromous fish species as larval hosts; mussel species diversity in Maine falls off sharply in watersheds inaccessible to diadromous fish; and diversity is highest in watersheds were diadromous fish were historically abundant (ie. lower Kennebec, Sebasticook, St. Georges, lower Penobscot).

Table III:
Degree of Diadromy in Fish Species Native to Central Maine

Species	Always Diadromous	Mostly Diadromous	Mostly Freshwater	Always Freshwater	Marine Relict
American eel	Y				
Atlantic sturgeon	Y				
Shortnosed sturgeon	Y				
American shad	Y				
Blueback herring	Y				
Striped bass	Y				
Tomcod	Y				
Mummichog	Y				
Alewife	Y				
Sea Lamprey	Y				
Atlantic salmon		Y			
Rainbow smelt		Y			
Ninespine stickleback		Y			
Brook trout			Y		
White perch			Y		
Yellow perch			Y		
Banded killifish			Y		
White sucker				Y	
Hornpout				Y	
Pumpkinseed				Y	
Fallfish				Y	
Blacknose & redbelly dace				Y	
Freshwater sculpin					Y
Burbot (cusk)					Y

Notes: Freshwater ('landlocked') Atlantic salmon are native to only four lakes in the United States, all in Maine, but have been extensively stocked elsewhere; freshwater rainbow smelt are native to at least several dozen lakes in Maine but have been extensively stocked elsewhere. Despite their colloquial names, white perch and yellow perch are in entirely separate families; the white perch being a close cousin to the striped bass, the yellow perch a member of the true perch family (ie. walleye, sauger, darters). Yellow perch have a diadromous ancestry in North America but are now almost wholly freshwater fish (Victoria et al. 1992). In Maine, native white perch and banded killifish are commonly found in wholly freshwater populations but also exist in brackish estuaries with access to freshwater. Burbot (cusk) and sculpins are true marine 'relicts' in that they only have wholly freshwater and wholly marine populations but lack any historic, intermediate diadromous phase. They most likely arrived in Maine lakes during the post-glacial period of maximum marine inundation, ie. 13,000 B.P.

Historic Observations of Fish in the Cobbosseecontee Watershed

One of the earliest direct observations of the fisheries of Cobbosseecontee Stream is from a manuscript of Henry S. Dearborn of Gardiner (b. 1783), who wrote: "Major Seth Gray built the first wharf and Gen. Dearborn established the first ferry in 1786. He was accustomed, as were others, to draw a seine around the mouth of Cobbossee and incredible numbers of shad, herring, salmon and sturgeon were taken every spring." J.W. Hanson (1852) wrote of early Gardiner residents that, "Jonathan Winslow used to relate that he captured 16 noble salmon one Sunday before breakfast."

In the State of Maine's first Fisheries Commissioners Report (1867), Charles Atkins and Nathan Foster provide valuable insights to the aboriginal and existing assemblage of the upper Cobbosseecontee watershed, ie. 50 years after construction of the Gardiner dams. At this time, they stated only one non-native fish species, the chain pickerel (*Esox niger*), had been introduced to the Cobbosseecontee watershed. Native, glacially relict, non-anadromous rainbow smelt were native to Cochnewagon Pond in Monmouth. Atkins and Foster state at p. 90:

> "In Monmouth they run into some very small rills that lead into Cochnewagon Pond, and are dipped out in considerable quantities. In May, 1867, after it was supposed they were all gone, a fresh run occurred, that yielded thirty barrels. In quality the fresh water smelts are fully equal to those from the tide waters. Those from Monmouth have been placed side by side with smelts from Damariscotta, and received the preference."

Aside from these non-anadromous rainbow smelt and extirpated anadromous Atlantic salmon, the brook trout (*Salvelinus fontinalis*) appears to have been the dominant, native resident salmonid of the middle and upper watershed. Togue were unknown. Atkins and Foster state at p. 87:

> "There is a brook running through the village of Manchester Forks, where each year quite a number of trout, weighing from two to four pounds, are taken as they come up to spawn. A pair has sometimes been seen together in the brook, and frightened under the bank, when it is only necessary to reach the hand under and take them unresistingly out."

