AFS 150TH ANNIVERSARY CELEBRATION

Tracking Fisheries Through Time: The American Fisheries Society as a Historical Lens

The Michigan Fish Commission performing an egg take on Lake Whitefish *Coregonus clupeaformis* on the Detroit River, circa 1885. Photo credit: Archives of Michigan

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The historical context of current environmental conditions offers vital guidance to North American fisheries professionals as they strive to develop effective management plans and policies. Through this retrospective we highlight the remarkable historic fisheries resources and reasons for establishing public fisheries agencies and the American Fisheries Society (AFS). Through a review of primary historical documents and literature for North America, this paper identifies factors contributing to the founding of AFS and public fish commissions; shows how selected resource issues evolved; and documents how and why selected fisheries and aquatic habitat policies changed in response to those issues. Overexploitation, landscape-scale habitat alterations, mining, and dams were the causative agents for emergence of fisheries agencies and AFS, and these factors remain relevant today. Beginning in the 1960s, after 100 years of policy inaction, North Americans grew tired of degraded waters and fisheries and forced policy changes that have directly and indirectly affected the fisheries we manage today. The historical events and resulting corrective legislation are taken for granted by those unaware that AFS has actively participated in developing policies to address these environmental harms. Further, AFS continues to play a vital role in identifying key issues, providing conduits for information to cope with impairments, and advocating for policies to conserve intact habitats and improve degraded systems. The struggles documented in this paper offer crucial lessons as we continue to be challenged by legacy resource issues and face emerging environmental stressors, such as climate change, as well as regression in long-standing environmental protection policies.

INTRODUCTION

Fisheries professionals face new and growing environmental challenges requiring innovative conservation actions. Yet, attempting to address current and future concerns without benefit of historical context will result in inefficient or ineffective actions. The American Fisheries Society (AFS) is a preeminent professional fisheries society and many members are unaware that environmental factors of the mid-to-late 19th century, when AFS was founded, remain as issues today. Many writings of early fisheries biologists remain relevant. In the 125th AFS Anniversary Issue of *Fisheries*, Larry Nielsen (1995) summarized the practical benefits of studying fisheries history to encourage better thoughts and actions that: (1) avoid bad decisions, (2) give accurate perspectives, (3) support strategic planning, and (4) test hypotheses. Thus, contemporary fisheries professionals can more fully understand the context for resource concerns by viewing the historical interactions between fisheries agencies and AFS.

With a tendency to focus on emerging issues or tackling new aspects of old problems, today's fisheries professionals may be unaware of how fisheries science and its professional society have evolved to address resource challenges; a knowledge gap attributed in part to an outgrowth of the Shifting Baseline "Syndrome" (Pauly 1995). From this perspective, there may be insufficient understanding of how resource issues have been addressed over the past 150 years or what actions may have been taken towards their resolution. Pauly (1995) noted that many fisheries professionals, as they start their careers, do not realize the long history preceding them. Others may be aware that history preceded them, but appear to have a type of "history amnesia," forgetting the successes and follies of the past. Indeed, many land use legacies continue to influence the structure and functions of our aquatic systems today (Foster et al. 2003). We intend in this paper to put these themes of historical knowledge and environmental concerns in perspective.

Nielsen (1999) illustrated how professions are often incubated by either real or perceived issues regarding a key societal interest, such as food security in the case of early fisheries history. As this paper will show, this was certainly the case for fisheries as the creation of AFS was a natural response to these issues. Focusing on North America (i.e., Canada, the United States, and Mexico), our objectives are to: (1) use case histories of regional fisheries resources and issues from 1860–1890 to identify factors contributing to the founding of AFS and public fish commissions; (2) document how AFS tracked and led key initiatives in fisheries policy over its history; (3) document the linkage between resource condition, resultant policy, and resource outcome illustrating key fisheries resource issues that have resonated for the past 150 years and continue to shape both our aquatic resources and profession; and (4) offer thoughts on the path forward for AFS and our aquatic resources using our collective history as guideposts for the road ahead.

METHODS

We reviewed and summarized a combination of historical source documents and published literature to provide a synopsis for the development of fish commissions and AFS. This information was compiled from the earliest available sources for each jurisdiction, with key reasons for their establishment. Additional information on causative environmental agents was developed by examining the articles in the Proceedings—now the AFS journal *Transactions of the American Fisheries Society*—over the first 20 years of AFS to determine issues driving the profession. Using condensed case histories from different North American regions, we further developed and traced key resource issues that all jurisdictions have confronted through time. For context, from these regions, we included a short description of aquatic resource conditions during early European settlement. These conditions are then tracked through to present day with the best prediction for their future trajectory. Within its temporal scale, this paper's scope is not intended to be a comprehensive review of environmental conditions, or development of tribal authorities, jurisdictional agencies and AFS, but rather to serve as a snapshot or watercolor painting that illustrates the importance of historical context in addressing current and future fisheries resource challenges.

FISHERIES AGENCIES AND AFS ESTABLISHMENT

A Cornucopia of Aquatic Riches

When Europeans colonized North America, the continent was considered a cornucopia of natural aquatic riches, with our rivers characterized as "seas of black, green and brown" masses of life (Waldman 2013). This description is reflected in pre-colonization estimates of annual Atlantic Salmon *Salmo salar* spawning runs of between 10 and 12 million fish with a biomass of 65.8 million kg in eastern Canada and the northeastern United States (Dunfield 1985). In the Maumee River, Ohio, Brown (1815) noted that the fish "so numerous are they at this place, that a spear may be thrown at random, and will rarely miss killing one!" In the Great Lakes, around 1880, Lake Sturgeon *Acipenser fluvescens* populations, already exploited for 3 decades, were estimated to range from 844,000 to 2,259,000 adults, with a standing stock up to 49 million kg (Haxton et al. 2014). At the time of pre- or early European colonization, annual spawning populations of U.S. West Coast Pacific salmon *Oncorhynchus* spp. have been estimated to be 160–226 million kg; the annual Columbia River Pacific salmon run alone was 77–103 million kg (Gresh et al. 2000). These resources were critical to indigenous peoples for thousands of years and are a cornerstone of tribal culture.

For the Columbia River basin treaty tribes, the First Foods include fish (e.g., salmon, Pacific Lamprey *Entosphenus tridentatus*), game animals (e.g., bison, deer, elk), and plants for food and medicinal purposes (e.g., camas, bitterroots, huckleberry), all of which depend on clean and plentiful water. Tribal culture, religion, and way of life of the many treaty fishing tribes are intertwined with the First Foods, as well as their considerable knowledge about food preservation and replenishment through the innovative and effective management of their natural resources (Figure 1).

The fisheries resources in Mexico were just as robust as elsewhere on the continent prior to European colonization. Ancient codex and Spanish chroniclers depict an active and diverse fishery in pre-Hispanic Mexico. A variety of freshwater and marine species were used and traded and *Opochtli*—the Mexican god for fishery, fishing nets, and spears—was revered (Cifuentes-Lemus and Cupul-Magaña 2002). Between the years 1500 to 1600, expeditions by colonial naturalists documented a diverse freshwater biota; native fish were farmed in monasteries, and whale fishery and pearl extraction were regulated. The 1600s saw the development of local, small-scale colonial inland fishery regulations to allow improved fish production and commerce (Cifuentes-Lemus and Cupul-Magaña 2002).

Fish Commissions and AFS Establishment

The above references are just a few examples of the aquatic bounty that played a key role in sustaining pre-European colonization native peoples, estimated at 26 million continent-wide (Koch et al. 2019). Yet, this bounty would not coexist with rapid development of the continent in the 1800s and, as a consequence, citizens forced governments to address the obvious degradation. To fully understand the factors contributing to establishing public fisheries management authorities and the founding of AFS, circumstances of that period need to be placed in context. By the 1860s, North America was in the middle of rapid industrialization, which required mass inputs of raw materials that were facilitated by waves of transportation improvements for both rail and water systems. The mass immigration into North America from all over the globe provided the human resources to facilitate the industrial revolution. This industrial development rapidly diminished the quality of the landscape that supported this remarkable fisheries heritage. Fisheries degradation was facilitated by the view from these immigrants that North America's resources were limitless; a view not shared by indigenous peoples.

Recognition of the degraded conditions across much of North America spurred establishment of public management authorities (e.g., state, provincial, federal, and ultimately tribal), to fix the clearly known issues with fisheries. For example, initial state efforts to improve fisheries started as early as 1856 in Massachusetts, where a prototype "Fish Commission"

Figure 1. Native Americans salmon fishing at Celilo Falls on the Columbia River, Oregon, *circa* 1920s. Location is now inundated by Dalles Dam. Historic postcard. Gary Whelan.

developed a report stating that unrestricted fishing, dams, and the loss of key fisheries were societal problems requiring a fix, but the commission had no legal ability to effect change. The emergence of state-level fisheries agencies started immediately after the U.S. Civil War with the establishment of the Commissioners on the Fisheries of the State of New Hampshire in 1865. From 1865 to 1869, 8 states formed fisheries commissions, and these were soon joined by 27 states and 1 territory (soon to be the state of Wyoming) forming similar entities during the period 1870–1879 (Supplemental Table 1). Congress established the U.S. Fish Commission in 1871. From 1880–1900, another 6 states and 1 territory (soon to be the state of Arizona) formed fisheries commissions, or similar entities, and by 1932 the remainder of the 48 states had fisheries commissions. The state of Alaska had a Fish and Game Department 10 years prior to statehood (1949) and degraded fisheries were the major reason for statehood (Alaska Department of Fish and Game 2009). Hawaii had an aquatic resources agency established upon statehood in 1959.

Tribal Fisheries

Indigenous people of North America always have depended on natural resources for their cultural, spiritual, and economic survival. These resources are so central to their way of life that when their sovereign nations ceded millions of acres of their lands in treaties with the United States and Canada, they forever reserved their right to hunt, fish, and gather in traditional places. These treaty rights have been reaffirmed by a number of federal, state, and provincial courts, including the U.S. and Canadian Supreme Courts. Today the tribes are often resource co-managers with state, provincial, and federal governments (Columbia River Inter-Tribal Fish Commission 2013).

In the Pacific Northwest, in addition to environmental stressors affecting First Foods, tribal fisheries were often among the first to be reduced to meet salmon escapement goals (i.e., salmon populations not caught by commercial or recreational fisheries returning to their freshwater spawning grounds). As late as 1969, the historic conflicts concerning appropriate harvest and allocation of the ever limited resource were still not resolved and led to a legal challenge in U.S. federal court (*Sohappy v. Smith,* 302 F. Supp. 899 [D. Or. 1969]), in which 14 Columbia River tribal citizens sued the Chair of the Oregon Fish Commission over discriminatory fishing regulations. This case later became *United States v. Oregon* and established tribal fishing rights to a fair share of the harvestable salmon. In a corresponding Western Washington case, *United States v. Washington* (384 F. Supp. 312, aff'd, 520 F.2d 676; the Boldt Decision), the Court decided a fair share was 50% of the amount exceeding spawner escapement needs and required fisheries agencies to allow adequate escapement past prior intercepting fisheries to meet the needs of tribal fisheries and conservation.

These court cases and subsequent others led to the establishment of many tribal fisheries agencies across the USA and Canada. The 41 treaty tribes of the Pacific Northwest and Great Lakes regions established five intertribal commissions (Columbia River Inter-Tribal Fish Commission, Northwest Indian Fisheries Commission, Chippewa Ottawa Resource Authority, 1854 Treaty Authority, and Great Lakes Indian Fish and Wildlife Commission) to help fulfill their treaty-reserved rights and manage natural resources. The treaty commissions are an effective and efficient mechanism, consistent with the goals of the Indian Self-Determination and Education Assistance Act (Public Law 93-638) and advance tribal self-determination and self-governance. They operate at a local level in close coordination with member tribes, provide an effective mechanism to partner with state, federal, and local agencies, and contribute to overall stewardship and better natural resources protection not only for tribal members, but for all citizens.

The Columbia River Inter-Tribal Fish Commission (CRITFC) is one such example. The CRITFC was founded in 1977 to, "ensure a unified voice in the overall management of the fishery resources, and as managers, to protect reserved treaty rights through the exercise of the inherent sovereign powers of the tribes." By putting fish back in the rivers and protecting their watersheds, the CRITFC supports the mission of its member treaty tribes, which include the Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation of Oregon, Confederated Tribes and Bands of the Yakama Nation, and the Nez Perce Tribe. The organization, among other things, protects tribal access to traditional fishing locations as reserved in the 1855 treaties between each of the four Columbia River treaty tribes (Yakama Tribe, June 9, 1855, 12 Stat. 951; Tribes of Middle Oregon, June 25, 1855, 12 Stat. 963; Umatilla Tribe, June 9, 1855, 12 Stat. 945; and Nez Perce Tribe, June 11, 1855, 12 Stat. 957) and the United States government. The CRITFC acts as the technical support and coordinating agency for fisheries management policies for the member tribes and is governed by each tribe's fish and wildlife committees. The CRITFC tribes co-manage fisheries programs across their ancestral homelands, encompassing over one-third of the portion of the Columbia River basin within the United States (172,470 km^2).

Canada

Canadian fisheries agencies followed a timeline similar to those in the United States, with a key difference of a much stronger federal government role, with provincial fisheries agencies established later. The same fisheries problems as documented in the United States led to the creation of the federal and, ultimately, provincial/territorial fisheries agencies. A key reason was the increasing degradation of highly valuable and societally important fisheries resources and their supporting habitat, particularly near areas of rapidly expanding population. More than 50 years before Canadian confederation in 1867, Upper Canada passed a law in 1807 regulating methods of capturing Atlantic Salmon in Lake Ontario. These regulations grew incrementally in subsequent years into a full-scale fishery policy for the Atlantic Ocean and the Great Lakes, resulting in the Canadian Fisheries Act of 1868 for the regulation of fishing and protection of fisheries.

The Fisheries Act, one of Canada's oldest and most important environmental laws, was enacted in 1868 by Canada's first Parliament. Penalties for violations were stringent, falling within the criminal code. In 1857–1858, the province of Canada combined earlier laws into a single fishery law referred to as "An Act Respecting Fisheries and Fishing" to better enact the preservation and regulation of fisheries. This was an amalgamation of laws resulting from consolidation of Lower Canada (Quebec) and Upper Canada (Ontario) into the Province of Canada in 1841. These regulations had grown primarily around Great Lakes fisheries. Regulators recognized problems of pollution, in particular the increasing problem of bark debris from timber rafts and sawdust waste from sawmills dumped directly into water bodies. The Province of Ontario embarked on a policy of regulation and conservation in all its waters. Bogue (2000), indicated a plan was established "very

Table 1. Cited reasons for state fish commission establishment in the USA.

Environmental or anthropogenic influence	Percentage (%) of commissions
Fisheries depletion/overharvest	80
Illegal or unethical methods of fishing	48
Dams causing loss of spawning grounds	36
Need for food resources to feed expanding population	26
Water pollution	20
Wanton waste of the resource	12
Landscape alteration and resulting habitat loss	10
Habitat destruction	6
Invasive species establishment	2

Figure 2. Lake Whitefish egg take on the Detroit River by the Michigan Fish Commission, *circa* 1885. Courtesy: Michigan State Archives.

much in contrast to that of what Canadian fishermen came to call 'the American system' of free and unlimited access to fisheries with few controls." However, enforcement remained difficult as fishermen balked at the system and resisted enforcement officers. In 1890, the Dominion government (similar to the U.S. federal government) employed 49 fisheries overseers and 6 wardens for protection purposes (Wright 1891). One overseer in 1869 at the west end of Lake Ontario reported that "all the salmon have been destroyed in consequence of contraventions of the fishery laws." It was said that overseers were too few and too poorly paid, such that "poachers with fyke nets and spears were at work as soon as their backs are turned" (Wright 1891). The Canadian system of regulation and enforcement, adopted in 1868, drew more and more favorable comments from conservation-minded observers in the next 2 decades. It was, however, an irritant for U.S. fishers, because it hampered their ability to fish in Canadian waters.

The two nations worked collaboratively using artificial propagation and stocking to mitigate declines and sustain fish populations. All these efforts were focused on the same concerns as those of fisheries agencies in the United States. The British North America Act of 1867, later known as the Constitution Act, created the federation and the Canadian constitution and government. It granted the federal government oversight of the coastal and inland fisheries. By the Fisheries Act of 1868, the Canadian government established the Department of Marine and Fisheries and gave the federal government primary management authority for Canadian waters of the Great Lakes up to 1899. In 1885, the province of Ontario passed a fisheries act similar to the federal legislation to exert provincial control of fisheries management. This authority was disputed until 1910, when the federal government agreed to allow increased provincial involvement.

The first dedicated federal agency involved in fisheries and administering the Fisheries Act of 1868 was the Department of Marine and Fisheries, with broad federal oversight of all fisheries, starting in Ontario. It was extended to British Columbia by 1876, although the British Columbia Terms of Union of 1871 required the federal government to protect and encourage fisheries in that province (Sutcliffe et al. 2018). The current federal Department of Fisheries and Oceans was established in 1979 after nine departmental name changes since its inception. The first provincial fisheries entity was established in New Brunswick in the Department of Agriculture in 1882, followed in Ontario by the Ontario Fisheries Act (1885) under the Department of Crown Lands (Kerr 2010). Some transfer of federal authority was given to Quebec in 1884, but most of the inland water authority was transferred in 1918. Subsequently, provincial agencies were established in British Columbia in 1898 by the Imperial Privy Council (Swenerton 1993); Manitoba, Alberta, and Saskatchewan in 1930 by the Constitution Act of 1930; and Newfoundland in 1936 through the establishment of the Newfoundland Fisheries Research Board, with authority transferred to the federal government in 1949 after confederation with Canada. Although provincial management and licensing of freshwater fisheries exists, the federal government manages anadromous, catadromous, and other marine species in all provinces except Quebec. The same applies to jurisdictions such as Northwest Territories, Nunavut, and Yukon. In 1995, the province of Saskatchewan enacted its own Saskatchewan Fisheries Act to provide for full provincial management and licensing of their fisheries.