This spawning brook described by Atkins can be located by aerial and field mapping as at the northeastern end of Cobbosseecontee Lake at the junction of U.S. Route 202 and Route 17 in the center of Manchester and flows through the Augusta Country Club. The large size of the brook trout (2-4 lbs.) indicates they were lake dwelling brook trout seeking spawning habitat; which would mean they originated from Cobbosseecontee Lake. This brief description in Atkins is the only known historic (ie. pre-stocking) eyewitness record of native brook trout behavior in the Cobbosseecontee watershed.

Atkins and Foster describe the white perch (*Morone americana*) as a native resident fish of the entire Cobbosseecontee watershed, stating at 92:

"It inhabits, generally, those lakes and ponds emptying into the Kennebec as far north as Skowhegan, those tributary to the Penobscot still farther into the intervening country, and the St. Croix, with the intervening country. This is supposed to be identical with the white perch that comes into the rivers in the spring with the alewives, and it is an interesting question whether it is naturally a salt water species which has strayed into the fresh waters and lost the instinct which should guide its return, or whether it was originally equally fitted to live in salt or freshwater. Some of the lakes in which it abounds have never been accessible to fish coming from the sea during the present age of the world. As an instance may be mentioned the Belgrade lakes. We know very little with regard to the reproduction of this species. Ripe males have, however, been found in the Kennebec River in June. In the spring of the year white perch approach the shores, and run into the mouths of many streams. At other seasons they constantly inhabit the deeper water, where they are gregarious to a greater extent than the yellow perch, being rarely caught by fishing from shore. It is to be presumed, then, that they are far less destructive to small fish than the pickerel and yellow perch, which frequent the shores. In July their food is found to consist mostly of larvae of insects, many larvae or pupae of the dragon fly, not a few small crustaceans, and rarely a small fish."

The first introduction of a non-native fish to the Cobbossee watershed occurred in the 1818 and was the chain pickerel. Atkins and Foster state at p. 159-60:

"We have a succinct account of the introduction of pickerel to the waters of the Cobbossee Contee from Dr. James Cochrane of Monmouth. It seems that in 1817 or 1818 they were brought from the Great Androscoggin Pond [Androscoggin Lake in Wayne] and placed in Winthrop south pond -- now known as Anebescook lake. From this they were transferred to other parts of that system of lakes, until they have reached nearly every part of it. It appears that about 1823 or 1824 they were also introduced into the Cobbossee stream above Gardiner from Nehumkeag pond, east of the Kennebec -- (see Mr. Boardman's article on Kennebec county in Agricultural Report for 1865, page 158). Of the results Dr. Cochrane says: 'Previous to their introduction white perch and trout were abundant in the ponds, now the perch are less abundant and the trout nearly destroyed." In the Belgrade lakes the same thing occurred later; it is said to be twenty years since the pickerel were first introduced, but they have already become more numerous than the trout, and the latter becoming very scarce. ... Williamson says: 'This species of fish was first brought to Penobscot county in 1819, and put into Davis Pond in Eddington, where they have increased surprisingly, but they devour the white perch, which is of as much or more value, and their immigration has not received much welcome.' Pickerel were unknown to the upper Penobscot previous to 1824 ... It is worthy of note that in all these cases the pickerel have increased rapidly. Dr. Cochrane says that eight pickerel were put into Cochnewagan Pond in 1825, and in 1833 they had increased to such an extent that he was able to catch a handsome string of them, averaging three pounds in weight."

At the time of Atkins and Foster's report, black bass (ie. smallmouth and largemouth bass) had not been introduced in Maine. On the topic of smallmouth bass they state at p. 155:

"It is a very common species in all of the Canadian lakes, except Superior, and on the St. Lawrence river, Lake Champlain and its tributaries. It is also found in several localities in the interior of New York, and has been introduced into some of the waters of Connecticut, Massachusetts and New Hampshire. From Mr. S.T. Tisdale of East Wareham, Massachusetts, we have the following: "They were introduced to the waters of this region by myself, in 1850, '51 and '52, to the extent of some two hundred, with which I stocked some in ponds in this vicinity. They were procured at Saratoga lake, N.Y., and brought here. .... We advise that legislation should forbid the introduction of pickerel into any waters where they do not now exist. The same prohibition should rest against sunfish and yellow perch, and the indiscriminate introduction of black bass should not be permitted."

Subsequent deliberate introductions in the early 20th century included the smallmouth bass and largemouth bass. Sebago Lake 'landlocked' Atlantic salmon were deliberately introduced to Cobbosseecontee Lake c. 1890, and for a short time produced fish up in the 10 pound range.[6] Several non-native minnow species (ie. golden shiner) have been inadvertently introduced from anglers' bait buckets in the 20th century. For much of the period since World War II, the MDIFW has annually introduced non-native brown trout to lakes and ponds in the watershed to create a 'two-story' coldwater and warmwater recreational fishery anglers. Northern pike were illegally stocked in the watershed during the mid 1990s, most likely from Sabbattus Pond and/or the Belgrade Lakes.

Table IV: MDIFW Fish Species Data for Major Ponds in the Cobbossee Watershed

Maranacook Lake: Brown trout, lake trout, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, hornpout, rainbow smelt, eel, white sucker, banded killifish, freshwater sculpin, golden shiner, pumpkinseed, redbreast sunfish.

Upper and Lower Narrows Pond: Lake trout, brook trout, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, hornpout, rainbow smelt, eel, white sucker, golden shiner, fallfish, pumpkinseed, freshwater sculpin. Note in MDIFW report (1982): "Finally, it should be noted that water quality has deteriorated somewhat since the pond was originally surveyed in 1940. Recently, in some years low dissolved oxygen concentrations have been observed in the deepest part of the lake in the summer. While this water quality problem has not yet affected a large enough portion of the lake to harm game fish directly, the decline in water quality that has been observed should be regarded as a warning that Lower Narrows Pond is not immune to the effects of 'progress.'"

Torsey Pond: Smallmouth bass, white perch, yellow perch, chain pickerel, hornpout, eel, white sucker, golden shiner, pumpkinseed, yellowbelly sunfish.

Annabessacook Lake: Brown trout, brook trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, golden shiner, white sucker, hornpout, redbreast sunfish,

6 See: *Kennebec Journal*, July 20, 1917: "George F. Winfield of Bretton Hall, New York, under the guidance of John Merrill, made a good catch early Wednesday morning at Cobbosseecontee, his prizes being a nine-pound salmon 30 inches long, and another salmon which measured 26 inches in length and weighed 7 3/4 pounds."

pumpkinseed sunfish, eel, northern pike.

Cobbosseecontee Lake: Brown trout, brook trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, northern pike, chain pickerel, golden shiner, emerald shiner, rudd, white sucker, hornpout, banded killifish, fourspine stickleback, redbreast sunfish, pumpkinseed sunfish, eel.

Cochnewagon Pond: Brown trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, golden shiner, hornpout, redbreast sunfish, pumpkinseed, eel.

Wilson Pond: Brown trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, golden shiner, hornpout, redbreast sunfish, pumpkinseed, eel, northern pike.

Berry and Dexter Ponds: Smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, minnows, white sucker, hornpout, pumpkinseed, eel.

Pleasant Pond: Brown trout, brook trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, golden shiner, white sucker, hornpout, pumpkinseed, black crappie, eel, anadromous alewife. Note in MDIFW report: "Pleasant Pond once provided an excellent smallmouth bass fishery but siltation of the rock gravel shores combined with the explosive growth of aquatic vegetation have severely affected the smallmouth bass population. Conversely, the abundant weedy areas is considered ideal habitat for largemouth bass and pickerel. The excellent largemouth bass fishery can be attributed to the habitat."

Sand Pond (Tacoma Lakes chain): Brown trout, brook trout, rainbow smelt, smallmouth bass, largemouth bass, white perch, yellow perch, chain pickerel, golden shiner, white sucker, hornpout, redbreast sunfish, pumpkinseed, slimy sculpin, eel. Note in MDIFW report: "Good catches of browns and brookies are common, as the fishery is supported by an abundant smelt population. The smelt population has not gone unnoticed by anglers and bait dealers and has sustained a popular fishery since the late 1970s."