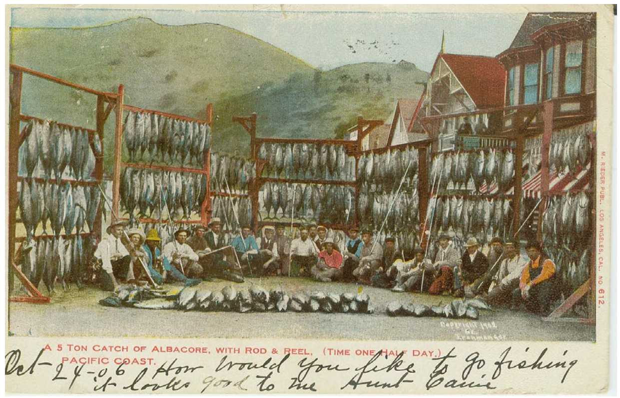


Figure 3. Albacore *Thunnus alalonga* catch from Pacific Coast, California, 1906. Historic postcard. Courtesy: Gary Whelan.

Mexico

Parallel with the development of fisheries commissions in the United States and Canada, Mexico showed a similar development path for fisheries management, both temporally and in policy formation. Naturalist associations and the first agencies dedicated to fishery regulations emerged after the social instability of the independence wars and a similar recognition of resource declines; by 1872 the first federal fishery regulations were instituted (Cifuentes-Lemus and Cupul-Magaña 2002; Martínez Martínez and González Laxe 2016). An Office of Aquaculture initiated state-sponsored fishery activities and promotion, leading to the first aquaculture facility (1884) rearing non-native Rainbow Trout *Oncorhynchus mykiss*, similar to the emphasis on fisheries propagation during this period in the United States. A strengthening public administration in the early 1900s led to creation of state-sponsored research institutions to study and aid in regulation of fishery resources in marine and fresh waters (Celaya Tentori and Almaraz Alvarado 2018). Research and efforts to register and inspect fishing vessels and cooperatives aided the Fishery Directorship in creating fishery regulations (1923) and a national fishery law in 1925; these would be updated throughout the 1920s to incorporate rules for fishery closures and authorizations, including sport fisheries.

A Degraded Continent and Its Effect on Fish and Fisheries

By the 1860s, the deplorable state of fisheries resources across the continent motivated establishment of North American fisheries commissions and their successor agencies. An analysis of the earliest available reports from these fish commissions provides the reasons for their founding, with each commission often attributing several factors. Consistent among the top five explanations were: (1) fisheries depletion/overharvest and illegal or unethical methods of fishing, (2) dams causing loss of spawning grounds, (3) need for food resources to feed the rapidly expanding population, (4) pollution, and (5) landscape-level land alteration (Table 1; Supplemental Table 1). The reasons for the degradation were well understood, with most still relevant today, yet the political climate was not conducive to dealing with the causative factors (Pisani 1984). This led early fisheries professionals to focus on fish culture and restocking of depleted waters (Figure 2).

The needs of early fisheries professionals from the United States and Canada to gather, network, exchange information, and to take collective action against degradation led to formation of the American Fish Culturists' Association in New York City on December 20, 1870, which transitioned to the American Fisheries Society in 1884 to reflect the broadening of the fisheries field, along with the challenges confronting fisheries commissions (Thompson 1970). From these early days, the interaction between the fisheries commissions and AFS was clear, as many of the early leaders in AFS were members of these fisheries commissions (Murphy 2020). The interest of, and supporting role for fish commissions in the early AFS are detailed in the 141 publications of *Transactions of the American Fisheries Society* (TAFS) between 1874 and 1886 (Table 2). The top three areas covered by this journal were: (1) fish culture, with population rehabilitation being a key subtopic (41%); (2) natural histories of a range of aquatic life, with commercial fisheries, fish culture, and fishways as key subtopics (27%); and (3) commercial fisheries with key subtopics of natural history, fishing gear, and statistics (13%). The remaining 18% of TAFS papers consisted of a broad range of topics (e.g., physiology, regulations, aquarium reports, fish health, fish introductions, habitat degradation, harvest methods, history, population rehabilitation, sampling, resource waste, and agency reports). All of these topics were key concerns to early fisheries scientists who were trying to rehabilitate badly degraded fisheries and demonstrate how the early AFS was working to assist public fisheries agencies in their work.

During the period from 1860–1880, the formation of fish commissions and AFS were influenced by public perception of readily accessible fisheries resources as depleted, examples of which are illustrated in the subsequent regional discussions. The regional discussions also provide more details on apparent factors contributing to degradation, yet the only viable remedy promoted was fish culture. Habitat protection and rehabilitation through societal regulation was not a politically viable option until the mid to late 1900s. Unfortunately, many of the same concerns and issues have continued to echo through to the present.

CASE HISTORIES

Overexploitation and Wanton Waste of Fish

One of the key reasons for formation of fish commissions and AFS was overexploitation and wanton waste (Figure 3). The following five brief case histories explore exploitation and management history of a range of resources across North America, highlighting the efforts and conflicts to control fishing mortality that were, and are, complicated by the effects from uncontrolled anthropogenic variables over the past 150 years.

Atlantic Cod, Striped Bass, and Atlantic Sturgeon: Exploitation Case Histories of Three Iconic Northeastern USA and Eastern Canadian Fisheries

Atlantic Cod. Since the 1500s, the fisheries of the U.S. Northeast have endured centuries of intensive exploitation. Chief among them, Atlantic Cod *Gadus morhua* fisheries have a legendary history and an uncertain future. Prior to European colonization, indigenous peoples valued plentiful Atlantic Cod as a food source (Spiess and Lewis 2011). The benefit of these fisheries extended to 16th century European explorers, to whom the vastly abundant cod was a survival necessity and economic goldmine (Betts et al. 2014). In the interim 4 centuries, fisheries in Labrador, Newfoundland, Georges Bank, and the Gulf of Maine (GOM) have actively pursued cod through both sustainable and notably "exhausted" population periods. Annual yields in Newfoundland alone increased from 125,000 to 250,000 tonnes from 1806 to 1866, and average total length of the largest fish declined from 1.5–2 m to 1–1.5 m from the 1600s to 1800s (Pauly and Maclean 2003; Gough 2007). Based on such historical statements, unsustainable levels of cod exploitation have occured since the mid 1800s (Goode 1887). In the past century, cod populations in both the United States and Canadian waters have been repeatedly overfished as technological developments greatly increased fishing efficiency, not dissimilar to efficiency changes in other areas witnessed in the 1800s, and necessary catch limitations were politically unavailable (Ludwig et al. 1993; Pauly et al. 2002; Pauly and Maclean 2003). With diminishing hope for stock restoration, this overharvest continues today. Despite substantially reduced catch quotas and short seasons, the cod fisheries are biologically unsustainable at this time, but remain open due to political pressure, a reason used many times in the history of this fishery.

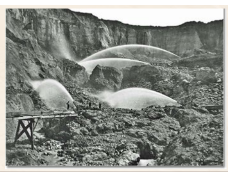
In 1968, the catch of cod peaked at approximately 1.7 million tonnes through the combined efforts of highly efficient foreign factory trawlers and domestic fleets. Afterwards, harvests plummeted (Lear 1998). In response, both the USA in 1976 by the Magnuson–Steven Fishery Conservation and Management Act (Public Law 94-265 of 1976, 90 Stat. 331) and Canada in 1977 by the Fishery Zones Act established 200 nautical-mile Exclusive Economic Zones. As a result, foreign trawlers departed and both governments subsidized domestic fleets, creating a "tragedy of the commons" for Atlantic Cod in the 1980s. Initially, harvest rebounded, but soon populations collapsed (Strub and Pauly 2011). Canada declared a moratorium on commercial Atlantic Cod fishing in 1992 and U.S. landings were at an all-time low of 4,000 tonnes (Hutchings 1996). Beyond commercial and recreational harvest moratoria

Environmental or Social Event

Native Americans (Powhatan) of the Mid-Atlantic region portraying culture of cooking fish (1590). Image by Theodor De Bry based on painting of John White. Courtesy: Mariner's Museum and Park.

1867 | US | Susquehanna River-first fishway constructed at Columbia (Wrightsville) Dam (Wolensky 2016)

Hydraulic mining, Malakoff Diggings, California (*circa* 1876). Photographer: Carleton E. Watkins, in Curtis et al. 2006



1868 | US | First reports of fire on the Cuyahoga River, Ohio. Source: Ohio History Central (February 2020)

1850

1860

Legislation

1854 | TR-US | 1854 Treaty Authority established

1857 | CA | Province of Canada Fishery Law Amalgamated

1865 | US | New Hampshire fish commission established

1866 | US | Connecticut fish commission established

1866 | US | Massachusetts fish commission established

1866 | US | Pennsylvania fish commission established

1866 | US | Vermont fish commission established

1867 | US | Maine fish commission established

1868 | CA | Canadian Fisheries Act passed by the first Parliament of Canada

1868 | US | New York fish commission established

1868 | CA | Department of Marine and Fisheries established, extending initial federal oversight of fisheries to Ontario

1868 | US | Rhode Island fish commission established

CA-Canada | MX-Mexico | TR-Tribal | US-United States | INT-International
The term "fish commission" indicates state fish authority. Actual name may differ.

Table 2. Paper topics in *Transactions of the American Fisheries Society* from 1874–1886.

Main Topic	Number	Percent (%)	Secondary Topics
Culture	58	41	Population rehab
Natural history	38	27	Commercial fisheries, culture, fishways
Commercial fisheries	18	13	Natural history, gear, statistics
Physiology	6	4	Commercial use
Habitat rehabilitation	4	3	Fishways
Regulation	4	3	Resource waste
Agency report	3	2	
Resource waste	2	1	
Aquarium report	1	1	
Fish health	1	1	
Fish introduction	1	1	
Habitat degradation	1	1	
Harvest methods	1	1	
History	1	1	
Population rehabilitation	1	1	
Sampling	1	1	

in both countries, management strategies in the following decades have included size restrictions, annual catch limits, area closures, boat decommissions, marine protected areas, and restricted sector (grouped limited access permits in the USA/stewardship and port limited access in Canada) fisheries; regulatory actions that were not conceivable in the 1800s for other stocks. Stock assessment research has examined prey availability, changing ocean temperatures, spatial shifts, habitat decline, predator impact, gear type, discards, and sub-population complexities to try to understand the lack of recovery.

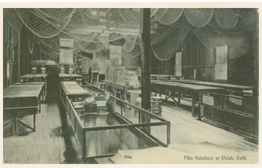
Some assessments provided hope, such as the 2008 GOM biomass assessment, which showed a recovery, while the Canadian Great Northern Atlantic Cod stock also took a promising turn in response to an influx of Capelin *Mallotus villosus* (Rose and Rowe 2015). A 2011 reassessment of GOM data found industry bycatch discards were below minimum catch size, which lowered the 2007 estimated biomass (Pershing et al. 2013) and in 2014, the GOM stock dropped to 3–4% of the sustainable biomass with fishing mortality "near all-time highs" (Palmer 2014). In Canada, hopes fluctuated when the Great Northern Atlantic Cod stock suddenly decreased by 30% in 2017 then rose again in 2018 as biomass increased to 48% of the target level, nearly halfway out of the "critical" zone, illustrating the high uncertainty in assessing the stock status of this species and resulting in poor acceptance of the information by fisherman and the public (Kelly 2018; Mckenzie-Sutter 2019).

As of 2017, the GOM population is not projected to meet recovery targets until 2024. The "in poor condition" Georges Bank population will not recover until 2027 (Northeast Fisheries Science Center 2017). Increases in 2019 Canadian commercial and U.S. recreational catch limits (Department of Fisheries and Oceans Canada 2019; National Oceanic and Atmospheric Administration 2019) were approved to a mixed response by the fishing and conservation communities, given the overfished status and recurring biomass overestimates. To focus specifically on the complexities of stock components, a joint U.S. and Canada Atlantic Cod Stock Structure Working Group was formed in 2018. Dean et al. (2019) found that two distinct spawning populations using marine protected areas in the GOM (spring and winter) are not contributing to recruits as would be expected. A better understanding of sub-population behavior leading to more accurate biomass estimates and successful management strategies is needed to restore Atlantic Cod sustainability. This fishery continues to struggle. Yet through lessons learned from past inactions on stock collapses and improved ecosystem management policies (National Oceanic and Atmospheric Administration 2019), there is a chance to recover this critical resource, unless prevented by massive ecosystem changes from climate change or food chain alterations.

Striped Bass. Two other Atlantic Coast case histories illustrate the continuing importance of identifying the primary drivers of population declines and then legislating adequate protection and remediation. Again, as with cod, specific actions were wanted but unavailable politically to early fisheries scientists. Striped Bass *Morone saxatilis* is an anadromous fish that can exceed 100 pounds (45.3 kg) and spawns in coastal rivers of the U.S. Atlantic and Gulf of Mexico. Populations natal to the Hudson, Delaware, and Roanoke rivers and the Chesapeake Bay are known as the Mid-Atlantic coastal migratory stock and have long been the focus of major commercial and recreational fisheries within these rivers and the mixed stock fisheries from the Bay of Fundy to Cape Hatteras.

Abundance of the Mid-Atlantic Striped Bass stock has varied, modulated by the often intense fisheries harvest and highly variable recruitment. The Chesapeake Bay population, which includes at least nine tributary subpopulations usually dominates this stock, as documented in 1975 estimates that showed this population comprised as high as 90% of the entire

Environmental or Social Event



Fish Hatchery, Ukiah, California. Historic postcard. Courtesy: Gary Whelan

1870 | US | **American Fish Culturists' Association founded.** *Later to become American Fisheries Society*

Oil boats on Allegheny River at Oil City, Pennsylvania (1864). Source: Tarbell (1904)

1870

Legislation

1870 | US | Alabama fish commission established

1870 | US | California fish commission established

1870 | US | New Jersey fish commission established

1871 | US | Office of Commissioner of Fish and Fisheries established {16 Stat. 593}

1871| CA | British Columbia Terms of Union; federal oversight of fisheries to British Columbia by 1876

1871 | US | Utah fish commission established

1871 |US-CA | Treaty of Washington {17 Stat. 863; Treaty Series 133}

1872 | US | The Mining Law of 1872 {Ch. 152, 17 Stat. 91-96}

1872 | MX | First federal fishery regulations

1873 | US | Michigan fish commission established

1873 | US | Ohio fish commission established coastal migratory stock (Berggren and Lieberman 1978). However, following a peak in 1973 of 6,700 tonnes in commercial landings, a series of recruitment failures of Chesapeake Bay Striped Bass driven by overfishing, likely enhanced by habitat degradation at that time, led to declines of nearly 90% in the following decade, to a low of 1,000 tonnes in 1983 (Richards and Rago 1999).

This decline stimulated the 1979 U.S. Congress to pass the Anadromous Fish Conservation Act (U.S. Public Law 96-118, 93 Stat. 859), which required an “Emergency Striped Bass Study” to monitor of the status of Striped Bass stocks and to determine why the Chesapeake Bay population had declined. An Interstate Fishery Management Plan (Plan) was adopted by the Atlantic States Marine Fisheries Commission (ASMFC) in 1981, and its third amendment in 1985 sought to protect females until 95% could spawn at least once. The effect of this protection would be an increasing age at entry to the remaining fishery from 2 to 8 years, either through moratoria or a progressive increase in minimum size limits scheduled to reach 97 cm in total length by 1990, steps out of the reach of early fisheries scientists.

The ASMFC is non-regulatory, thus its Plan was only a management recommendation that its constituent states could ignore without legal consequence. The fishery management plan process was strengthened in 1984 by passage of the Striped Bass Conservation Act (U.S. Public Law 98-613, 98 Stat. 3187), which required states to comply with the Plan or submit to a federal moratorium on Striped Bass fishing. The Conservation Act also ensured equitability—since all states must comply, all share in the restriction hardships. Given the political and economic unpalatability of the ASMFC Striped Bass Interstate Fishery Management Plan Amendment 3, it is likely that all states would not have fully complied without the impetus of the Conservation Act. Federal moratoria were threatened several times and implemented once under the Conservation Act before state fishing regulations across the region were brought into compliance with the Plan (Ballou 1987).

Amendment 4 to the ASMFC’s Plan, adopted in 1989, represented a new, adaptive approach to conservation of the Mid-Atlantic Striped Bass stock, which emphasized managing populations first to restore and maintain spawning stocks and, secondarily, to provide fishery yield. Despite improvement in the Chesapeake Bay spawning stock, recruitment indices in Maryland’s waters of the Chesapeake Bay remained at or near their lowest levels until 1989. However, this approach soon worked, with numbers of juveniles rising to average levels in 1992 and exceeding previous highs twice during 1993–1996. Demonstrating how properly implemented harvest regulations can work, by 1995 the stock was considered fully recovered, nearing or reaching all-time high levels (Hartman and Margraf 2003). This was the case for over 20 years until 2017, when ASMFC stated the Mid-Atlantic Striped Bass stock was again overfished relative to established reference points due to poor recruitment during the period from 2005–2011 (ASMFC 2018). As a result of monitoring, strategic regulatory oversight, and adaptive management, fisheries professionals expect that this stock will once again recover from overfishing.

Atlantic Sturgeon. The final and very different population and management scenario for the East Coast is illustrated by Atlantic Sturgeon *A. oxyrinchus.* Atlantic Sturgeon, with a distributional range similar to Striped Bass, is an anadromous species with a life expectancy of 60 years. The species can reach the behemoth sizes of 4.27 m and 363 kg. Similar to Chesapeake Bay Striped Bass and Atlantic Cod, Atlantic Sturgeon were also greatly overfished a century ago. In the late 1800s, there was a worldwide “caviar craze” for sturgeon roe. In the USA, intense fishing effort focused on Atlantic Sturgeon, specifically the Delaware River stock (Waldman 2013). Peak harvest of Atlantic Sturgeon in the United States occurred in 1888, with 3,175 tonnes landed, and despite the species being found in rivers from Maine to Florida, almost 2,721 tonnes came out of the Delaware River alone. By 1897, the Delaware fishery engaged nearly a thousand fishers who lived on the river on scows or houseboats where they landed and processed their catches during the spawning season. Large mesh gill nets were used to target bigger individuals that are nearly always females, with the average female captured in New Jersey weighing 126 kg (Secor and Waldman 1999).