Jimmy Pond: Brook trout, splake, rainbow smelt, smallmouth bass, largemouth bass, yellow perch, chain pickerel, golden shiner, white sucker, hornpout, banded killifish, pumpkinseed, eel.

Based upon available historic data, species listed in the MDIFW lake and pond surveys that are non-native include brown trout, lake trout, splake, chain pickerel, northern pike, smallmouth bass, largemouth bass, golden shiner, black crappie. Native species are brook trout, white perch, yellow perch, pumpkinseed, hornpout, American eel, sculpin, rainbow smelt, banded killifish, fallfish and fourspine stickleback. Equivocal are redbreasted sunfish and yellowbreasted sunfish.

Rainbow smelt are only confirmed as native to Cochnewagon Pond (Atkins & Foster 1867) but may have naturally inhabited other ponds in the watershed and were not reported. Because MDIFW routinely introduced rainbow smelt to 'suitable' lakes throughout Maine during the 20th century as forage for introduced and native salmonids, many or most of the extant rainbow smelt populations in the watershed may be more properly characterized as 'introduced and naturalized' (Pellerin 2001).

Brook trout were likely native to nearly all of the lakes and ponds in the watershed in numbers proportional to available summer habitat (ie. well oxygenated deepwater habitat) and riverine or lake shoal spawning habitat, as noted in Atkins & Foster (1867) for the spawning brook at the north end of Cobbosseecontee Lake in Manchester. Of all native extant species, brook trout are perhaps most vulnerable to watershed disturbances (ie. land clearing, pollution discharge, dam building, impounding of riverine spawning habitat). MDIFW survey data does not distinguish between native brook trout populations, self-sustaining naturalized brook trout populations and those maintained wholly by annual stockings of hatchery-reared individuals. Fish species diversity in brook and stream habitat in the watershed is not included in MDIFW survey data.

MDIFW lake and pond survey notes (dating from the 1940s to present) document the effect of direct pollutant discharge to the lakes and ponds and the watershed in the 20th century as well as non-point source pollution from development in the latter half of the 20th century, as confirmed by CWD data from 1971-present. A consistent theme is a reduction in the areal expanse of highly oxygenated water in the deeper portions of the watershed's lakes and ponds during the summer, which has a direct effect on the ability of the pond to support coldwater species (ie. trout, smelt, sculpins). Another effect noted is a dramatic increase in shoreline siltation and weed growth in Pleasant Pond in the 1940-present era which MDIFW states caused a major population shift from smallmouth bass to largemouth bass and pickerel.

A 'check' on native species assemblage is that all of the lakes and ponds in the MDIFW surveys contain a consistent suite of species: ie. white perch, yellow perch, pumpkinseed, hornpout, white sucker and American eel. Sculpin are noted in three of the deepest lakes (Maranacook, lower Narrows Pond, Sand Pond), but are absent from all others. Slimy sculpin is specifically identified from Sandy Pond while 'freshwater sculpin' are noted from Maranacook and lower Narrows. Banded killifish are noted in Maranacook, Cobbossee Lake and Jimmy Pond, but may have evaded or been omitted from identification in other waters (ie. Annabessacook, which should have them since it lies directly between Maranacook and Cobbosseecontee). Fallfish are only noted from Narrows Ponds. Fourspine stickleback are only noted from Cobbosseecontee Lake.

Table V: Fish Species Present In MDIFW Surveys of Lake and Ponds in Cobbosseecontee Watershed

Species	# of Lakes Present	Native	Naturalized	Stocked Only
American eel	All	Y	N	N
White perch	All	Y	N	N
Yellow perch	All	Y	N	N
White sucker	All	Y	N	N
Hornpout	All	Y	N	N
Pumpkinseed	All	Y	N	N
Sculpin	3	Y	N	N
Banded killifish	3	Y*	N	N
Fallfish	1	Y	N	N
Alewife	1	Y	N	Y
Brook Trout	6	Y	N	Y**
Rainbow smelt	6	Y	Y***	N
4-spine stickleback	1	Y*	N	N
Chain pickerel	All	N	Y	N
Smallmouth bass	All	N	Y	N
Largemouth bass	All	N	Y	N
Brown trout	7	N	N	Y
Splake	1	N	N	Y
Lake trout	1	N	N	Y
Golden shiner	All	N	Y	N
Redbreast sunfish	6	Y*	Y	N
Northern pike	6	N	Y	N
Black Crappie	1	N	Y	N

Notes: * = uncertain if native or naturalized; ** = Native but primarily supported by hatchery stocking; *** = Native, but mostly likely naturalized to current range by deliberate introductions.