Atlantic Sturgeon management is constrained by females of Mid-Atlantic populations that require approximately 15 years to mature and spawning intermittently thereafter. The mostly unregulated fishery persisted for about a decade as it was whittled down by about 10% per year. In 1890, fishers landed about 60 sturgeon per net haul (Figure 4); by 1898 it was down to 8 per net haul. In 1901, Delaware River landings had been reduced 94% from their peak and the fishery was ended, having fully exploited decades of accumulated biomass (Secor and Waldman 1999).

Other rivers, such as the Hudson River, also had substantial Atlantic Sturgeon fisheries and similar population reductions by 1910. Afterwards, many systems supported little or no sturgeon harvest because of the low profitably in pursuing a rare catch. However, in the 1980s slowly recovering sturgeon populations attracted fishers both on the mixed fish stock in nearshore and coastal waters and on individual stocks in selected rivers, such as the Hudson River. This led to progressively more restrictive regulations, which were

Environmental or Social Event

Eel spearing, Eel Bay, Upper St. Lawrence River. H. Pyle Illustration (1878). Courtesy: John M. Casselman

Camfield Rollway on the Pine River, Lake County, Michigan (*circa* 1870s). Courtesy: Michigan State Archives

1870 *(Continued)*

Legislation

1874 | US | Iowa fish commission established

1874 | US | Maryland fish commission established

1874 | US | Minnesota fish commission established

1874 | US | Virginia fish commission established

1874 | US | Wisconsin fish commission established

1876 | US | Arkansas fish commission established

1876 | US | Georgia fish commission established

1876 | US | Kentucky fish commission established

1877 | US | Colorado fish commission established

1877 | US | Kansas fish commission established

1877 | US | Missouri fish commission established

1877 | US | North Carolina fish commission established

Figure 4. Atlantic Sturgeon fishing in 1870 mural in Hyde Park, New York Post Office. Painted by Olin Dows through a commission by the Works Progress Administration of Fine Arts; Art in Public Building Program in 1940. Photographed by C. B. Ross and Edward Campeau. Available: https://bit.ly/36Uetpt (February 2020).

unavailable as management tools in 1890. In 1998, a 40-year fishing moratorium was enacted to protect 20 year–classes of females (ASMFC 1998). Prior to the moratorium, the ASMFC developed a fishery management plan outlining conservation and restoration measures to achieve population levels that would support harvests at 10% of the historical peak landings. Protection culminated in 2012 with designation of federal endangered species status for four distinct population segments for the species and threatened status for one other distinct population segments (Federal Register, 2012-77FR 5880; 77FR 5914) under the U.S. Endangered Species Act of 1973 (ESA; Public Law 93-205, 87 Stat. 884).

Atlantic Sturgeon, a species that lives in coastal waters and seasonally inhabits deep estuarine and river waters can be surprisingly cryptic considering their large sizes. By about 2000, surveys were showing evidence of increasing abundances and the presence of populations in systems where they were thought to be extirpated, such as in the James River, in Virginia (Balazik et al. 2012). In the Delaware River, there was only a small number of observations of Atlantic Sturgeon through the 1900s. However, successful reproduction was again documented in 2009 and 2014, with an estimate of more than 3,600 young-of-the-year and yearlings (Hale et al. 2016).

All three case histories illustrate the importance of harvest regulation, as noted by early fisheries professionals and AFS, and the need for conservative levels of fishing pressure. In all three instances, removals exceeded the capacity to sustain them, resulting in both economic losses and likely less well-understood ecosystem consequences. The time series for the declines of these fisheries also show a spectrum of concern prior to their collapses; from no apparent warnings for the Atlantic Sturgeon fishery, to moderate concern for Striped Bass, and to dire warnings for Atlantic Cod. All three case histories argue for the importance of adhering to the Precautionary Principle (Gonzalez-Laxe 2005) when managing fisheries; prevention of collapses is more easily accomplished and less sociologically painful than rebuilding severely diminished stocks and livelihoods. The resource allocation conflicts in these case histories were the same that initiated the formation of fish commissions and AFS, and for two of the three, Atlantic Cod and Atlantic Sturgeon, these conflicts continue today with nearly all of the same constraints.

Pacific Salmon Fisheries: The loss of a resource legacy

On the Pacific Coast, case histories similar to those on the Atlantic Coast exemplify the long noted need for harvest regulation on, and equitable allocation of, Pacific salmon populations. These concerns, raised by early fish commission staffs and AFS, contributed to formation of entities along the Pacific Coast to address those concerns. Recent archaeological research found "a remarkable stability in salmon use" by Native Americans over a 7,500-year period and this record showed resilience in the ecological–human system (Campbell and Butler 2010). By 1870, Euro-Americans dominated the salmon fisheries and their management and, in the relatively short expanse of ~150 years, the switch from the subsistence fisheries of Native Americans to the commoditized industrial fisheries of Euro-Americans depleted the Pacific salmon (Figure 5). By 1991, the decline was clearly defined by Nehlsen et al. (1991), who reported that 101 Pacific salmon stocks were at high risk of extinction, 58 at moderate risk of extinction, and 54 of special concern in the states of California, Oregon, Idaho, and Washington. By this time, one stock, the Sacramento River winter Chinook Salmon *O. tshawytscha* was already listed as threatened under the ESA.

Commercial exploitation commenced in 1829 when ships entering the Columbia River left with barrels of salted salmon (Lichatowich 1999). The poor marketability of salted salmon on the East Coast—owing to a lack of flavor—precipitated a new method of preserving the fish, canning, which was developed by four Maine fishers, George, John, William, and Robert Hume, and their friend Andrew Hapgood on the Sacramento River, California (Craig and Hacker 1940). They solved the problem of poor taste and launched the salmon canning industry, which initiated the decline in Pacific salmon on the Columbia River. Hapgood was the key as a tinsmith with experience making cans, and also canning Atlantic Salmon and American lobster *Homarus americanus* in Maine. The Hume brothers and Hapgood set up a cannery on a barge in the Sacramento River in 1864 (NPS 2018) and, in their first year, produced 2,000 cases of canned salmon.

Environmental or Social Event

Fisherman's Wharf, Santa Cruz, California (*circa* 1900). Historic postcard. Courtesy: Gary Whelan

Grassy Island Fishery in the Detroit River (1874). Courtesy: U.S. Commission of Fish and Fisheries

1870 *(Continued)*

Legislation

1877 | US | Nevada fish commission established

1877 | US | West Virginia fish commission established

1878 | US | South Carolina fish commission established

1879 | US | Delaware fish commission established

1879 | US | Illinois fish commission established

1879 | US | Nebraska fish commission established

1879 | US | Texas fish commission established

1879 | US | Washington fish commission established

1879 | US | Wyoming fish commission established

1880

1881 | US | Arizona fish commission established

1881 | US | Tennessee fish commission established

Figure 5. Pacific salmon catch from the Eel River, Humboldt County, California, *circa* 1900. Historic postcard. Courtesy: Gary Whelan.

They realized the Sacramento River and its salmon were being destroyed by hydraulic gold mining, so they moved to the Columbia River. Their move to the Columbia River began a process that would characterize the industry; move into a river, massively exploit the salmon, and then move on to the next river. They settled at a place called Eagle Cliff on the Columbia River approximately 24.1 km west of Longview, Washington, and in their first year canned 4,000 cases of 48 cans, each weighing 1 pound. The importance of this new wealth-creating industry was quickly recognized. In 1860, the entire salmon fishery on the Columbia River was worth US$13,450 ($416,421 in 2020). By 1866, the first year of the Hume–Hapgood cannery, the value of their 4,000 cases of canned salmon alone was $32,000 ($517,180 in 2020; Lichatowich 1999).

The fishermen and cannery operators knew that Pacific salmon were vulnerable to the same threats that caused the collapse of the Atlantic Salmon fishery. They petitioned Spencer Fullerton Baird, the newly appointed U.S. Commissioner of Fish and Fisheries, for advice. He correctly identified what would cause the Pacific salmon to decline in abundance: overharvest, dams, and habitat degradation—issues that continue today. He believed that laws designed to prevent overharvest, dams, and habitat degradation would be unavailable, ineffective, and unnecessary. He proposed:

> A still better procedure, however, would be to employ the now well-understood methods of artificial multiplication of fish [Sic] so as to maintain the present numbers indefinitely, and even to increase them…. A small and inexpensive hatching establishment could easily be erected on the Columbia near one of the great spawning grounds and eggs hatched out in any…number (Baird 1875).

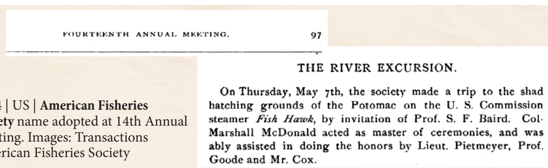
Baird viewed hatcheries as a necessary substitute for conservation actions, such as effective harvest regulation and habitat protection, because the political will for conservation was nonexistent. The fishermen and cannery operators in the Columbia River quickly grasped and interpreted Baird's proposal. A total of 170 of them petitioned the government through a letter published in the *Oregonian* newspaper that the only protection they wanted for their industry was hatcheries (Bottom 1997). The use of hatcheries as a substitute for conservation opened the door for a massive tradeoff of salmon habitat for hatcheries. Much of this exchange took place well before fish culturists knew how to culture salmon that could survive and return as adults in adequate numbers.

Canneries rapidly spread to every Pacific salmon river with sufficient numbers to keep the cannery line supplied with fish (Table 3). In the Pacific Northwest, the cannery pack peaked then declined before the second decade of the 20th century (Table 4). By 1920, the commercial harvest of salmon in the Columbia River was in steep decline, the result of excessive harvest and habitat degradation (Lichatowich et al. 1996). The wanton waste in this industry was exemplified by Mont Hawthorne, who moved to Astoria, Oregon in 1883 and worked in the canneries (Figure 6). He recalled throwing 500 large salmon off the end of the dock every other night as the cannery was beyond processing capacity (McKeown 1949). In 1932, the Oregon Fish Commission concluded that approximately 50% of the Columbia Basin's salmon habitat had been lost, based on data collected over 15 years (Oregon Fish Commission 1933). The last major salmon cannery on the Columbia River closed in 1980. The capitalist goal of economic efficiency unrestrained by regulations created horrendous waste and salmon population collapses.

Similar to the East Coast experience, the advent of ever-improved technology and harvest systems led to increased issues with managing salmon fisheries. Prior to the end of the 19th century, fishermen employed five types of gear to supply fish to the canneries: gill nets, beach seines, set nets, fish wheels, and traps. At the dawn of the 20th century a new fishery appeared, the offshore troll fishery. F. J. Larkin moved to Portland, Oregon with a new innovation, installing internal-combustion engines in fishing boats to increase fishing range. By 1906, 50% of the Columbia River fishermen's boats operating out of Astoria had Larkin's engines. Powered vessels could move out of the river and

Environmental or Social Event

1884 | US | **American Fisheries Society** name adopted at 14th Annual Meeting. Images: Transactions American Fisheries Society


FOURTEENTH ANNUAL MEETING. 97

THE RIVER EXCURSION.

On Thursday, May 7th, the society made a trip to the shad hatching grounds of the Potomac on the U. S. Commission steamer *Fish Hawk*, by invitation of Prof. S. F. Baird. Col. Marshall McDonald acted as master of ceremonies, and was ably assisted in doing the honors by Lieut. Pietmeyer, Prof. Goode and Mr. Cox.

Large dredge mining operation-Alder Gulch area, Madison County, Montana (*circa* 1920s). Courtesy: Montana Heritage Commission 2016

1880 *(Continued)*

Legislation

1882 | US | Indiana fish commission established

1882 | CA | New Brunswick provincial fisheries established in Department of Agriculture

1884 | MX | Office of Aquaculture initiated state-sponsored fishery activities and promotion

1884 | CA | Quebec provincial fisheries authority initially established

1885 | CA | Ontario Fisheries Act establishes Ontario provincial fisheries authority

1885 | US | Montana fish commission established

1887 | US | Oregon fish commission established

1890

1892 | CA | Ontario Game and Fish Commission established

1897 | US | Florida fish commission established

1898 | CA | British Columbia provincial fisheries authority established

1899 | US | Idaho fish commission established

Table 3. Year of construction of the first cannery in selected rivers and regions in the Pacific Northwest of the USA (Cobb 1930).

State	River or Region	Year
Washington	Puget Sound	1877
	Grays Harbor	1883
	Willapa Bay	1884
	Queets River	1905
	Quinault River	1911
	Sol Duc River	1912
	Hoh River	1917
Oregon	Columbia River	1866
	Rogue River	1877
	Siuslaw River	1878
	Umpqua River	1878
	Coquille River	1883
	Tillamook Bay	1886
	Alsea River	1886
	Nehalem River	1887
	Nestucca River	1887
	Coos River	1887
	Yaquina River	1887
	Siletz River	1896
California	Sacramento River	1864
	Smith River	1878
	Klamath River	1888
	Noyo River	1917

Table 4. Peak cannery pack in cases of 48 one-pound cans of Pacific salmon at selected locations south of the Fraser River (Cobb 1930).

Location	Year	Cases of 48 Cans
Sacramento River	1882	200,000
Columbia River	1895	634,696
Willapa Bay	1902	39,492
Oregon Coastal	1911	138,146
Grays Harbor	1911	75,941
Klamath River	1912	18,000
Puget Sound	1913	2,583,463
Coastal Washington	1915	31,735

fish the marine waters creating the new fishery with 2,000 boats plying the waters off the Columbia River by 1920 (Lichatowich 1999).

Figure 6. Pacific salmon at Seattle, Washington cannery, *circa* 1900. Courtesy: Jim Lichatowich.

The rapid growth of the troll fishery had important consequences. Salmon undertake long ocean migrations so when the salmon fishery largely moved from the rivers to the ocean, the harvest included salmon from California to Alaska from a broad mixture of stocks from different rivers. The river of origin of harvested salmon was unknown, making it impossible to ensure sufficient escapement of each population to its home stream. This unresolved problem was recognized as early as the 1920s (Washington State Fisheries Board 1925) and was confirmed through tagging studies (Rich 1939).

Fisheries allocation battles continued in various venues and courts through the 1980s and included the development of management plans by the federal agencies and the tribes. The federal court case *United States v. Oregon* (302 F. Supp. 899) ordered that the 1977 Columbia River Fish Management Plan be limited to allocation issues between non-Indian and Indian fisheries in the Columbia River. The court also recognized that a more comprehensive management plan was necessary to contribute to the recovery of salmon and steelhead *O. mykiss*. During the same period, the development of the Columbia River basin water resources by large dams was nearly complete. In 1980, the U.S. Congress passed the Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501, 94 Stat. 2697), which set up the Northwest Power Planning Council (later renamed the Northwest Power and Conservation Council). This Act authorized Idaho, Montana, Oregon, and Washington to develop a regional power plan and a fish and wildlife program to balance the Northwest's environment and energy needs. The 1986 Columbia Fish Management Plan expanded the salmon allocation process

Environmental or Social Event

1900 | US | City of Chicago reverses flow of Chicago River from Lake Michigan to Des Plaines River/Illinois River. Construction May 22, 1895. Photographer unknown. Courtesy: Metropolitan Water Reclamation District

Lake Huron-pound net fishermen and Lake Sturgeon *Acipenser fulvescens* catch. Source: Ontario Game and Fisheries Commission (1912). Courtesy: John M. Casselman

1890 *(Continued)*

1899 | US | Rivers and Harbors Appropriation Act of 1899 {33 U.S.C 403; Ch. 425, 30 Stat. 1151}

1900

1900 | US | Lacey Act {16 U.S.C. 3371-3378; 18 U.S.C. 42-43}

1902 | US | The Reclamation Act {Ch. 1093, 32 Stat. 388}

1903 | US | New Mexico fish commission established

1908 | US | Louisiana fish commission established

1909 | US | North Dakota fish commission established

1909 | US | South Dakota fish commission established

1909 | CA-US | Boundary Waters Treaty of 1909 established International Joint Commission

Legislation

to ocean fisheries south of the USA–Canada border and addressed hatchery production issues.

Based on studies of fin-clipped fish, fisheries managers knew that Columbia River salmon migrated north of the USA–Canadian border, but the effect of ocean fisheries could not be reliably quantified. That changed with the advent of the coded-wire tag, which was developed in the late 1960s. Data collected from coded-wire tags allowed estimates of the stock composition in specific fisheries and fishing effects on specific populations across fisheries. Pacific Northwest tribes and others used the coded-wire-tag information to support claims that salmon originating from the southern United States. and caught in southeast Alaska fisheries should count in the non-Indian allocation. The tribes filed suit in federal court, but these cases were put on stay with adoption of the Pacific Salmon Interception Treaty in 1985.

After decades of negotiations, the USA and Canada agreed to the Pacific Salmon Interception Treaty (Shepard and Argue 2005). The status of salmon populations, the ability to quantify interceptions, and the threat of lawsuits domestically in the USA all contributed to the completion of this treaty (Jensen 1986). Ocean Chinook and Coho Salmon *O. kisutch* fisheries in British Columbia and Southeast Alaska were managed for a ceiling catch. The hope was that enhancement activities and improvements in environmental conditions would increase populations and lower exploitation to below agreed upon rates (Brown 2005). In 1998, the Chinook Salmon provisions were modified to an abundance-based management regime (Buck 2006).

Despite efforts to control harvest, improve habitat and fish passage conditions at dams and other barriers, and the large-scale stocking of hatchery fish, many populations in the Columbia River Basin remained at depressed levels through the 1990s (Williams 2006). An exception was the Hanford Reach fall Chinook Salmon, which benefited from harvest constraints and the Vernita Bar Water Management Agreement to protect the spawning grounds. The result was large returns of Hanford Reach fall Chinook Salmon in the late 1990s.

As a result of conservation measures and favorable environmental conditions, Pacific salmon returns to the Columbia River increased in the early 2000s. In 2000, the improved return of Sockeye Salmon *O. nerka* resulted in the first commercial fisheries in 11 years. In 2001, the largest return of upriver spring Chinook Salmon since 1938 was recorded, and commercial fisheries were opened for the first time in 23 years. Improved summer Chinook Salmon returns in 2002 resulted in the first mainstem recreational fishery since 1973 and the first treaty Indian commercial fishery in 36 years. Returns have decreased since the peak in the early 2000s, but remain sufficiently healthy to allow limited fisheries.

Continued low returns for many Columbia Basin salmon and steelhead populations have led to renewed efforts to list populations for protection under the ESA. The first attempts to list salmon for protection under the ESA occurred in the 1980s, with status reports prepared for several Snake River salmonid populations, but the National Marine Fisheries Service initially concluded the listings were unwarranted, partly due to the mitigation program envisioned under the Northwest Power Act (Volkman and McConnaha 1993), until overwhelming evidence required the Snake River Sockeye Salmon to be listed in 1991. With continuing harvest and anthropogenic issues known for the last 150 years, Pacific salmon are currently extinct in 40% of their historical range (The Wilderness Society 1993) and 26 evolutionary significant units are protected under the ESA.

The great salmon resource of the Pacific Northwest withstood 7,500 years of stable harvest by Native Americans; then with the arrival of Euro-Americans, declined to the brink of extinction in a short 150 years. The decline resulted from the belief that engineering solutions, hatcheries, and fishways could substitute for conservation, which led to poorly regulated fishing mortality, inadequate habitat protection, and large dam construction. This was facilitated by the massive trade of salmon habitat for hatcheries. The resource allocation conflicts in this case history were the same that initiated the formation of fish commissions and AFS, and they continue today with nearly all of the same constraints.

The Mexican Experience – The Story Remains the Same South of the Border

Mexican fisheries resources were also considered overexploited during the period from 1872 through the 1930s when concerns with foreign fishing fleets became paramount. The 1930s were marked by protectionist efforts to defend fisheries against foreign exploitation (Martínez Martínez and González Laxe 2016). Regulations by the Department of Forestry, Hunting, and Fishery and the General Law of Cooperatives (1938), assigned fishermen's cooperatives exclusive access to the most important fish stocks including shrimp, abalone, and lobster (Aguilar et al. 2000; Espinoza-Tenorio et al. 2011) within Mexico's 9 miles of exclusive economic zone, which was later enlarged. This decade saw the initiation of recurrent 6-year policy changes associated with public administration turnover that continue today and have generally impeded adoption of stable management strategies (Guzmán del Próo 2012).

Between the 1940s and the 1970s, a new fishing law (1947) regulated industrial and commercial fisheries imposing fishing restrictions during reproductive seasons for some stocks and also gear controls (i.e., banning trawl fisheries). This was also a period of intensive agricultural and industrial growth,

Environmental or Social Event

Unregulated Lake Herring *Coregonus artedi* catch, Lake Erie near Sandusky, Ohio (*circa* 1916). Courtesy: U.S. Bureau of Fisheries

1905 | US | Gifford Pinchot named first Chief of the U.S. Forest Service

Sea Lamprey *P. marinus* attached to a Lake Trout *Salvelinus namaycush*. Courtesy: M. Gaden, Great Lakes Fishery Commission

1921 | CA-US | Sea Lamprey *Petromyzon marinus* first reported in Lake Erie. Dymond (1922), *in* Hubbs and Pope (1937)

1910

1920

Legislation

1910 | CA | Canadian federal government allows Ontario to increase provincial involvment in fisheries

1911 | US | Weeks Act enacted {16 U.S.C. 515; Ch. 186, 36 Stat. 961}

1915 | US | Oklahoma fish commission established

1917 | US | Flood Control Act of 1917 enacted {Ch. 144, 39 Stat. 948}

1920 | US | Federal Power Act {16 U.S.C. 791-828c; Ch. 285, June 10, 1920; 41 Stat. 1063, as amended by 41 Stat. 1353}

1923 | MX | Fishery regulations developed

1924 | US | Clarke-McNary Act enacted {Ch. 348, 43 Stat. 653}

1925 | MX | First Mexico Fishery law enacted which saw state-sponsored efforts and programs (the "March to the Sea" and "Maritime Progress") to renovate the Mexican fishery fleet. It was also the start of applied fisheries management research via the inception of what would become the research-oriented National Institute of Fisheries. Improvements to the Mexican fleet and strengthening of national fishing cooperatives continued into the early 1980s with strong federal and state government involvement. A new Federal Law for Fishery Promotion (1972) and the first National Plan of Fishery Development were enacted to promote development of the fisheries sector (Soberanes 1994; Espinoza-Tenorio et al. 2011). The strengthening of the fishery sector and the implementation of natural coastal and marine protected areas in this period of rapid national growth also saw a doubling of the national population and an oil boom, both causing environmental deterioration. Additionally, fishery management duties continued to switch between administrative agencies and secretariats, impeding implementation of consistent policies between *sexenios* (the 6-year presidential term).

Significant administrative changes were made from the mid-1980s to the mid-1990s with passage of the Federal Fishery Law (1986), which was amended in 1992. This law aimed to fully exploit federal fisheries resources and diminish state control of fishing activities. Fishing cooperatives lost exclusive rights to fisheries and gained independence, the private sector gained access to fisheries, and institutions dedicated to funding fishery expansion disappeared or were privatized. At the same time, increased attention to environmental protections led to Ecological Ordinance Programs regulating fisheries in marine and coastal areas, and federal Mexican standards were developed to detail management requirements for commercial and threatened species. By 1994, fishery management had become the realm of the Secretary for Environment, Natural Resources, and Fisheries, which was the first government agency responsible for reconciling the use and conservation of natural resources. The amended Fisheries Law and the recent National Program for Responsible Fisheries promoted creation of the National Fisheries Commission (CONAPESCA) and the National Fishery Chart (2000), whose aim to date has been to control fishing effort by regulating gear use and detailing fishing-ground opportunities and access (Espinoza-Tenorio et al. 2011). This period saw the implementation of several additional coastal and marine protected areas and increased concern over fisheries conditions (Arreguín-Sánchez and Arcos-Huitrón 2011; Espinoza-Tenorio et al. 2011).

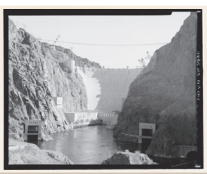
In the 2000s, agencies tasked with environmental issues and the fisheries sector were once again separated following government policy changes. Today, fisheries management is in the realm of CONAPESCA (2001) under the Secretary of Agriculture, Livestock, Rural Development, Fisheries, and Food. A 2007 Sustainable Fishery and Aquaculture General Law gave states and municipalities more decision-making power and promoted co-responsibilities among local users. Management policies (i.e., Federal Rector Program for Sustainable Fishery and Aquaculture) were implemented to, at least on paper, address long-term fisheries problems (Espinoza-Tenorio et al. 2011; Arreguín-Sánchez and Arcos-Huitrón 2011). Yet, nationally, by 2009, 46% of the fisheries stocks were at maximum exploitation; 28% were overexploited, 7% were in development, and 18% collapsed (Arreguín-Sánchez and Arcos-Huitrón 2011; Espinoza-Tenorio et al. 2011).

While the Mexican fishery has lately adopted environmental perspectives that should lead to better resource conservation, the policies have generally lacked long-term stability that would allow their implementation and science-based evaluation. Today, Mexican fisheries attain annual yields of approximately 1.3 million tonnes and dominant export-oriented commercial fisheries are tuna, sardines, and shrimp. The rest are small-scale fleets, or data-deficient artisanal fisheries of tremendous importance for subsistence and local consumption. Freshwater aquaculture has increased in the country, particularly since the 1970s, but most operations have favored non-native species commonly stocked into more than 4,000 reservoirs in the country. Overcapacity, obsolete vessels, commercial monopolies, loan-payment failures, and lack of fishing effort control remain in many of the country´s fisheries (Csirke et al. 2005).

Despite the above, fisheries remain a key resource in Mexico, which needs to provide protein for a largely (42%) impoverished population, nationwide. To do so, implementation of science-based strategies to administer resource use and importantly, ecosystem-based management strategies for habitat conservation and protection, are needed and require administrative continuity to be successful. The advantages of this approach include, but are not limited to: providing more stability and resilience from ecosystem-wide regulatory measures; allowing the examination of the effects of management actions on individual and aggregated system components, along with responses to multiple stressors; and the ability to balance individual priorities along with social and ecosystem needs (National Marine Fisheries Service 2016). The lessons from this case history are much like those in the rest of the continent, mirroring the same reasons for fisheries exploitation, as well as formation and policy needs of fisheries commissions and their successor agencies, and AFS.

Environmental or Social Event

Hoover Dam, Colorado River. Source: Library of Congress, Prints & Photographs Division, HAER NV-27-7



1931 | US | Susquehanna River- four hydroelectric dams completed (Wolensky 2016)

1931-1936 | US | Hoover Dam constructed on Colorado River

1933-1941 | US | Civilian Conservation Corps (CCC) established

Bonneville Dam spillway construction, January 1, 1937. Source: Library of Congress, Prints & Photographs Division, Image: HAER ORE, 26-BONV,2-F--87, Photographer R. W. Oliver

1933-1938 | US | Bonneville Dam constructed on Columbia River

1933-1941 | US | Grand Coulee Dam constructed on Columbia River

1930

Legislation

1930 | CA | Constitution Act of 1930, established provincial fisheries in Manitoba, Alberta, Saskatchewan

1932 | US | Mississippi fish commission established

1933 | US | Tennessee Valley Authority Act {16 U.S.C. 831, 48 Stat. 58-59}

1934 | US | Fish and Wildlife Coordination Act {16 U.S.C. 661-667e; the Act of March 10, 1934; Ch. 55, 48 Stat. 401}

1935 | US | Grand Coulee Dam Project (Columbia River) {Ch. 831, 49 Stat. 1028}

1936 | CA | Newfoundland Fisheries Research Board founded, Newfoundland provincial fisheries agency established

1938 | MX| General Law of Cooperatives enacted

1938 | US | Rivers and Harbors Act of 1938 {33 U.S.C. 540, and other U.S.C. Sections; Ch. 535, June 20, 1938; 52 Stat. 802

1939 | US | Bureau of Fisheries transferred from Department of Commerce to Department of Interior

HABITAT ALTERATION CASE HISTORIES

In concert with fisheries exploitation, another causative factor contributing to formation of fish commissions and AFS was continent-scale habitat alteration, which included construction of dams and mining. The following brief case histories explore the scale of these modifications, highlighting a few of the many insults to North American ecosystems, including their effects and outcomes. Many of these issues remain with us today and the legacy effects from these resource decisions are readily apparent across the continent from actions taken as far back as 200 years ago. This section concludes with an emerging threat of climate change that, if model predictions are realized, will cause historic and landscape-scale changes complicating fisheries professionals' efforts to rehabilitate previously damaged systems.

A Vastly Altered Landscape – The Great Lakes, Midwest, and Plains

The Midwest region of North America in the early 1800s was a land of seemingly unlimited resources including vast dense forests, unhabitable swampland, and an endless sea of tallgrass. These remarkable resources supported a broad range of equally "limitless" fisheries resources in the Great Lakes, Great Rivers, and many smaller inland lakes and rivers as described by Captain Daniel Bradley in September 1793 for the Great Miami River near Hamilton, Ohio (Wilson 1935):

> ….On September 3, we caught 2,500 weight of fish and as about as many on the 4th, which makes 5,000 weight in two nights. The fishes taken were [sic] Buffelow, Pearch, Catfish, Ells, etc. We have more fish than the whole garrison can make use of.

Similarly, Farmer (1890) stated that the catch of coregonids from the Detroit River was 3,500 barrels per year with an amazing 30,000 whitefish, likely Lake Whitefish *Coregonus clupeaformis,* caught at Grosse Isle, Detroit River on October 23, 1824. The Lewis and Clark journals provide many descriptions of capturing fish, in particular large catfishes (Siluriformes), from the Missouri River during their Voyage of Discovery (Ambrose 1997; Schainost 2010). The wholesale transformation of this landscape from prairies, forests, and wetlands to agriculture and urban areas along with logging of the old growth forests was a significant contributing factor to the decline of the continent's fisheries legacy in this region and resulted in the call for the establishment of fisheries commissions to "fix" the fisheries problems.

Prairies

Historically, North American prairies covered 240 million acres (970,000 km^2), with most of this land cover occurring in the central United States. Today, only 1% remains in the USA and 24% in Canada (Winkler 2004). Nearly all of this landscape was permanently converted to agriculture involving multiple actions, such as busting of sod across the region and establishing permanent drainage networks to drain wet areas (McCorvie and Lant 1993; Shirey et al. 2020). Additionally, poor soil and crop management until the late 1930s resulted in the "Dust Bowl" and associated huge loss of topsoil across the region, as did plowing to the riverbanks. This change has been permanent, with only minor rehabilitation and restoration in this ecotype.

Forests

In 1600, forest cover in the United States was 1.044 billion acres (4,224,918 km^2), but was reduced to 737 million acres (2,982,533 km^2) by 1992 (USDA–FS 1989; MacCleery 1993) with 319 million acres (1.3 million km^2) converted to cropland by 1900, with most of this loss in the Midwestern United States. Much of this lost forestland was converted into products required for settlement and transportation including: 3.2 million miles of split rail fencing; 20–40 cords of wood annually for each household's heating; railroad ties requiring 15–30 million acres (60,702–121,405 km^2) of forest through 1900; steamboats requiring 900,000 cords annually in 1840; and 20,000–30,000 cords annually for each iron works. From 1850 to 1900, wood product use was six times greater than the sustainable wood volume produced during this period, which mirrored the rate of U.S. population growth. During this time, wood consumption for construction rose from 5.4 billion board feet in 1850 to 44.5 billion board feet by 1900 (USDA–FS 1989; MacCleery 1993). These estimates for wood consumption from the Midwestern USA are likely similar for other parts of the continent. An example of the landscape-scale implications of this conversion is demonstrated in Ohio, which changed from 96% hardwood forest in 1800 to 25% by 1900, and in Michigan, 160 billion board feet were cut by 1896 (Michigan State Extension 2015).

One result of cutting old-growth forests was the leftover slash, creating conditions for landscape-level fires, which occurred annually, often burning from coast to coast, and completely consuming any residual organic material from logging or in forest soils. The outcome was a wasteland that in many areas could not be adapted for any other purpose (Figure 7). These lands were considered unusable, and generally abandoned by the 1930s, and thus were either purchased by state or federal governments or were tax-reverted back to the states or counties, becoming the backbone of today's public land holdings. Similar experiences were documented for all forested states where the lands were marginal for agricultural purposes.

By 1920, forest cover stabilized in the United States at approximately 600 million acres (24.3 million km^2) then slightly

Environmental or Social Event

Fish culturalists (May1949). Courtesy: Pennsylvania Fish & Boat Commission

Everglades drainage canal near Miami, Florida between 1910-1920. Source: Library of Congress, Prints & Photographs Division, Detroit Publishing Company Collection, Digital ID det 4a24101

1947 | US | *The Everglades: River of Grass* published by Marjory Stoneman Douglas

1940

Legislation

1942 | US | Atlantic States Marine Fisheries Compact-ASMFC {P.L. 80-77, 56 Stat. 267}

1946 | US | Administrative Procedure Act {P.L. 79-404, 60 Stat. 237}

1947 | MX | Regulations imposed on industrial & commercial fisheries seasonal and gear restrictions

1947 | US | Pacific (States) Marine Fisheries Compact-PSMFC {P.L. 80-232, 61 Stat. 419}

1948 | US | Federal Water Pollution Control Act (Clean Water Act) {33 U.S.C. 1251-1376; Chapter 758; P.L. 845, 62 Stat. 1155}

1949 | US | Gulf States Marine Fisheries Compact {P.L. 81-66, 63 Stat. 70}

1949 | US | Alaska fish commission established

1950

1950 | US | Dingell-Johnson Federal Aid in Sportfish Restoration Act {16 U.S.C. 777-777k; 64 Stat. 430}

1954 | CA-US | Convention on Great Lakes Fisheries {6 U.S.T. 2836, TIAS 3326}

1956 | US | Colorado River Storage Project Act {43 U.S.C. 620; 70 Stat. 105}

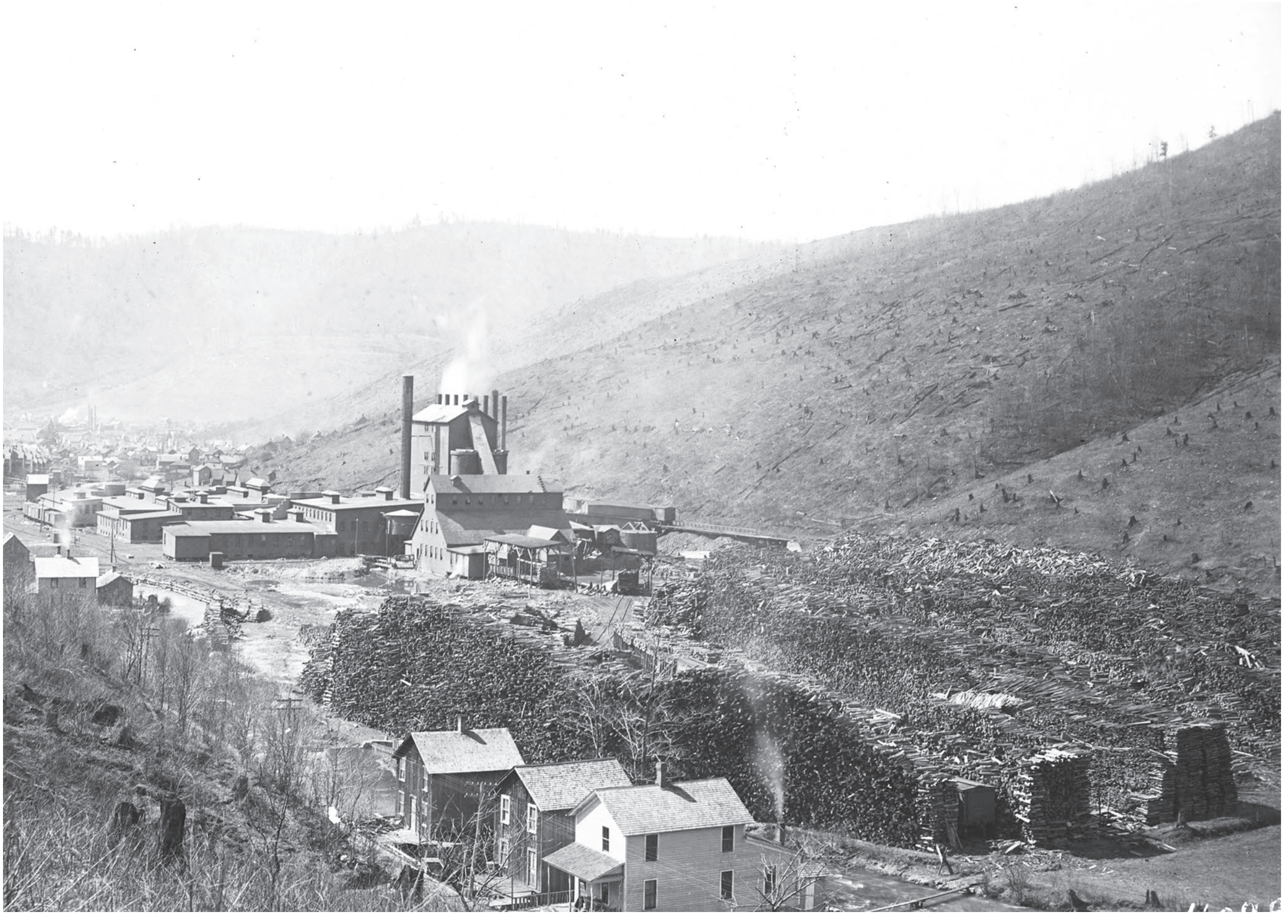


Figure 7. Industrial logging in Pennsylvania, late 1800s to early 1900s. Photographer William T. Clarke. Image RG-6.20; #4099. Courtesy: Pennsylvania Historical and Museum Commission, Pennsylvania State Archives, Harrisburg.

increased through 2017 to 823 million acres (33.3 million km^2), about one-third the United States landscape (MacCleery 1993; Oswalt et al. 2019). As with the decline, stabilization and subsequent increase in forest cover were brought about by several factors, particularly reforestation, that were encouraged by fisheries agencies and AFS. Improvements in agricultural productivity resulted in the conversion back to second-growth forests of many low productivity farms in the eastern and Midwestern parts of the continent, although often to very different forest types from the original old-growth forest. In the United States, fire management improved through legislative action of the Weeks Act of 1911 and the Clarke–McNary Act of 1924, enhancing federal and state coordination. Reforestation and tree planting efforts that started in the 1920s and 1930s greatly increased by mid-century and were coupled with a reduction in wood needs by society for purposes noted above. Finally, the rise in professional forest management, which began in the 1910s, increased following World War II with development of large industrial forest holdings (MacCleery 1993).