Table VI: Fish Species Present in Cobbosseecontee Stream below Impassable Dams

Species	Native	Naturalized	Stocked Only
American eel	Y	N	N
White perch	Y	N	N
Yellow perch	Y	N	N
White sucker	Y	N	N
Pumpkinseed	Y	N	N
Alewife	Y	N	N
Brook Trout	Y	N	N
Rainbow smelt	Y	N	N
Tomcod	Y	N	N
Atlantic salmon	Y	N	N
American shad	Y	N	N
Blueback herring	Y	N	N
Striped bass	Y	N	N
Ninespine stickleback	Y	N	N
Banded killifish	Y	N	N
Sea lamprey	Y	N	N
Smallmouth bass	N	Y	N
Largemouth bass	N	Y	N
Brown trout	N	N	Y
Chain pickerel	N	Y	N*
Northern pike	N	N	N*
White catfish	N	Y	N*
European carp	N	Y	N*
Rainbow trout	N	N	Y*

Notes: * = documented in Kennebec River, not certain if present in Cobbosseecontee Stream in Gardiner. Atlantic sturgeon and shortnosed sturgeon are common at the tidal mouth of the stream, but are not believed to travel past the stream's head of tide at the Rt. 201 bridge.

Table VII: MDIFW Fish Stocking in Cobbosseecontee Watershed -- 2010

Waterbody	Species	Number
Cobbosseecontee Lake (Manchester)	BK	2,150
	BT	3,150
Cobbosseecontee Stream (Gardiner)	BK	1,600
Cochnewagon Pond (Monmouth)	BK	900
	BT	300
Dennis Brook (Litchfield)	BK	12,500 (fry)
Jimmie (Jamies) Pond (Hallowell)	BK	2,250
Lower Narrows Pond (Winthrop)	BK	700
Upper Narrows Pond (Winthrop)	BK	950
	AS	200
Torsey Pond (Readfield)	BK	875
	BT	350
Wilson Pond (Monmouth)	BK	200
Wilson Stream (Monmouth)	BK	200
Woodbury Pond (Litchfield)	BK	750
	BT	250
Maranacook Lake (Winthrop)	BK	2,100
	BT	550
	AS	250
Sand Pond (Litchfield)	BK	975
	BT	250

Species code: BK = brook trout; BT = brown trout; AS = 'landlocked' Maine Atlantic salmon

Total Watershed Fish Species Diversity

One equation for total watershed fish species diversity is:

$$(N - Ne) + I = T$$

where:

N = Native species
Ne = Native species extirpated
I = Introduced species
T = Total species present

Using the above formula, the native species diversity index (NDI) is:

$$\frac{(N - Ne) + I}{N + I} = NDI$$

A native diversity index (NDI) of unity (1) represents a condition of full preservation of native species diversity even with the introduction of non-native exotic species. An NDI of less than unity represents a loss of native species diversity even when total fish species diversity (T) is equal to or larger than (N) due to the introduction of exotic species.

For Cobbosseecontee Stream below the Gardiner Paperboard dam the native diversity index (NDI) is now at unity: all native fish species are present in the stream in addition to a number of exotic, introduced fish species. However, for Cobbosseecontee Stream above the New Mills Dam the NDI drops to 0.69:

$$\frac{(23 - 10) + 10}{23 + 10} = 0.69$$

The NDI shows about one third of the total fish species diversity in the Cobbosseecontee watershed above the Gardiner Paperboard Dam is attributable to non-native, introduced species. If all of the native species were present above the Gardiner Paperboard Dam, the total number of fish species present in the watershed above the dam, T, would be 33 species instead of 23.