Wetlands

Wetlands provide direct fisheries benefits and have undergone declines similar to forests. In 1800, wetlands covered 392 million acres (1.6 million km^2) of the USA with 211–221 million acres (853,886 to 894,355 km^2) of coverage in the contiguous states (Dahl 1990). Much of the North American landscape not covered by forests or prairies was

Environmental or Social Event

Paper mill effluent, Androscoggin River (*circa* 1973). Photographer: Charles Steinhacker. Courtesy: National Archives

1952 | US | Cuyahoga River catches fire, Cleveland, Ohio

1959 | US | Trout Unlimited founded

1962 | US | *Silent Spring* published by Rachel Carson

1968 | US | Bass Anglers Sporting Society founded

Detroit River Industrial Complex, Wayne County, Michigan. Courtesy: Michigan Department of Natural Resources

1950 *(Continued)*

Legislation

1956 | US | Fish and Wildlife Act of 1956 {16 U.S.C. 742a-742j, 742 d-l; 70 Stat. 1119}

1956 | US | Great Lakes Fishery Act {16 U.S.C. 931-939c; P.L. 557, 70 Stat. 242}

1958 | US | Fish and Wildlife Coordination Act {P.L. 85-624, 72 Stat. 563}

1959 | US | Hawaii fish commission established

1960

1963 | US | Clean Air Act of 1963 {P.L. 88-206}

1964 | US | Commercial Fisheries Research and Development Act of 1964 {P.L. 88-309, 78 Stat. 197}

1964 | US | Wilderness Act {16 U.S.C 1131-1136; P.L. 88-577, 78 Stat. 890}

1965 | US | Anadromous Fish Conservation Act {16 U.S.C. 757a-757g; P.L. 89-304, 79 Stat. 1125}

1966 | US | An Act for the conservation, protection, and propagation of native species of fish and wildlife {P.L. 89-669, 80 Stat. 926}

Table 5. Selected effects of habitat alterations, system response, and current status with relevant laws by process/factor as detailed in Whelan (2019). Effects, responses, and laws are not all inclusive and provide key examples for each process/factor.

Process/ Factor: Hydrology		
Conversion Effect	**System Response**	**Current Status**
• Increased peak flows and reduced baseflows from hardened surfaces and agricultural drainage projects. • Altered hydrographs from water projects with dams and diversions.	Urban and agriculture • Channel widening due to peak flow adaptation, • Increased sediment transport • Reduced pool volumes • Increased sediment deposition in receiving waters • Destabilized channels • Reduced watershed storage capacity with decreased wetlands Water projects • Loss of natural peak and base floods • Alteration of natural hydrograph with life history cue loss for aquatic biota	• Ongoing Impairment with rehabilitation in some areas • Rehabilitation in USA using a. Federal Energy Regulatory Commission Project licensing proceedings (Federal Power Act of 1920; 41 Stat. 1353 as amended and b. Clean Water Act of 1972; 86 Stat. 816 as amended), at large federal water projects c. Fish and Wildlife Coordination Act of 1934; 48 Stat. 401 as amended and Clean Water Act of 1972; 86 Stat. 816 as amended) and in state water adjudication proceedings. • In Canada, rehabilitation through Federal Fisheries Act (R.S.C., 1985, c. F-14 as amended).
Supporting Literature: Novak et al. (2016)		

Process/Factor: Geomorphology		
Conversion Effect	**System Response**	**Current Status**
• River channelization and channel alteration by agriculture and log transport • Altered sedimentation rates from hydrograph changes	• Homogenization of river and stream habitat • Lateral connectivity loss • Nutrient dynamics changes • Loss of rapids and rock outcrops by log transport requirements • Channel destabilization	• Impairment continues today • In the USA, some rehabilitation using the Clean Water Act of 1972, federal grants, and through state proceedings. • In Canada, rehabilitation through the Federal Fisheries Act.
Supporting Literature: Brooker (1985); Bukaveckas (2007); Elosegi and Sabater (2013); Kennedy and Turner (2011); Sedell and Duval (1985); and Shankman (1996)		

Process/Factor: Material Transport and Recruitment		
Conversion Effect	**System Response**	**Current Status**
• Greatly altered riverine sediment recruitment and transport rates from: a. unnaturally high peak flows and gullying by agriculture, b. splash dam construction (Figure 9) for log transport along with log drives (Figure 10), and c. use of river high banks as log rollways. • Complete alteration of large woody debris recruitment and transport by logging all old growth tree and removal of natural log jams	• Homogenization of river and stream habitat • Destabilized channels by changed sediment recruitment and loss of large woody debris aggraded stream beds • Disrupted connectivity • Altered receiving waters (i.e., lakes, estuaries and larger rivers)	• Impairment continues from legacy effects with rehabilitation evident from reforestation efforts and termination of log drives across continent. • Additional rehabilitation using U.S. Farm Bill conservation programs and non-point pollution funding from Clean Water Act of 1972.
Supporting Literature: Higgins and Reinecke (2015); Sedell et al. (1991); Sedell and Duval (1985); Trimble (1981, 1999); and Wohl (2014)		

Process/Factor: Connectivity		
Conversion Effect	**System Response**	**Current Status**
• Disruption and complete loss of connectivity for material transport and biota by the large scale conversion of lotic to lentic habitat by construction of splash dams (five to hundreds per watershed in Oregon, Minnesota, Wisconsin and Michigan), and mill dams starting at the first high gradient reach and reaching watershed densities up to 0.61/km^2	• Fragmentation, loss of connectivity for material transport downstream • Long-term aggregation of sediment that filled valleys • Disruption and loss of adfluvial, potamodromous, and local fish and water associated wildlife movements • Complete alterations in fish community composition	• Impairment continues from legacy dams in Northern Hemisphere and new construction in Mexico. • Rehabilitation seen with the removal of obsolete dams and installation of fish passage in the USA (U.S. Fish and Wildlife Service Fish Passage Program and U.S. Environmental Protection Agency Grants) and Canada (Federal Fisheries Act).
Supporting Literature: Arnott et al. (2013); Higgins and Reinecke (2015); Miller (2010); Walter and Merritts (2008)		

Continues

Environmental or Social Event

1969 | US | Santa Barbara, California oil spill. Union Oil Platform A, Collection SBHC Mss 10. Courtesy: Department of Special Research Collections, UC Santa Barbara Library, University of California, Santa Barbara

1970 | US | *EARTH DAY* first celebrated (April 22nd)

1970 | US | National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) established

Earthrise, December 24, 1968; Image by Apollo 8 Astronaut William Anders. Courtesy NASA

1960 *(Continued)*

Legislation

1968 | CA-US | Great Lakes Basin Compact Congressional consent {P.L. 90-419; S 660}

1968 | US | Wild and Scenic Rivers Act {16 U.S.C. 1271-1287; P.L. 90-542, 82 Stat. 906}

1969 | US | National Environmental Policy Act (NEPA) of 1969 {42 U.S.C. 4321-4347; P.L. 91-190, January 1, 1970, 83 Stat. 852}

1970

1970 | US | Clean Air Amendments of 1970 {42 U.S.C. 7401; P.L. 91-604, 84 Stat. 1676}, amends Clean Air Act of 1963 {P.L. 88-206}

1972 | US | Coastal Zone Management Act {16 U.S.C. 1451-1464, Ch. 33; P.L. 92-583, October 27, 1972, 86 Stat. 1280}

1972 | US | Federal Water Pollution Control Act-Clean Water Act of 1972 {33 U.S.C. 1251; P.L. 92-500, 86 Stat. 816}

1972 | US | Federal Environmental Pesticide Control Act {7 U.S.C. 136-136y, P.L. 92-516, October 21, 1972, 86 Stat. 973}

1972 | CA-US | First Great Lakes Water Quality Agreement (GLWQA) signed

1972 | US | Marine Protection, Research and Sanctuaries Act {33 U.S.C. 1401-1405; P.L. 92-532, October 23, 1972, 86 Stat. 1052 and 1061}

Table 5. Continued

Process/Factor: Water Quality		
Conversion Effect	**System Response**	**Current Status**
• Massive increases in nutrient, toxicants, and chemical loadings from untreated wastes and sawdust from cities and factories (Figure 11)	• Entire sections of watersheds had little or no aquatic life from eutrophication, toxics, or no dissolved oxygen • Accumulations of materials was so extreme that rivers ignited (Figure 12) • Organic loadings caused large scale anoxic conditions with some locations having so much sawdust that it was used to guide ships back to Columbia River and Great Lakes harbors	• Much improved from historical condition with localized impairments from code violations and legacy issues in the USA and Canada with non-point source pollution continuing as an issue. • Full implementation of U.S. Clean Water Act and similar legislation in Canada (Canada Water Act R.S.C. 1985, c. C-11 and provincial laws) have rehabilitated fisheries with some of the best fisheries in areas that were fishless or nearly fishless 50 years ago. • Impairments continue in Mexico due to population growth and untreated wastes even with passage of the National Water Law of 1992.
Supporting Literature: Hartig (2010); Lichatowich (1999)		

Process/Factor: Living Habitat		
Conversion Effect	**System Responses**	**Current Status**
• Removal of riparian woody cover changed water temperatures in forested areas • Changes to woody cover in riparian zones in prairie rivers • Hydrologic changes eliminated high flow events changing the riparian and instream communities, • Overabundant aquatic vegetation from excess nutrients altered water chemistry as noted above • Loss of freshwater mussel beds from connectivity loss, sedimentation, and overharvest	• Increased water temperatures and water chemistry altered fish community composition in forested systems • Loss of point bars, side channels, and cottonwood based riparian zones homogenized habitat in prairie systems • Loss of channel diversity and changed nutrient cycling from the loss of freshwater mussel beds	• Impairment continues today with some rehabilitation in all three countries (mostly in the USA and Canada) with changes in dam operations, land zoning and use restrictions, and implementation of water quality laws.
Supporting Literature: Friedman et al. (1988)		

covered by wetlands, with a large percentage of this landcover concentrated in the central part of the continent. By 1980, 53% of all the original wetlands in the contiguous states were converted to other uses (e.g., urban, agriculture [Figure 8], silviculture, and rural development), leaving 104 million acres or 5% of the United States landscape. In Alaska, another 170 million acres (687,965 km^2) of wetlands remain, with this amount mostly unchanged since 1800. In the contiguous United States, California lost the most by percentage (91%) of its wetland coverage, and Florida lost the most by area (9.3 million acres, 37,635 km^2), 46% of the state. Twenty-two states lost over 50% of their wetland coverage and in aggregate, the upper Midwestern USA lost 36 million acres (145,686 km^2) of wetlands in that period. Losses continued during the period from 1986 to 1997, when 644,000 wetland acres were converted to urban (30%), agriculture (26%), silviculture (23%), and rural development (21%) land uses (Dahl 2000). Wetland losses essentially stopped overall with some small increases noted during the period from 1998 to 2009 due to regulatory changes supported by AFS and improved recognition by society of the importance of wetlands (Dahl 2006, 2011).

Aquatic Habitat Implications

The results of these landscape-scale alterations from prairies, forests, and wetland to urban, agriculture, and rural development land uses completely changed the aquatic habitat of much of the continent. The range of effects and their status are summarized in Table 5, using the processes and factors from the National Fish Habitat Partnership (Whelan 2019). Thus, the degraded fisheries resulting from these continent-wide land use changes provided a major impetus and foundational reasons for establishing fish commissions and AFS. Improvements

Environmental or Social Event

Tellico Dam Construction, Tennessee
Source: Tennessee Valley Authority

1973 | US | Tennessee Valley Authority Tellico Dam construction delayed due to federally endangered Snail Darter *Percina tanasi* per provisions of the Endangered Species Act of 1973

Bighead Carp *H. nobilis*, collected on the Illinois River near Morris | Kevin Irons, Program Manager-Aquaculture and Aquatic Nuisance Species Program, Illinois Department of Natural Resources (IDNR). Courtesy: IDNR

1981 | US | First record of Bighead Carp *Hypophthalmichthys nobilis* in natural waters (Ohio River) of the United States. Source: Freeze and Henderson 1982; Kolar *et al.* 2005

1970 *(Continued)*

1980

Legislation

1972 | MX | Federal Law for Fishery Promotion and National Plan of Fishery Development

1973 | US | Endangered Species Act {16 U.S.C. 1531-1544; P.L. 93-205, 87 Stat. 884}

1974 | TR | Northwest Indian Fisheries Commission established

1976 | US | Magnuson-Stevens Fishery Conservation and Management Act {16 U.S.C. 1801; P.L. 94-265, 90 Stat. 331}

1976 | US | Water Resources Development Act of 1976 {33 U.S.C. 59m; 547a; 577; 579; 701e; 702a-12; 90 Stat. 2917}

1977 | TR | Columbia River Inter-Tribal Fish Commission founded

1977 | US | Surface Mining Control and Reclamation Act {P.L. 95-87, 91 Stat. 445}

1979 | CA | Canadian federal Department of Fisheries and Oceans established

1980 | US | Alaska National Interest Lands Conservation Act {16 U.S.C. 3111; P.L. 96-487, 94 Stat 2371}

1980 | US | Pacific Northwest Electric Power Planning and Conservation Act {16 U.S.C. 839; P.L. 96-501, 94 Stat. 2697}

Figure 8. Agricultural drainage project in a historic wetland, Potter Creek, Isabella County, Michigan, 1995. Courtesy: Michigan Department of Natural Resources.

in the processes and factors that have reduced the historic habitat impairments of the last 150 years have been enabled by the policy changes noted in Table 5 and below in the policy discussion. While the largest improvement has been seen in water quality, challenges remain in all processes and factors requiring ongoing attention from fisheries agencies and AFS. The legacies of this massive landscape alteration remain apparent in many parts of the continent, and fisheries professionals continue to rehabilitate abuses from 100 to 200 (or more) years ago. When the scale of modification is viewed in its entirety, it is remarkable that any aquatic communities remain, reflecting the resilience of these communities to catastrophic events.

The Really Big Dams

The numerous small mill and hydropower dams, as noted in Table 5, fragmented and degraded many river systems and were a clear habitat issue noted by early North American fisheries professionals and AFS. Yet, these structures pale in comparison to the environmental and social changes caused by development of orders of magnitude larger federal dams whose history in the USA is detailed in Billington et al (2005). In the United States at the start of the 20th century there were about 200 large impoundments (>100 ha). Invention of the light bulb, electrification of urban areas, and devastating floods aligned with development of the internal combustion engine and advances in civil engineering to trigger a boom in dam construction (Figure 13). The boom was fueled through much of the century by the Flood Control Act of 1917, Roosevelt's New Deal programs in 1933–1936, the Flood Control Act of 1937, and various River and Harbor Acts through the 1970s. The rise of reservoirs peaked in the 1950s–1970s and currently there are nearly 4,200 large impoundments totaling near 16 million hectares across the contiguous USA (Graf 1999). Throughout this rise in reservoirs, the AFS was deeply engaged in the debate about the effects of dams on fisheries and aquatic habitats, which influenced national and regional reservoir policy and provided a vital framework for information sharing.

Alarmed by the rapid reservoir development in the early 1900s and its effects on riverine fishes, AFS passed a resolution at the 1922 Annual Meeting in Madison, Wisconsin, to encourage agencies involved in dam construction to consider the needs of fishes and pledged "every aid possible in solving the biological phases of the problems" (American Fisheries Society 1923). This resolution was the first in a series of 28 AFS statements about reservoirs through 1968 (Benson 1970). Indeed, early in the 20th century AFS expressed great interest in reservoirs through resolutions that promoted fish passage, pollution abatement, increased research to advance management, and ultimately propelled the enactment of the Fish and Wildlife Coordination Act of 1934. This act directed the U.S. Bureau of Fisheries (now U.S. Fish and Wildlife Service) to use impounded waters for fish culture stations and mandated consultation between state fish and wildlife agencies and the Bureau prior to the construction of any new dams. This was further expanded to consultation with other federal agencies.

Two case histories are used to contrast the interactions between fisheries commissions and their successor fisheries agencies and AFS. The Tennessee Valley Authority (TVA) case history shows a symbiotic and mutualistic relationship between large dam projects and fisheries agencies and AFS. This relationship was created because there was no possibility of fisheries professionals interacting on whether the project would be built until its last decade of construction and the fisheries resources being altered were not of national significance at the time. In contrast, the Columbia River case history shows how fisheries agencies and AFS worked diligently to minimize the harm on Pacific salmon populations, a long fought over and nationally significant resource, and highlighting a much less collaborative relationship with water developers.

Environmental or Social Event

Central Arizona Water Project near Phoenix. Courtesy: Gary Whelan

Agricultural Drainage, Eaton County, Michigan. Courtesy: Michigan Department of Natural Resources

1980 *(Continued)*

Legislation

1981 | TR | Chippewa Ottawa Treaty Fishery Management Authority (COTFMA) established

1984 | TR | Great Lakes Indian Fish & Wildlife Commission formed

1984 | US| Atlantic Striped Bass Conservation Act {16 U.S.C. 5151-5158; P.L. 98-613, 98 Stat. 3187}

1985 | MX | General Law of Ecology (Ley General del Equilibrio Ecologico y Proteccion al Ambiente)

1985 | CA-US | Treaty Between the Government of the United States of America and the Government of Canada concerning Pacific Salmon {Vol. 1469, I-24913, pgs 357-400}

1985 | US | Food Security Act (Farm Bill) {P.L. 99-198, 99 Stat. 1354, December 23, 1985, Title XII, 16 U.S.C. 3801-3824, provisions contributing to wetland conservation}

1985 | CA | Canada Water Act {R.S.C., 1985, c. C-11} enacted

1985 | CA | Federal Fisheries Act {R.S.C., 1985, c. F-14} enacted

1985 | CA | Ontario passes Fisheries Act similar to federal legislation

1986 | MX | Federal Fishery Law enacted, allowing exploitation and diminished state controls

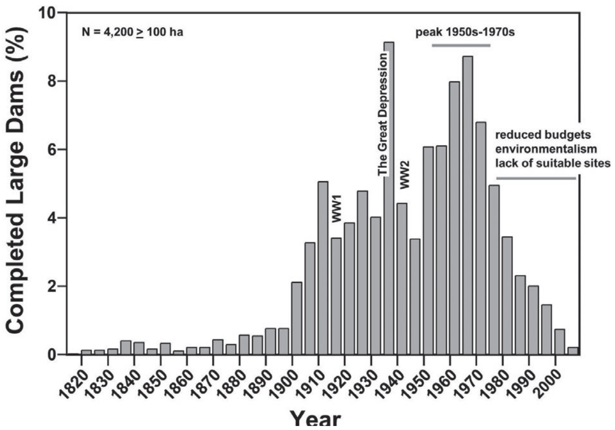


Figure 13. The rise of large dam and reservoir construction in the USA, 1815–2010. Selected events are identified (WW = World War). Data from Rodgers (2017).

Figure 16. Dalles Dam, Columbia River near The Dalles, Oregon, 1993. Courtesy: Gary Whelan.

TVA Case History

The TVA is a large federal dams project established in 1933 as one of President Franklin Delano Roosevelt's Depression-era New Deal programs. This project provided jobs and electricity to the rural Tennessee River Valley, spanned seven southern states while completely, and likely nearly forever, altering the Tennessee River ecosystem (Figure 14). The TVA was envisioned as a federally owned electric utility and regional economic development agency that also conducted social engineering. Among power companies, the TVA is unique as it was not created just to empower the economic aspects of southeast society, but also to "protect" the natural resources of the Tennessee River Valley. The TVA's reservoirs and altered rivers soon became a central fisheries resource in the south, leading to the interdependence of the evolving TVA and AFS as reservoir fisheries management was an unclear science, requiring investigation by fisheries professionals, and AFS was there to contribute.

The TVA began studying the effects of reservoirs on fishes in the mid-1930s. At the time, it was believed that after an initial expansion in fish recruitment, reservoirs had drastically lower fish production than natural lakes or rivers. James Henshall (1920) had warned:

> It has been said that the immense storage reservoirs to be constructed in connection with the reclamation projects will furnish a home and a haven for millions of fish—but not on your life. These reservoirs will be built in narrow mountain gorges, where the water will be too deep for fish life to exist, and the rocky bottom and sides will forever preclude the existence of fish food.

While Henshall's prognostics were unambiguous, others acknowledged that little was known about reservoirs. Emmeline Moore (1931) noted:

> The fact is we know little about how nature works on the sudden drowning of a valley, in what manner the biological and other factors operative in the newly created reservoir differ from the normal state of affairs in our natural lakes…

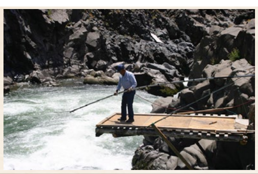
It was against this backdrop of uncertainty about reservoirs as fish habitats that Alvin Cahn (1937), chief of the newly created Biological Readjustment Division of TVA, announced at the 1936 AFS Annual Meeting in Grand Rapids, Michigan that TVA was building several hatcheries strategically located along the reservoir system in anticipation of the stocking needed to maintain adequate fish populations. Cahn (1937) stated:

> It is a familiar fact, which has been emphasized by Mr. Jay N. Darling, Dr. M. M. Ellis, and others, that impounded lakes become, after the first few years of their existence, decidedly lacking in fish productivity. Mr. Darling has referred to the results of dam construction as "biological deserts."

Discontent in the 1920s and 1930s with the perceived depressed biological productivity in reservoirs and the devastating effect of dams on anadromous fishes was evident in a resolution passed at the 1941 AFS Annual Meeting in St. Louis, Missouri (American Fisheries Society 1942):

Environmental or Social Event

Scaffold fishing on the Klickitat River, Washington. Courtesy: Columbia River Inter-Tribal Fish Commission



Mississippi, Missouri and Illinois Rivers near St. Louis, Missouri, before (1991-left) and during historic flood (1993-right). Source: NASA 2005. *Labeling by Diana Day*

1997 | INT | Kyoto Protocol on climate change enacted

1990 … **2000**

Legislation

1990 | US | Great Lakes Fish and Wildlife Restoration Act {16 U.S.C. 941; P.L. 101-537, 104 Stat. 2370, enacted November 8, 1990}

1990 | US | Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 {16 U.S.C. 4701; P.L. 101-646, 104 Stat. 4761}

1992 | MX | National Water Law of 1992 enacted

1992 | US | Clean Vessel Act of 1992 {33 U.S.C. 1322; P.L. 102-587, Subtitle V(F)}

1994 | US | Indian Self- Determination and Education Assistance Act amended {P.L. 93-638} (org. 1975)

1995 | CA-MX-US | Trilateral Committee for Wildlife and Ecosystem Conservation and Management formed

1995 | CA | Saskatchewan Fisheries Act enacted by Province of Saskatchewan

2000 | MX | National Fisheries Commission (CONAPESCA) and National Fishery Chart established

2000 | US | State and Tribal Wildlife Grants Program {P.L. 106-553, 114 Stat. 2762A-118}

> Whereas, these immense projects [high dams], present and planned for the future wholly ignore the biology of water, existing aquatic biological resources, and the public's right to enjoy them; and there are present threats to blanket the country with high dams;
>
> Therefore be it resolved, that the American Fisheries Society … oppose the authorization or construction of any more high dams regardless of their stated purpose until such time as biologists have an adequate role in the preliminary planning of all such projects.

During the 1940s, the TVA became a pioneer in reservoir fisheries research. Research included pre-impoundment faunal surveys, water quality and stratification, commercial and recreational fisheries interactions, creel surveys to estimate intensity and distribution of fishing as well as catch, reservoir productivity, and sampling and harvesting methodology (Eschmeyer 1942, 1943; Wiebe 1942; Smith and Miller 1943; Tarzwell and Miller 1943; Tarzwell 1945). These studies provided the foundation and inspiration for further advancement in reservoir research in the decades to come. Interestingly, and unfortunately, some studies conducted during that period were never published because researchers "left for the armed services" (Smith and Miller 1943). The TVA also established partnerships with the U.S. Bureau of Fisheries and state conservation commissions in the valley, setting the stage for future regional collaboration among southeastern states.

Results from these early TVA investigations questioned assumptions about reservoirs developing into biological deserts. Eschmeyer and Tarzwell (1941) reporting on their work in TVA reservoirs wrote:

> … the catch in the reservoirs is now undoubtedly far greater than it was in the river before the dams were built. There is little reason to believe that these impoundments will tend to become biological deserts after a few seasons.

Three years later Tarzwell (1945), summarizing TVA investigations, concluded:

> Contrary to preconceived notions, the investigations conducted to date indicate that fish populations in these reservoirs are large … legislation permitting netting should be liberal and legalize all types of gear … to provide food for the war effort, to protect the sport fishery [from competition with nongame fish], and to utilize the present market for the coarse species which has been created by the war, it is desirable that the commercial fishery in TVA main-stream reservoirs be expanded immediately.

That year, Tennessee opened its reservoirs to year-round fishing, followed by Nebraska and Ohio, and subsequently other states across the country. By the late 1940s, follow-up studies by TVA confirmed that reservoir fish populations had not been diminished by fishing (Miller 1945, 1950) and that population changes in reservoirs were caused primarily by natural biological and environmental phenomena (Stroud 1948). The 1940s TVA investigations set in motion further fisheries profession developments in the 1950s with intense engagement by the AFS Southern Division (Southern Division).

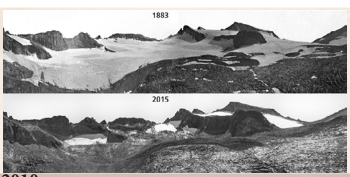
The U.S. Dingell–Johnson Act of 1950 authorizes the Secretary of the Interior to provide financial assistance for state fish restoration projects using excise taxes on fishing gear. The first payment to the states occurred in 1952. That same year, the Southern Division was established to promote dialogue on problems peculiar to the region (Allen et al. 2002). This synchronization is likely coincidental, but there is no doubt that the Act allowed state agencies to expand personnel that built the Southern Division. By 1957, the Southern Division had formed a reservoir standing committee that included partners from 13 southern states, TVA, U.S Army Corps of Engineers, and U.S. Bureau of Sport Fisheries and Wildlife. The first meeting was convened in 1958 to develop a coordinated approach to solving reservoir problems, a path that followed in the steps of the model established by TVA a decade earlier. Items in the first agenda included water level management, reservoir clearing, creel surveys, recreational fishing, need to expand commercial fishing, shad control, and the need to introduce species to fill vacant reservoir niches.

Under the auspices of the Southern Division, the Reservoir Committee has held regular meetings two to three times per year for the last 60 years, functioning as a clearinghouse, communication center, and project facilitator among federal, state, academic, private, and other programs concerned with reservoir management in the southern United States. This gathering of interests, institutions, and personal energy, along with the significance of reservoir fishery resources in the South, created a synergy that led to many significant accomplishments. A short list of some of these successes includes establishing standard methods for collecting and reporting fish population data in reservoirs; performing meta-analyses to resolve questions of regional interest; coordinating multi-agency field evaluations of sampling procedures; and organizing various national symposia published by AFS (Allen et al. 2002).

In its first 11 years, TVA had constructed 16 hydroelectric dams and had acquired another 5 dams from the U.S. Army Corps of Engineers and the Tennessee Electric Power

Environmental or Social Event

2015 | US | Olympic National Park Glacier climate change effects. Courtesy: USGS-Israel Russell 1883 Photo; NPS-Keenan Takahashi 2015 Photo



2016 | INT | Paris Agreement on climate change signed

2017 | INT | United States announces withdrawal from Paris Agreement on climate change

2019 | INT | Globally, 2nd warmest year on record 2.07°F (1.15°C) above pre-industrial average (1800-1900). Source: Lindsey and Dahlman 2020, NOAA Climate.gov, NCEI

Dewatered streams may reflect climate change effects. Courtesy: Michigan Department of Natural Resources

2000 *(Continued)*

2010

2020

Legislation

2002 | CA | Species at Risk Act (SARA) enacted

2007 | MX | Sustainable Fishery and Aquaculture General Law enacted

2019 | US | National Fish Habitat Conservation Partnerships Act (Bills H.R. 1747; S. 754) introduced in U.S. Congress *(under consideration at time of publication)*

2019 | US | Recovering America's Wildlife Act of 2019 (Bill H.R. 3742) introduced in U.S. Congress to support State and Tribal Wildlife Action Plans *(under consideration at time of publication)*

2019 | US | Environmental Protection Agency and Department of the Army repeal the 2015 rule defining "Waters of the United States" (WOTUS)

2020 | US | Environmental Protection Agency and Department of the Army redefine "Waters of the United States" (WOTUS) and reduces federal jurisdiction to four categories

Figure 9. Logging splash dam, Indian River, Schoolcraft County, Michigan, *circa* 1870s. Courtesy: Michigan State Archives.

Figure 11. Paper mill discharge, Escanaba River near Escanaba, Delta County, Michigan, *circa* 1970. Courtesy: Michigan Department of Natural Resources.

Figure 10. Log drive, Black River near Onaway, Cheboygan County, Michigan, *circa* 1880. Courtesy: Michigan State Archives.

Figure 12. Cuyahoga River fire, Cleveland, Ohio, November 3, 1952. Photographer: James Thomas. Courtesy: Cleveland Press Collection, Michael Schwartz Library, Cleveland State University.

Company (Figure 15). Construction of dams in the tributaries continued into the 1970s against mounting opposition. This opposition gained nationwide attention when TVA started work on the Tellico Dam. With the discovery of the Snail Darter *Percina tanasi* in 1973, environmentalists believed they could use the freshly signed ESA to stop construction of the dam. The TVA was pushed into a series of court cases that eventually stopped construction. However, in 1979 Congress granted the dam an exemption from the ESA and Tellico Lake was impounded. This experience resulted in other TVA projects in the valley to be abandoned and no additional construction has occurred. This downward trend in dam construction was paralleled throughout the country (Figure 13). Attempts to export the TVA model to other basins across the USA failed because of opposition from private hydropower companies and Congress, but the TVA concept was exported to basins in countries across most continents (Molle 2009).

The 20th century was the golden age for reservoir construction in the United States, which has left a legacy of an aging suite of infrastructure and reservoirs that are filling with sediment. Accordingly, the focus of reservoir management has shifted towards improving fish habitat in an aging resource that in 2020 reached a median age of 70 years. Other challenges facing reservoir managers include addressing anticipated effects of climate change that threaten to exacerbate the symptoms of reservoir aging through the indirect effect of shifts in precipitation. AFS remains heavily engaged in the challenges associated with maintaining desirable fisheries in this aging infrastructure, and in developing and advocating for an exit policy for dams that may no longer serve their purpose (Shirey 2020).

Columbia River Case History

The Tennessee Valley was not the only area in North America where large federal dam projects were constructed as nearly every U.S. major river system had such projects (Billington et al. 2005). Another case history concerning dams, fish, and AFS in the Columbia River basin. In addition to the nearly unregulated harvest pressure and the lack of key management information for Pacific salmon, landscape-scale anthropogenic changes occurred in the Pacific Northwest from the 1930s to the mid-1970s as the result of a massive water storage and hydropower dam building effort, as exemplified by Dalles Dam on the Columbia River (Figure 16). This was facilitated by the attitude of the U.S. federal government as stated in a memorandum approved by the Secretary of Interior Julius Krug in 1947 (Gardner 1947):

It is, therefore, the conclusion of all concerned that the overall benefits to the Pacific Northwest from a thorough-going development of the Snake and Columbia are such that the present salmon run must be sacrificed. This means that the Department's efforts should be directed toward ameliorating the impact of this development upon the injured interests and not toward a vain attempt to hold still the hands of the clock.

Ultimately this mindset resulted in 29 large U.S. federal government dams along with 4 additional large dams in Canada in the Columbia River basin. Overall, the Columbia River basin has 281 hydroelectric dams and nearly 200 other dams, most built during the great dam construction period from the 1920s to the 1970s. The last of the mainstem hydroelectric projects, Lower Granite Dam on the Snake River, was completed in 1975 and at least 31% of the pre-1850 anadromous fish habitat has been lost in this river basin (National Academy of Science 1996). Remarkably, the initial design for Bonneville Dam, the lowermost Columbia River mainstem dam, did not include any fishways, but always included a mitigation fish hatchery. It was thought by the project proponents that the effects of these dams would be ameliorated through engineering solutions such as hatchery mitigation and fishway construction, a generally poor passage substitute for the no-dam scenario. Additionally, the term "mitigation" was a softer way of saying that hatcheries could be used to circumvent conservation concerns. This mitigation was implemented even though Pacific salmon culturists were not able to produce artificially propagated salmon that survived to adulthood in adequate numbers until 1962, when the Oregon Fish Commission declared that for the first time its Coho Salmon *O. kisutch* hatcheries were able to fill their egg take from returning hatchery-origin salmon (Oregon Fish Commission 1962). Prior to that date, wild populations were mined for eggs.

To address the Pacific salmon issues in 1980, Northwest Power Planning Council (later renamed the Northwest Power and Conservation Council) was established by the Northwest Power Act, which authorized the states of Idaho, Montana, Oregon, and Washington to develop a regional power plan and fish and wildlife program to balance the Northwest's environmental and energy needs. The Council oversees mitigation activities for federal water projects and is funded by the Bonneville Power Administration, a U.S. federal agency established by Congress in 1937 to market power from all federal power dams in the northwestern United States. In spite of the large investment of billions of U.S. dollars to mitigate the effects of dams in this basin (Lee 1993), only limited progress has been made as many Pacific salmon stocks in this river basin have been federally listed or considered at-risk, as noted above. The mitigation investments and funding of other supporting research by the Council has greatly expanded our knowledge of Pacific salmon ecology and systems, as evidenced by the large number of peer-reviewed publications in AFS and other journals since the 1980s that have supported reform efforts in this and other basins.