While this might seem a long way of saying that the Cobbosseecontee watershed has lost one third of its native fish species, the advantage of the NDI is that it explicitly recognizes that save massive applications of rotenone, once exotic, introduced species (ie. black bass, chain pickerel, northern pike) have become naturalized in a watershed, they cannot be *removed* from a watershed. As such, the only way to move the NDI toward unity is to work more aggressively to restore the lost native species. While we have no control over which exotic species were introduced into the Cobbosseecontee watershed in the past, we can enhance the restoration of lost native species.

Today, if there were no non-native, exotic species in the watershed above New Mills Dam, the fish species assemblage of the watershed would consist of white perch, yellow perch, brook trout, rainbow smelt, American eel, hornpout, white sucker, pumpkinseed, banded killifish, fallfish and sculpin, producing an NDI of 0.60; with the proviso that the status of self-sustaining native brook trout in the watershed is unclear due to the masking effect of long-term annual stockings of hatchery-reared brook trout by MDIFW (Table VII).

Native Fish Restoration and Water Quality

During planning discussions for the 2004 removal project at Gardiner Paperboard Dam, CWD staff expressed concerns about the potential water quality impact of full-scale 'free-swim' restoration of native alewives to the lakes of the watershed due to the species' ecological role as a consumer of lake zooplankton, principally *Daphnia*. CWD staff noted that since zooplankton are the primary consumers of phytoplankton, the introduction of a 'new' zooplankton consumer to lakes in the watershed could stall or reverse the CWD's long-term efforts to curb the superabundance of phytoplankton resulting from past pollution and cultural eutrophication.

Table VIII: Historic Kennebec River Alewife Production

Watershed	# of adults @ 235/acre	% of total
Sebasticook	4,541,610	41
Seven Mile Stream	625,805	5.6
Wesserunsett Stream	339,810	3
Sandy River	275,185	2.5
Total above head of tide	5,782,410	52
Cobbosseecontee	2,714,955	24.4
Togus Stream	174,135	1.6
Small drainages	555,396	5
Tidal freshwater river section	1,916,190	17
Total below head of tide	5,360,676	48
Total for Kennebec Watershed	11,143,086	

Source: Squiers, T. S., Jr., MDMR (1988).

Studies in Maine to date have failed to show any significant effect (ie. above 'background') on water quality from the restoration of native alewives to Maine lakes and ponds. The nine-year cooperative MDIFW/MDMR/MDEP study at Lake George in Canaan, Maine showed no observable change in water quality parameters when native alewives were re-introduced to the lake at a density of six adults per acre (Kircheis et. al. 2004). Data collected since the late 1980s by MDEP in nearby lakes with a history of moderate to severe cultural eutrophication, ie. Sebasticook Lake, Unity Pond and Webber Pond, have shown no observable effect on water quality attributable to the presence of native sea-run alewives. Closer to home, the restoration of alewives to Pleasant Pond in the Cobbossee watershed beginning in 1997 has shown no observable change or effect in water quality indices during the past 15 years in which native alewives have been present. One of the purposes of the nine-year Lake George Study was to assess the degree of competitiveness between alewife juveniles and naturalized rainbow smelt for zooplankton in the lake, primarily *Daphnia sp.* A seemingly counter-intuitive finding of the study was that rainbow smelt abundance in Lake George slightly increased during the period when native alewives were present in the lake as compared to when they were no present. While no causal effect for this phenomena could be firmly established, the study confirmed the *absence* of negative effects on rainbow smelt with the restoration of alewives.

To the extent that adult and juvenile alewife density could play a role in any observable effects on zooplankton and phytoplankton populations, it is useful to examine lakes with fully natural 'free-swim' native alewife populations. A type locality for this analysis is the 4,000 acre Assawompsett Pond Complex (APC) in southeastern Massachusetts which has maintained a full 'free-swim' native alewife run since the early 1970s. Four of the five natural lakes in the APC serve as public water supplies for the cities of Taunton and New Bedford, Massachusetts and all are fully accessible to native alewives. Adult run count data collected by the Middleboro-Lakeville Herring Commission show an average of 1 million adults entering the lakes each year since the early 1990s, resulting in a density of approx. 250 spawning adults per surface acre, which is approx. 20 times the density used by MDMR in alewife restoration efforts in Maine. Water quality data collected by the public water systems using the ponds show no observable effect on water quality due to the presence of alewives. However, it must be noted that four of the five waters in the APC have had their shorelines intensely protected against anthropogenic impacts since 1900 when they became municipal public water supplies.