Anthropogenic pressures in the Columbia River basin, in particular the fragmentation of the system by dams, but also agriculture, forestry and urban development, climate change, and overharvest have greatly reduced salmon runs and fisheries (Williams 2006). Development activities have degraded or blocked habitat for migrating salmon and lamprey, and mitigation hatcheries along with fishway development have not fully compensated for the lost production. The American Fisheries Society has been involved in discussions on Pacific salmon in the Columbia River from the beginning and in 1892, Livingston Stone even discussed the concept of a national salmon park for that basin before the Pacific salmon could become like the then rare bison in Yellowstone National Park (Stone 1892). At the Society level, AFS policy statements on the Columbia River Basin continued to be passed through the 1970s including resolutions that: opposed the Chief Joseph Dam construction on the Columbia River (1959); expressed deep concerns about gas supersaturation and requested research to resolve these issues at Columbia River dams (1978); and the early implementation of the Lower Snake River Compensation Plan for the recently completed dams on that river, along with preparation of similar plans across the basin (1978). In addition to Society-level efforts, AFS Chapters have also been directly involved on this system, with the AFS Oregon Chapter most recently passing a resolution concerning Snake River salmon and steelhead recovery (2000); and providing direct written input to Judge James Redden in 2009 on court actions concerning the operation of the Columbia River power system operation to protect salmonids in the system. These efforts have clearly expressed long-held resource concerns and influenced management and research efforts to improve salmonid stocks. Even with these efforts, AFS and agency fisheries professionals have and will continue to wrestle with these seemingly intractable resource conflicts that influenced establishment of fisheries commissions and their successor agencies and AFS 150 years ago.

Figure 14. Norris Dam Completion Ceremony, Tennessee Valley Authority, Clinch River, Tennessee, 1936. Courtesy: Tennessee State Library and Archives.

Digging to Demise: Fisheries and Mining in the Intermountain West

Land alteration and mining effects on aquatic resources were additional formative reasons for fisheries commissions and AFS, and the effects of both legacy and current mining operations remain evident today across the North American landscape (Figure 17). Three example case histories for mining come from the U.S. Intermountain West.

Open lands and seemingly unlimited, uninhabited stretches are emblematic of the arid Intermountain West region,

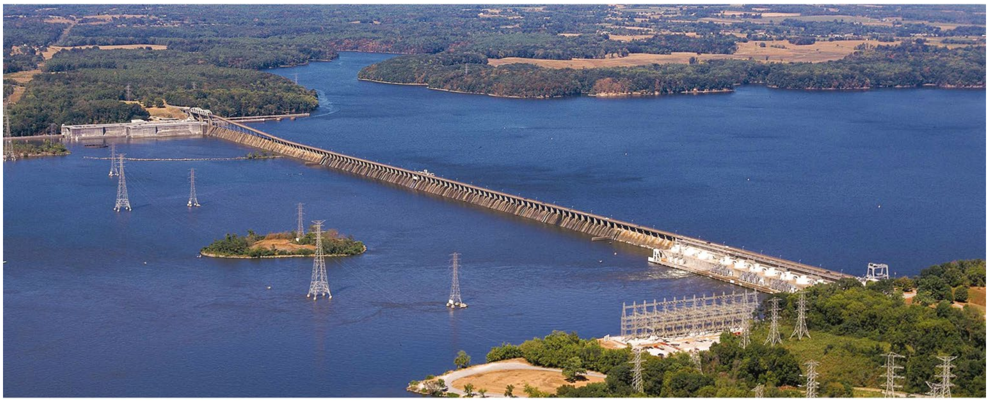


Figure 15. Wheeler Dam, Tennessee River near Rogersville, Alabama. Courtesy: Tennessee Valley Authority.

where water years are influenced by higher altitude snowpack, which supplies streamflows in summer. From the Continental Divide on the east, to the spine of mountains that delineate the Pacific Crest on the west, the region encloses a large basin. By acreage, the Intermountain West is immense, but population density is low; from 6 to 100 people per square mile (16–259/km^2) in the United States (U.S. Census 2010). The average population density in the western USA is approximately 43 people per square mile (111/km^2), less than half that of other major U.S. regions (e.g., southern states, the Midwest, and the Northeast). Climate patterns drop much of the moisture on the west side of the Cascade and Sierra mountains, creating a rain-shadow effect that generates comparatively arid and desert conditions in much of eastern Washington, Oregon, and California, as well as much of Nevada, Arizona, Montana, Colorado, Wyoming, Utah, and New Mexico. Mean annual precipitation can approach 100 inches (254 cm) on the west side of this divide and drop to 10 inches (25.4 cm) or less on the eastern side (WRCC 1998).

Landscape characteristics have also provided prime opportunities for landscape-scale anthropogenic degradation of the region's natural resources. Here, the uplift geology that created the mountainous boundaries of the region instigated, and continues to drive, the mining legacy. Metal deposits including copper, gold, silver, lead, and zinc not only spurred settlement and development, but continue to dominate resource extraction activities. In the 1860s, the relative ease of developing these resources at sites like Silver Valley, Idaho, and gold prospecting in Comstock, Nevada, set up a pattern of boom and bust cycles. Minerals and metals could be removed from the ground at the surface or through underground tunnels, but early methods used water in the processing or sorting of the mineral ore. Placer mining—where stream sediments and surface soils are run through a sieve that uses water to wash the heavier metals from the sand and gravels—required consistent water supply and reworked streambeds and adjacent lands into sorted piles of rocks. With these activities, excavation and redeposition relocated streams and disrupted the hydrology so that flowing surface waters were often no longer present. Underground mining excavated ore and often transported it offsite for processing. Processing plants were usually located near larger streams to provide consistent water for processing and power. Mining is still common in the western United States, and the Silver Valley in Idaho and the Carson River in Nevada provide a few examples of how legacy mining activities, including placer or hydraulic mining, have forever altered fisheries resources and will require fisheries agency and AFS engagement for the next century.

Bunker Hill and Silver Valley – Idaho Case History

In Idaho, mining commenced with the discovery of gold in the 1860s, but in the Coeur d'Alene area and Silver Valley near Wallace, Idaho, gold and silver were not discovered until the 1880s (Davenport 2017). The Bunker Hill Mine, which ceased production in the early 1990s, produced over 1 billion oz of silver and in the later years of operation produced over 10,000 tonnes of lead (Hudson Institute of Mineralogy 2006). As a result of these activities, the Bunker Hill Mine and its associated smelting facility have been designated a Superfund site since the 1980s, administered by the U.S. Environmental Protection Agency. Superfund cleanup has focused on treating the water that flows through the more than 150 miles (241 km) of abandoned underground mine shafts and the soils contaminated by heavy metals from smelter operation (U.S. Environmental Protection Agency 2018). The ore processing near Coeur d'Alene dumped tons of sediments, or tailings, into the Coeur d'Alene River with high concentrations of zinc, lead, and cadmium as a result of inefficient milling processes. In the 1940s, the U.S. Bureau of Fisheries published findings that the mine wastes were the cause for the precipitous decline in the fishery, but the economic engine of the mines was seen as too valuable to restrict activities (Ellis 1940). Several hydroelectric dams to support milling operations were also established downstream of Coeur d'Alene Lake, blocking anadromous salmon runs and changing the ecology of the lake by allowing introduced species to flourish and outcompete native salmonids.

Coeur d'Alene Lake is fed by the Coeur d'Alene River and once supported a large adfluvial population of Bull Trout *Salvelinus confluentus* (ESA Status: Threatened) as well as Westslope Cutthroat Trout *O. clarkii lewisi*. These fish constituted an important food source for the Coeur d'Alene and Spokane tribes prior to the establishment of the Silver Valley and Coeur d'Alene mining districts. The vast legacy mining wastes and tailings dumped into Coeur d'Alene River and its tributaries have resulted in degraded fish communities and establishment of the Bunker Hill Superfund site, which encompasses 166 river miles (267 km) along the South Fork Coeur d'Alene River from near Wallace to Coeur d'Alene Lake, Idaho (U.S. Environmental Protection Agency 2018). Fish consumption advisories remain in effect for fish taken from Coeur d'Alene Lake for Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *M. dolomieu*, Kokanee *O. nerka*, and other sportfish due to the elevated tissue concentrations of mercury, lead, arsenic, and cadmium that are directly linked to the mining and mineral processing activity in the basin that began almost 140 years ago (Idaho Department of Health and Welfare 2019). Numerous studies have demonstrated that direct effects of metals in water and sediments, as well as behavioral avoidance of metals in streams, contribute to persistent declines and suppression of fish populations throughout the system (Woodward et al. 1997; Maret and MacCoy 2002).

Carson River Basin – Nevada Case History

Further south in the Intermountain region, mining often has an intermittent presence, but its history and effects are similar. Westward expansion led to discovery of metals and minerals by settlers and mining towns sprung up to exploit these discoveries. For those trekking across the Great Basin, the few rivers dictated travel routes because of the lack of other water sources. The gap between the Humboldt and Carson rivers in Nevada was known as the "40-mile desert" to those following the California Trail. The desert conditions made crops and livestock less tenable as sources for income, and mining was a seductive "get-rich-quick" alternative.

The Carson River begins in western Nevada near the town of Genoa and flows east to the Carson Sink where it ends in a broad marshland, home of the Stillwater National Wildlife Refuge complex. Lahontan Cutthroat Trout *O. clarkii henshawi* (ESA Status: Threatened) are native to the Carson River, and there are historic accounts of these large fish being harvested in large numbers to sustain the 1800s mining camps. Gold and silver were found in the Comstock Lode and mine tailings were dumped along the Carson River, similar to practices on the Coeur d'Alene River, and resulted in the same legacy contamination. Anglers are still advised not to consume any fish from the Carson River from Dayton to the Lahontan Reservoir or within any waters of the Lahontan Valley due to mercury contamination from legacy mine processing and mining wastes and the entire area is a Superfund site (NDOW 2019; NDEP 2019). The mine wastes, historic overharvest, and introduction of non-native fish have directly contributed to the tenuous status of Lahontan Cutthroat Trout in the Carson River.

Placer Mining Case History

Extracting metals from ore usually requires chemical processes, which is why mercury is often part of the legacy of hard rock mining. However, placer or hydraulic mining can disrupt streams without the addition of chemicals. The process works by using water to move ore bearing rock from the alluvial deposits, and then separating heavy minerals like gold from sand or gravel on an industrial scale when compared to gold panning. When applied on a large scale with sluice boxes or mechanical dredges, the gravel or alluvium is excavated and sorted using water, gravity, and sometimes metal screens. Gold is sorted out and kept, and the excavated gravels are redeposited in piles along the edge of the stream or in the floodplain. The redistribution and excavation disturb the stream channel and result in the water flowing in the interstitial spaces in the piles of alluvium. Historically, mine operations did not reconstruct a channel in the deposited gravels, and surface waters often became limited to a series of disconnected ponds. This effectively removes the stream from the landscape and subsequently eradicates fish habitat. One example of a placer operation can be found along Alder Gulch in the Ruby River watershed in southwestern Montana (Figure 17). Placer mining was active along Alder Gulch from the 1860s to the 1920s and it remains a disconnected system of settling ponds with many miles of placer piles easily visible on satellite imagery (Montana Heritage Commission 2016).

Although most mine operations are not as directly destructive to streams as placer mines, the legacy of excavation, chemical contamination of water and sediments, and the associated exploitation of native fish stocks combine to make mining, in all its permutations, a continuing dominant, negative influence on the fisheries of the Intermountain West. Enactment of both the U.S. Clean Water Act and Surface Mining Control and Reclamation Act (1977, Public Law 95-87, 91 Stat. 445), and similar legislation in Canada and Mexico have reduced some of the legacy issues and, in places, minimized current negative effects. AFS actively supported the passage of these acts, passed resolutions to reform U.S. laws as recently as 1992 on the U.S. 1872 Mining Law (17 Stat. 91-96), ensured that peer-reviewed research on mining and mining pollution effects was published that supported regulatory action, and has recently released a position and policy paper for additional mining reform (Hughes et al. 2016). However, these gains are currently threatened by hemispheric deregulation efforts and only minor progress has been made in rehabilitating tens-of-thousands of miles of degraded streams and rivers from legacy mining operations across the continent.

The Rapidly Emerging Habitat Issue of the Future – Climate Change

Thoughts about the Future from the Columbia River System

Legacy habitat degradation and impairment remain key issues across the continent and were important to establishment of fish commissions and AFS, yet a recent even larger-scale habitat threat has emerged with the potential to completely alter our current and future aquatic landscape. A perspective on climate change from the Columbia River basin provides context to this emerging threat. Under "relatively" stable climatic conditions, the indigenous people of the Columbia River basin long gathered the knowledge to maintain and nurture the resources on which they and future generations relied. Yet, these peoples are among the most climate-sensitive communities as tribal, cultural, and economic reliance on First Foods (e.g., native cold-water fishes such as salmon, Pacific Lamprey, and sturgeon) will be greatly affected by climate change, making the tribes' cultural traditions uniquely vulnerable. Climate change harms fish and wildlife in many ways, including, but not limited to, alteration of the seasonal and annual hydrograph; increased winter runoff and flooding; earlier and smaller snow melt-related spring runoff peaks; decreased summer flow volumes; increased frequency, duration, and severity of state and federal water temperature standard exceedances; and increased incidence of disease (ISAB 2007; Yearsley 2009; Isaak et al. 2012; Ficklin et al., 2013; Hamlet et al. 2013; RMJOC-II 2018). These hydrologic changes will also require further alterations in hydropower operations.

Figure 17. Placer mining legacy, Alder Creek, Montana, 2018. Image from Google Earth with labeling by LeAnn Roulson.

Many groups in the Columbia River basin, including tribal (i.e., CRITFC), state, and federal government agencies have made great progress in developing, implementing, and evaluating strategies to protect and restore populations of salmon, Pacific Lamprey, White Sturgeon *A. transmontanus*, and other resident fish and wildlife. But these efforts have been insufficient to address climate change effects. Climate change is significantly altering the Pacific Northwest ecology and economy and is expected to continue to exacerbate the situation for the foreseeable future (Mantua et al. 2009; Schnorbus et al. 2011). Increasing air temperatures and erratic changes in precipitation patterns are decreasing snowfall and increasing rainfall during winter, leading to shifts in the timing and quantity of runoff. A consequence is increased flooding during the winter when water is plentiful, and decreased flows during the summer, when water demands are high. These changes have significant implications for freshwater and marine fisheries, hydropower production, flood risk management, and water supply for agriculture and municipalities.

Columbia River basin salmon still face challenges as tribal, state, and federal fisheries agencies work to support sustainable fisheries. Development pressures and land conversions, mostly toward urbanization, are expected to increase as the human population grows as projected. Climate change will likely affect the availability and timing of cold water during key life salmonid stages. Therefore, future agreements on fisheries management strategies and objectives should fully incorporate the implications of these abiotic changes on fish populations into these agreements. Similarly, future negotiations on Columbia River basin water management should recognize the large-scale changes in precipitation patterns that will change seasonal and annual hydrographs and use that information to protect the aquatic resource legacy, while providing opportunities for human uses.

Climate change is expected to interfere with aquatic community function, as well as interspecies relationships (Woodward et al. 2010). Changes in ecological function and process will necessitate coordinated, ecosystem-scale strategies to achieve not only species recovery, which is the current focus, but to protect currently intact systems and ensure continued ecological function of rehabilitated systems within the expected variance of the system. Thus, regional collaboration should be enhanced to meet the needs of the aquatic system, which will result in institutional and process challenges for future fisheries professionals. Ecosystem-scale analyses and rehabilitation will rely on multidisciplinary approaches that should include biologists, physical scientists, and social scientists to solve what will become an increasingly complex set of climate change issues. These multidisciplinary approaches will contribute to modeling the relationship among abiotic and biotic factors and consider the results in relation to the socioeconomic realities that determine whether sustainable futures are realistically achievable.

To preserve and enhance First Foods, which all Columbia River basin inhabitants rely on or identify with in some way, climate change will become one of the key issues considered in the management of finite and potentially reduced Columbia River Basin water resources. AFS should become increasingly involved in large-scale policy issues on both mitigating current and reducing future climate change effects on aquatic systems across the country. Developing climate adaptive measures and planning for maintaining ecosystem function will be a key future challenge that AFS needs to facilitate and support. Failure to do so could be catastrophic for fish and people of our hemisphere and will be the critical fisheries challenge for the foreseeable future.

POLICY EMERGES FROM THE REASONS FOR ESTABLISHING FISH COMMISSIONS AND AFS

Ruin Creates Social Movements for Improved Fisheries

Communities and societies eventually become weary watching resources wasted for the benefit of the few. In North America, as illustrated above, the degradation and loss of aquatic resources offer a similar perspective, though it has taken between 50 and 100 years for societal attitudes to be transformed into legislation and regulation to protect fisheries and their habitats. This delayed response reflects the typical reactionary approach to problems of overharvest, pollution, and habitat destruction caused by European colonists and their descendants, who viewed the fisheries of North America and their habitats as commodities to be exploited (Moffit et al. 2010). As noted above, formation of state fish commissions was an early reactionary approach to address loss of fisheries and the substantially degraded aquatic resources of the mid-to-late 1800s (Pisani 1984), even though the appetite for enacting meaningful measures to cope with the causes of the degradation was decades away.

In the same period, the American Fish Culturists' Society (1870), later AFS, formed to provide an organized response to the crisis of losing fisheries and focused on fish culture, resource management, politics, and federal funding (Moffitt et al. 2010). From its early years and throughout its history, AFS has been publicly influential on behalf of its membership to provide a conduit for member input into resources issues, even when they may not be able to do so through their employers; to amplify fisheries agency resource concerns; and to engage policymakers to share knowledge of fish conservation and data to inform water resource policy (Benson 1970; Thompson 1970; Frye and Gottschalk 1995; Starnes 1995). Members have debated AFS's level of activism since its beginning, yet members have been at the forefront of recognizing fisheries resource problems and have worked to help foster public awareness (Starnes 1995). Early on, this resource activism was conducted directly by the Secretary of AFS with the first example being Livingston Stone within months of the founding of AFS. He wrote the U.S. State Department and Canada on behalf of AFS to protest illegal obstructions being placed on the St. Lawrence River in Canada to capture salmon, preventing their return to spawning grounds and affecting the local harvest in headwater streams on tributaries within U.S. jurisdiction (Stone 1872).