Since several of the waters of the Cobbossee watershed are still suffering from the stress of past and ongoing cultural eutrophication, a risk-averse, precautionary approach would be to limit initial adult alewife density to the lower end of the range (ie. well below 250 adults/acre) in order to allow for follow-up water quality studies. An avenue still poorly examined, in part due to the lack of suitable study lakes in New England, is the extent to which native alewives at a natural population density are net exporters of culturally derived phosphorus from inland lakes, since the entire alewife biomass exits the lakes by early fall to migrate to sea, which in effect means they are taking phosphorus out of the lake in the form of their physical bodies. Since the actual implementation of the fish passage necessary to result in anywhere near full population restoration of native alewives to the watershed remains quite far off, there is plenty of time and opportunity for all involved to devise methods to study these issues more thoroughly.

Table VI updates the MDMR (1988) Cobbossee watershed alewife production estimates using MDEP/CWD surface acreage data; includes several lakes not included in MDMR (1988) that records indicate were historically accessible to alewives (ie., Tacoma Lakes, Cochnewagon Pond, Hutchinson Pond, Jimmie Pond, Little Cobbossee Lake); and uses a return rate of 250 adults per surface acre of lacustrine habitat.[7]

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7 This figure is selected as a 'compromise' between the 235/acre used by MDMR based on mid-coast Maine harvests in the mid 20th century and higher levels (up to 375 adults/acre) observed in the 1990s and early 2000s in the 4,000 acre Assawompsett Pond Complex (APC) in southeastern Massachusetts where alewives are 'free-swim' and harvest levels are minimal. The MDMR (1988) figures are based on reported commercial harvests at or near head of tide with an addition of 15 percent based on the traditional two-day per week closure of the commercial harvest. The APC data are derived from actual daily counts of fish entering the spawning ponds upstream of the harvest site and 25 miles above the head of tide.

Table IX: Historic Alewife Production in Cobbosseecontee Watershed

Lake	Acreage	Est. Production
Cobbosseecontee Lake	5,238 acres	1,309,500
Maranacook Lake	1,844 acres	461,000
Annabessacook Lake	1,415 acres	353,750
Pleasant Pond	800 acres	200,000
Torsey Pond	679 acres	169,750
Woodbury Pond	513 acres	128,250
Cochnewagon Lake	394 acres	98,500
Dexter/Berry Ponds	288 acres	72,000
Sand Pond	279 acres	69,750
Upper Narrows Pond	239 acres	59,750
Lower Narrows Pond	223 acres	55,750
Carlton Pond	223 acres	55,750
Hutchinson Pond	105 acres	26,250
Jimmie Pond	99 acres	25,000
Little Cobbossee	91 acres	22,750
Horseshoe Pond	74 acres	18,500
Total	13,092 acres	3,273,000

Native American Eel Restoration and Water Quality

Historic and region-wide ecological data suggests that the American eel (*Anguilla rostrata*) was the apex fish predator in the Cobbosseecontee watershed and composed a large component of its fish biomass. Unlike all other fish native to the freshwaters of Maine, eels are *catadromous*, ie. they spawn in the Atlantic Ocean, enter freshwater as 1-3 inch juveniles and live their adult life in freshwater until sexually mature and then return to the Sargasso Sea, a mid-ocean eddy east of Bermuda. Unlike other fish, eels do not have a set 'biological clock' or age at spawning. They can live from 4, 6, 8, 10, 15, 20, 25, 30, 35 or 40 years in a lake or pond prior to returning to the ocean to spawn, which they do only once. American eels are by far the *longest-lived* freshwater fish in Maine; and in those waters which native striped bass, Atlantic salmon, sturgeon and lake trout did not inhabit, eels were by far the *largest* native Maine fish.

Estimates of American eel biomass and abundance in Maine coastal lakes are not easily obtainable, especially under pre-19th century ('aboriginal') conditions. Recent MDMR studies at Hermon Pond near Bangor, Maine on the Penobscot River, lying less than 10 miles from the Penobscot River via Soudabscook Stream, showed an adult eel biomass of XXX per surface acre. An independent metric of historic American eel abundance in central Maine coastal watersheds can be inferred by direct counts of juvenile American eel at 'eel ramps' designed specifically to attract and pass juvenile eels over dams. MDMR eel count data at the Fort Halifax Dam at the mouth of the Sebasticook River (approx. 25 miles above Cobbosseecontee) is shown in Table X:

Table X: Juvenile American Eel Passage at Fort Halifax Dam, Sebasticook River, 1999-2006.

Year	Start Date	Shutdown Date	Operating Days	Eels Passed
1999	June 4	Sept. 15	80	473,273
2000	June 19	Aug. 29	59	71,879
2001	May 26	Aug. 24	89	223,184
2002	June 10	Sept. 13	75	56,376
2003	June 11	Sept. 11	50	154,624
2004	June 28	Sept. 1	40	67,217
2005	June 28	Aug. 29	44	7,818
2006	July 28	Aug. 30	27	43,755

Source: MDMR.

Compatibility with Maine Stream Connectivity Guidelines

Due to a renewed focus on preserving and restoring Maine's native fish biota, particularly endangered Atlantic salmon, the State of Maine has recently emphasized the importance of restoring *natural stream connectivity* in Maine watersheds. In 2009, the Maine State Planning Office, Maine Stream Connectivity Work Group, defined this concept as follows:

"Centuries of land and water resource development in Maine, while supporting historical economic and social goals, have impaired chemical, physical, and biological linkages within and among Maine's estuaries, streams, lakes, and other aquatic systems. A notable source of this impairment is the loss of in-stream, or longitudinal connectivity. Construction of dams and road crossings that were not designed with ecological needs in mind limit connectivity by blocking access to habitat that is critical to the survival of Atlantic salmon, alewife, native brook trout, freshwater mussels and other organisms requiring unimpeded movements throughout watersheds during some or all of their life cycle. Along with ecological impacts, impaired connectivity also has considerable economic and social costs, including the loss of income and jobs historically supported by thriving commercial and recreational fisheries. Likewise, the population-suppressing effects of lost connectivity on certain riverine species has led to increasingly restrictive, costly and complex environmental regulatory processes created to protect these imperiled organisms from further harm." [8]

The Cobbosseecontee watershed is a type watershed of stream disconnectivity due to waterway development practices that have been considered 'traditional' since the mid 17th century. CWD (1996) reports 22 dams in the watershed, all without passage and interconnectivity for fish and aquatic life. This number does not count public and camp road culverts and other non-dam obstructions and diversions of streams and wetlands. This yields a conservative average of 1-2 impassable obstructions for every 10 square miles of watershed area.

While the deleterious effects of stream and lake disconnectivity on highly migratory native fish like salmon, shad and alewives are well known, the effects of disconnectivity on non-anadromous, freshwater fish are much less well studied. Recent MDIFW radio telemetry studies of native brook trout on Maine's lower Magalloway River (Boucher 2008) show a wide diversity of migrational behavior in one watershed:

> "Brook trout traveled least during the summer period (average of 0.30 miles), then generally moved short distances (average of 0.72 miles) to spawning areas. Greatest movements occurred in the fall to reach overwintering habitat (average of 6.5 miles) and in the spring (average of 11.7 miles) as they returned to their summer range. The greatest distances traveled by individual trout during the entire study period (late June 2005 to mid July 2006) ranged from 35 to 72 miles .... Two tagged fish traveled upstream 24.6 and 25.1 miles to reach summer range in an approximate 30-day period .... These studies also confirmed the need to maintain free passage of brook trout throughout this subdrainage, because fish from all three populations travel long distances to reach habitat critical to their life history."

8 Sourced at: http://www.maine.gov/spo/coastal/coastal-habitat-restoration.htm

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