To evaluate how the aforementioned formative reasons for fisheries commissions and AFS were converted into policy and law, we have divided up the last 150 years into five time periods which illustrate the approximate order in which resource issues were addressed.

1870–1919

During this period, fish commissions and their successor agencies treated the symptoms of declining fish populations by focusing on fish culture, wanton waste, and harvest restrictions rather than the causes of habitat destruction. By the late 1800s, most states responded to the crisis by enacting legislation that restricted fisheries harvest (Rahel 2016). Generally, these early regulatory actions were ineffective and greatly hampered by the lack of supporting science—as the knowledge of fish population dynamics was decades away—few resources for enforcement, and poor political support. Yet, AFS members recognized the broader environmental issues and passed resolutions calling on governments to set checks on the volume of pollution, "to set aside fish refuges or aquatic preserves in which the contamination of water and any modification of natural conditions for aquatic existence shall be forbidden," and to advocate for establishing formal fisheries education at universities (Thompson 1970). Early fisheries professionals knew the causes of fisheries decline, as indicated from publications at the time (i.e., TAFS), but recognized that society at large lacked the political will to address the problems with effective governance. True resource changes would have to wait many decades for society to take note, along with a willingness to challenge the orthodoxy of the norm (Benson 1970; Thompson 1970).

Canadian management agencies initiated regulatory efforts earlier with more restrictions than those of U.S. agencies (Bogue 2000). The Ontario legislature passed legislation providing for fish passage over mill dams and regulation of fishing methods, seasons, and locations for Atlantic Salmon in Lake Ontario tributaries as early as 1828. Canada regulated harvest of Cisco *Coregonus artedi*, Lake Whitefish, and Lake Trout *S. namaycush* fisheries in Lake Erie between 1823 and 1843.

Despite cooperative efforts among North American fisheries agencies, particularly in fish culture, boundary issues remained a significant area of conflict among North American countries. Canadian and American government disputes regarding fishing were longstanding by this period and continued until the mid-to-late 1900s when many joint fisheries commissions and councils (i.e., Great Lakes Fishery Commission) were formed, providing forums to resolve fisheries disputes and allocation issues. Notably, in 1870, the year the AFS was formed, Canada established an Order of Council that forbade foreign fishermen from fishing Canadian waters, which created intense conflicts. The Washington Treaty of 1871 between the United States and Canada somewhat mitigated the tension by allowing American fishermen access to inland Canadian waters to fish in return for similar Canadian access and free entry of Canadian fish to American markets.

1920–1969

Between 1920 and 1969, AFS membership passed 114 resolutions focused primarily on pollution, problems with dams and reservoirs, and management of fisheries and habitats, with additional resolutions on research, federal–state relations, international treaties, technology, and economics (Benson 1970). Further, the 1938 North American Fish Policy influenced state, provincial, and federal fishery regulations (Van Oosten 1948). Additional policy engagement by AFS in the 1940s included facilitating a request by the U.S. President Harry S. Truman's Water Resources Policy Commission to provide input on broad water use policy and advocating for the passage of the Dingell–Johnson Act (1950, 64 Stat. 430), which provided large amounts of new financial resources, along with fisheries agency license fund accountability after years of supporting the legislation (James 1951). These measures were foundational in nature, yet they did not curb the ever-increasing losses in fisheries from landscape-scale habitat degradation, particularly caused by industrial pollution and development. When combined with the ever-increasing demands for fisheries opportunities by an expanding human population with

Figure 18. Steel mill and refinery pollution, Indiana Harbor Ship Canal, East Chicago, Indiana, 1968. Courtesy: Michigan Department of Natural Resources.

disposable income, it was clear that something drastic had to change from a landscape perspective to accommodate these societal needs. Through its publications, AFS played a large role in highlighting this degradation and effects of pollution on fish populations along with providing peer-reviewed information for regulatory proceedings. AFS also provided foundational information on the effectiveness of harvest regulations for both freshwater and marine fisheries that led to the development of a set of tools for professionals to implement that have reduced or eliminated this issue, where the political will existed. This work provided the science support for later efforts, along with needed social interactions and networks for fisheries professionals to be successful in the next social steps, such as the Clean Water Act efforts in the United States. In every corner of North America, the public had clearly tired of wanton waste of aquatic resources and by the end of this period the tide was clearly changing with emergence of the "environmental movement" and anglers wishing to limit their own harvests to improve fish population structure and fishing quality. This resulted in many North American jurisdictions putting restrictive harvest regulations into place that attempt to match harvest to system productivity and angler desires, a trend that has continued to the present. Overexploitation and wanton waste, key historical reasons for fisheries agencies and AFS establishment, have been controlled for most areas and species, where the societal will exists. Additionally, size restrictive regulations have generally improved fish population size structure where implemented when abiotic conditions are favorable.

The public was aware of environmental issues, as illustrated for fisheries professionals by Gray and Meldrim (2000), who stated, "by the 1960s, water quality conditions in the United States had deteriorated to such an extent that many fisheries biologists were consumed with studying, managing, or abating water quality problems." Some North American rivers had sections either devoid or nearly devoid of fish due to mine drainage, sewage, chemical effluent, and industrial waste (Figure 18). For example, the Monongahela River, in western Pennsylvania, and its tributaries regularly had pH measurements less than 4 and low fish abundance and diversity in the 1950s and 1960s due to acid mine drainage and industrial effluent (Argent et al. 2007). The St. Joseph River in the vicinity of South Bend, Indiana only supported carp because of pollution and low oxygen (Dolley 1933). The Illinois River in Illinois (Thompson 1925), and the Hudson River in New York (Talbot 1954) had fish described as being disagreeable for food with "gassy" taste comparable to kerosene, tar, or coal gas. As early as 1881, the mayor of Cleveland, Ohio, called the Cuyahoga River an open sewer through the middle of the city. For over a century, the residents of industrialized cities in North America lived with discharges of sewage and industrial effluent flowing in open waters (Benidickson 2007). Under such conditions, the value of fish was an afterthought. Pollutants went unchecked because they were viewed as a sign of economic progress, along with a lack of will by citizens to challenge those in power; yet this dramatically changed in the 1960s. By the 1960s, people living in or near urban areas could not take water quality for granted, and "the four main groups of river conservationists—park supporters, fishermen, landowners, and canoeists—were growing in power" (Palmer 1986).

Concerned over losing more rivers to pollution, industrial development, and new dams in the 1960s, the U.S. Congress passed the Wild and Scenic Rivers Act (WSRA) in 1968 (Public Law 90-542, 82 Stat. 906), initially protecting eight rivers:

> It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations.

By taking a more proactive approach to protect remaining intact rivers for values of scenery, recreating, and fishing, the WSRA was a major milestone in North American legislation with many states soon passing similar legislation. Yet, even after 200 rivers have been added, the WSRA covers less than 0.4% of river length in the United States. (12,700 of 3.7 million miles) and the law has not been fully extended to rivers flowing through more developed and urban areas.

Pursuant to a broadening view of the need for environmental protection, the National Environmental Policy Act (83 Stat. 852) of 1969 changed the planning that the U.S. federal government could take in actions that result in damage to the environment. This law not only mandated federal agencies to consider environmental consequences, but resulted in use of analytical tools to quantify impacts on both individual and cumulative resources and required federal agencies to consider alternatives, such as leaving a river alone when a dam is being considered (Palmer 1986).

1970–1994

As AFS membership grew, and environmental concerns of the 1960s and 1970s prompted members to demand further policy engagement, elected AFS officers delegated engagement on resource policy to the growing number of subject matter experts. This work evolved to become AFS Sections such as the Water Quality Section, which developed in the 1970s from a standing committee on water quality. The Committee on Pollution–Water Quality was charged by the Executive Committee with developing a program of positive action to be implemented by AFS (Berkson 1971). In 1969, AFS passed a resolution advocating for full funding of the Clean Water Restoration Act of 1966 (80 Stat. 1246) to support construction of wastewater treatment plants to ensure promulgated state water quality standards required by the Water Quality Act of 1965 (79 Stat. 903) could be met. Additionally, AFS resource policy included the 1975 Committee on Ecological Concern representing Canada, Mexico, and the United States. This committee became the Environmental Concerns Committee and finally, in 1992, the Resource Policy Committee (Starnes 1995). During this period, Carl Sullivan's leadership as AFS Executive Director helped AFS with a major achievement of increasing federal funds for state fishery programs through the Wallop–Breaux Amendments in 1984 (Frye and Gottschalk 1995). These funds dramatically changed and enlarged public fisheries management programs across the USA.

Clean Water Act of 1972

The Federal Water Pollution Control Act of 1972, also known as the Clean Water Act (CWA; Public Law 92-500) is the exemplary clean water law from which many other countries have modeled their water quality laws and there has been no greater influential policy on fisheries and aquatic habitats. Lingering water quality issues remain in the United States, yet the last 50 years have seen dramatic improvement in U.S. water quality, primarily due to the CWA. It has been over 50 years since the Santa Barbara oil spill (1969) and the 13th and final fire on the Cuyahoga River in Cleveland, Ohio, with the first fire occurring over a century earlier in 1868 (Ohio History Central; www.ohiohistorycentral.org). These events ignited public support and pressured the U.S. Congress to require specific federal standards to improve water quality by reducing point-source pollution (Hines 2013). The objective of the CWA was to "restore and maintain the chemical, physical, and biological integrity of the nation's water." The CWA helped reduce damage to aquatic life from discharges of sewage, chemical effluent, and industrial waste (Figure 18). Reflecting the successes of this legislative path and public support, in 2019, the U.S. Environmental Protection Agency lifted human consumption advisories for fish caught from the Cuyahoga River. Other environmental laws like the Surface Mine Control and Reclamation Act of 1977 and the Clean Air Act of 1970 (84 Stat. 1676), and its amendments from 1990 to reduce sulfur dioxide emissions, have had positive impacts on water quality, returning species like Brook Trout *S. fontinalis* to areas that were fishless due to acidity from mine drainage or sulfur deposition (Sutherland et al. 2015). Canada and Mexico formed similar laws either in parallel or soon afterward.

Despite water quality improvements and triumphs of gradually making rivers usable for fishing, boating, and swimming again, emerging stressors require AFS to remain vigilant. A growing concern for the health of humans and fisheries focuses on toxic algal blooms caused by excess nutrients and soil from non-point source pollution runoff (Davis et al. 2019). For example, the high mortality rates of endangered Lost River Suckers *Deltistes luxatus* in Upper Klamath Lake, Oregon are associated with cyanobacteria blooms, but identifying a direct link from poor water quality to mortality is complicated (Burdick et al. 2020). In 2020, the regressive action of redefining the extent of "Waters of the United States" by restricting the Clean Water Act jurisdiction to fewer waters means that more waters and fish species dependent on those waters will be increasingly at-risk from diminished federal protection (Colvin et al. 2019). There are clear signs of national policies in North America retreating toward the destructive policies of the past.

Endangered Species

With habitats damaged and water quality and quantity often both degraded, some species showed population declines to the point of extirpation or extinction (Minckley and Deacon 1968). This brought additional public attention to species extinction and resulted in the passage of the landmark U.S. Endangered Species Act (ESA) in 1973, which also served as a template upon which many similar laws were enacted across North America at the federal, state, and provincial levels. Engagement by AFS on imperiled species issues started with members who were alarmed about habitat destruction and decline of fish populations (Shirey et al. 2018). In 1964, these fisheries biologists formed the AFS Endangered Species Committee. A resolution adopted at the AFS Annual Meeting in Atlantic City, New Jersey (1964) charged the committee to develop an atlas of rare and endangered fish species. At the same time, a Committee on Rare and Endangered Wildlife Species, composed of nine biologists, was established within the Department of the Interior to draft the first federal list of species at risk of extinction (Yaffee 1982), predating the U.S. Endangered Species Preservation Act (Public Law 89-669) of 1966. In 1972, the Endangered Species Committee published its first account of imperiled species (Miller 1972), which provided scientific support for enactment of the ESA as subsequently amended in 1969 (Endangered Species Conservation Act; Public Law 91-135). This was followed with updated lists in 1989 (Williams et al. 1989) and 2008 (Jelks et al. 2008). As the U.S. Congress debated reauthorization of ESA in 1994, the American Fisheries Society dedicated the January issue of *Fisheries* to imperiled species issues, wherein AFS argued for strengthening the ESA in a policy statement (Angermeier and Williams 1994), again providing key science-based support for policy. ESA helped prevent further extinctions with some species populations improving to the extent that U.S. Fish and Wildlife Service delisted them, including Oregon Chub *Oregonichthys crameri* (2015), Modoc Sucker *Catostomus microps* (2015), Foskett Speckled Dace *Rhynichthys osculus ssp*. (2019) and Borax Lake Chub *Siphateles boraxobius* (2020). Another recent breakthrough for imperiled species has been expansion of fish culture practices to include "conservation aquaculture" hatcheries that focus on propagating imperiled species (AFS Fish Culture Section 2017; Hutson et al. 2018; Tave et al. 2019).

For fish not listed as threatened or endangered, laws in the U.S. require agencies to consider effects on fisheries in the decision-making process (Administrative Procedure Act of 1946; 60 Stat. 237; Fish and Wildlife Coordination Act of 1958; 72 Stat. 563; National Environmental Policy Act of 1969). However, the USA lacks comprehensive legislation that requires federal agencies to prevent threats to fish and fish habitat in their actions. The closest law is the Fish and Wildlife Coordination Act of 1958, which requires consultation with state fisheries agencies on federal projects (Ballweber and Jackson 1996). From an initial focus on regulating sustenance and recreational fishing, state governments have increasingly shifted toward watershed and biodiversity management (Rahel 2016).

1995–2020 and Beyond

The history of reactive fisheries management in North America coupled with emerging challenges envisages the future of fisheries conservation requiring a proactive approach. This contemporary view, which relies on landscape and watershed/coastal-scale levels of action as the solutions to most fisheries problems, is well beyond a single waterbody or area (i.e., climate change and landscape-scale land use alteration). This will require fisheries professionals capable of working in, and communicating with a much broader range of disciplines than their predecessors. An example of such an approach in the USA is embodied by the National Fish Habitat Partnership (NFHP; www.fishhabitat.org), which is focused on landscape-scale fisheries habitat projects designed to repair the problems, rather than just the symptoms of habitat degradation. They do so by conserving remaining intact habitat, rehabilitating degraded systems, and acknowledging that some habitats, particularly engineered systems, require improvement. The NFHP uses broad voluntary partnerships of resource agencies, NGOs, and private individuals and groups with a broad range of professional disciplines to put conservation actions on the ground. This type of landscape level action is likely the route of future fisheries conservation; for problems beyond the realm of fisheries professionals to solve on their own. Legislation is pending in the U.S. Congress to codify this approach with similar initiatives under consideration in Canada.

Landscape-scale approaches are just one focus for the future. Fisheries conservation will need to broaden beyond recreational or commercial species and embrace broader ecosystem and biodiversity perspectives in management (Williams et al. 2011). Steps in this direction within the United States include the 2000 Congressional requirements for Comprehensive Wildlife Conservation Strategies, as stated in State and Tribal Wildlife Action Plans and authorized by Public Law 106-553. With the overarching purpose of preventing species endangerment and federal listing, the eight required elements (i.e., species status and distribution, condition and location of key habitat(s), threats, conservation actions, monitoring, plan review and revision process, coordination with other partners, public participation) in State Wildlife Action Plans offer crucial information to guide management of Species of Greatest Conservation Need. By identifying conservation actions, State Wildlife Action Plans provide the management framework to address threats, such as climate change and associated environmental impacts (Essig 2016), and, because they are state or tribal plans, may work on a much larger spatial scale than a single waterbody. To more fully implement these plans, additional funding is essential and Recovering America's Wildlife Act, a bill under consideration in the U.S. Congress at the time of this writing, is designed to provide this vital support for proactive conservation.

CONCLUSION

Into the future, fisheries professionals will need to implement proactive approaches to address the needs of fish and fish habitats, using scientific objectivity of facts and knowledge to inform the public, and to assist in effective governance by policymakers (Alverson 1995). Beyond traditions of western science, we need to protect tribal-reserved treaty rights for fishing and fish management, not only because it is legally, ethically, and morally just, but also because the traditional ecological knowledge and cultural traditions of indigenous communities can help conserve and manage fisheries (Colvin et al. 2019; Lavoie et al. 2019; Al-Chokhachy et al. 2020). In geographic regions without tribal-reserved rights, the most effective proactive approach is for people to become indigenous to a place where communities build an intimacy and attentiveness to the land, then become materially and spiritually integrated with the landscape, always considering future generations in decision making (Kimmerer 2000). This approach is just as meaningful for non-indigenous people in the care of our shared landscape. To fulfill this vision, AFS can commit to including an Indigenous perspective into each Annual Meeting plenary in addition to symposia and field trips, as was done for the 149th meeting in Reno, Nevada.

History is a keen teacher from which we have learned that human behavior seems to move toward the lowest denominator of concentrating resources in the hands of the few, except when intensive societal inputs of time and energy prevent this tendency. We hope you are moved to consider how fisheries history, along with AFS's significant role in this history over the last 150 years, will be critical to our future work. Clearly, to see our fisheries flourish into the future, which they can and should, AFS must continue to remain aware of and respond to changing conditions. Having strong peer-reviewed evidence and professionals to communicate fisheries science to the public ensures we will effectively engage them to conserve our aquatic resource for future generations to appreciate and wisely use. To do so will require the many skill sets of our members and collective science to motivate and encourage the North American public and political leaders to fully account for the effect of their decisions on fisheries and aquatic habitat as history has shown. We hope the recognition and understanding of our collective history will help future generations avoid repeating the ugly past of habitat degradation, wanton waste, and over exploitation, and will pave a bright future for our shared fisheries resources.

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SUPPORTING INFORMATION

Additional supplemental material may be found online in the Supporting Information section at the end of the article.

Table S1. Year, state and reasons for establishing state fish commissions in the USA. AFS