# Population increases of nonindigenous American shad in the Columbia River

## Augmentation de la population non indigènes D'American shad dans le fleuve Columbia

Stan Gregory

Oregon State University, Corvallis, Oregon, USA
(Stanley.gregory@oregonstate.edu)

## RÉSUMÉ

En 1871, American shad (*Alosa sapidissima*) a été introduite dans la rivière Sacramento, en Californie, à partir de la rivière Hudson, dans l'État de New York. En 5 ans, l'alose a colonisé le fleuve Columbia, à plus de 1,000 km au nord. Pendant 80 ans, le nombre d'aloses dans le fleuve Columbia est resté faible, mais a considérablement augmenté après 1960, avec près de 8 millions d'aloses adultes entrant dans la rivière en 2019. Au cours d'une période où les populations indigènes de saumon ont diminué, les aloses sont devenues le poisson anadrome le plus abondant. dans le fleuve, comprenant plus de 90 % des migrants en amont certaines années. L'augmentation brutale de l'alose a coïncidé avec l'achèvement d'un barrage en 1957 qui a inondé une barrière naturelle à la migration en amont de l'alose. L'alose a colonisé 700 km en amont au fur et à mesure que la série de barrages s'étendait, utilisant des installations de passage pour les espèces de salmonidés indigènes. La migration de frai en amont au printemps est étroitement liée au débit et à la température de la rivière. La gestion de l'hydrosystème a réduit les débits de pointe au printemps et décalé le moment des débits de pointe plus tôt. Ces changements ont déplacé les signaux thermiques plus tôt, entraînant une migration plus précoce de l'alose. Les interactions possibles entre l'alose et les poissons indigènes, en particulier les salmonidés, sont nombreuses mais mal comprises. Pour le rapport complet, voir https://www.nwcouncil.org/reports/american-shad-columbia-river-past-present-future.

## ABSTRACT

In 1871, American shad (*Alosa sapidissima*) was introduced into the Sacramento River, California from the Hudson River, New York. Within 5 years, shad colonized the Columbia River, more than 1,000 km to the north. For 80 years, shad numbers in the Columbia River remained low, but increased greatly after 1960, with nearly 8 million adult shad entering the river in 2019. During a period when native populations of salmon have declined, shad have become the most abundant anadromous fish in the river, comprising more than 90% of upstream migrants in some years. The abrupt increase in shad coincided with completion of a dam in 1957 that flooded a natural barrier to the upstream migration of shad. Shad have colonized 700 km upriver as the series of dams expanded, using passage facilities for native salmonid species. Upriver spawning migration in spring is closely linked to river discharge and temperature. Hydrosystem management has decreased peak discharges during spring and shifted the timing of peak flows earlier. These changes shifted thermal cues earlier, resulting in earlier shad migration. Possible interactions between shad and native fishes, especially salmonids, are many but poorly understood. For full report, see https://www.nwcouncil.org/reports/american-shad-columbia-river-past-present-future.

## KEYWORDS

Dams, Discharge, Fish, Nonindigenous, Temperature

# 1 POPULATION INCREASES OF NONINDIGENOUS AMERICAN SHAD IN THE COLUMBIA RIVER

In 1871, American shad (Alosa sapidissima) was introduced into the Sacramento River in California from the Hudson River in New York because of their popularity as a food and game fish in their native range (Hasselman et al. 2012). Within 5 years, shad moved 1,000 km north and colonized the Columbia River and smaller rivers along the West Coast of North America.

This rapid geographic expansion was a consequence of their anadromous life history that allowed them to leave their natal river and then colonize other rivers at maturity. For more than 80 years, shad numbers were relatively low in the Columbia River; however, shad numbers have increased greatly since 1960, with nearly 8 million adult shad entering the Columbia River in 2019 (Figure 1). The abrupt increase in shad numbers coincided with the completion of The Dalles Dam (river km 308) in 1957, which flooded Celilo Falls, previously a barrier to the upstream migration of shad (Hinrichsen et al. 2013). Shad are now found almost 700 km upstream from the Pacific Ocean. Shad colonized upriver reaches as the series of dams expanded, using passage facilities provided for native salmonid species. Shad are now the most abundant anadromous fish in the river, making up over 90% of the upstream migrants in some years. This raises questions about the management of shad populations because populations of shad have decline substantially within their native range on the East Coast of North America and populations of native anadromous salmon and steelhead in the Columbia River system have declined.

American shad spawn in spring or early summer, influenced by rising water temperatures and river discharge. The fertilized eggs become embryos that float just off the bottom, drifting downstream to favorable rearing habitats. Following hatching, young-of-the-year remain in their river of origin during the summer, enter marine waters in the fall, spend several years at sea, and return in spring or early summer to spawn. Shad in the Columbia River appear to be favored by warmer ocean conditions, making climate changes a potentially important factor in future shad populations.

Upriver migration for spawning in the Columbia River occurs in spring (primarily in May and June, at present), closely follows peak discharge, and is closely linked to rising water temperature. Shad migrate earlier in warmer years than in cooler years. Observers have used 15.5° C as a convenient index of spring warming on the Columbia River, and shad migration timing is correlated with the date each year when this temperature is first reached (though the peak migration occurs later, at ca. 18° C). Quinn and Adams (1996) also used 15.5° C as an index value for consistency. They reported that the Columbia River was warming earlier in the year than in the past (as well as reaching higher maximum temperatures), and the shad were migrating earlier. After several decades of the 15.5° C index value occurring earlier, the timing of this temperature has remained similar since the mid-1970s. This timing has important implications for understanding potential interactions of adult and juvenile shad with other species in the Columbia River.

While temperature is a cue for fish migratory behavior, discharge also plays a role. Quinn and Adams (1996) discussed the influence of temperature and discharge on migration and concluded that migration timing was more highly correlated with temperature than discharge. They also noted that temperature and flow are themselves correlated, and the spring upriver migration of shad in the Columbia River coincides with peak flows related to snowmelt in headwater tributaries Because water temperature in the Columbia River during the spring migration is also significantly related to discharge, the spring upriver migration of shad coincides with peak flows from snowmelt in headwater tributaries along with spring precipitation. The majority of adult shad migrate up the Columbia River from mid-April through the end of August. River regulation has substantially modified the annual hydrograph, decreasing peak discharges during spring and early summer and increasing flow from November through March during fall and winter seasons. Maximum outflow from Bonneville Dam in the spring decreased from the 1940s to the late 1970s, remaining fairly consistent from 1980 to the present although the day of the year when maximum daily outflow has occurred continues to occur earlier. Peak outflow from Bonneville Dam now occurs approximately 25-30 days earlier than in the mid-20th century which is consistent with the general change in timing of the peak of adult shad returns. In 1950-1970, average adult shad return peaked in early July approximately 25 days after the peak discharge period. In 1980-2020, average adult shad returns peaked in mid-June approximately 20 days after the peak discharge. Such changes in the hydrology and thermal regimes could influence shad migrations further and have major implications for their interactions with anadromous salmonids

and native aquatic communities.

Despite their abundance, few management or research programs have targeted shad. The possible interactions within the Columbia River ecosystem between shad and native fishes, especially salmonids, and between shad and predatory fish, birds and mammals are poorly understood.

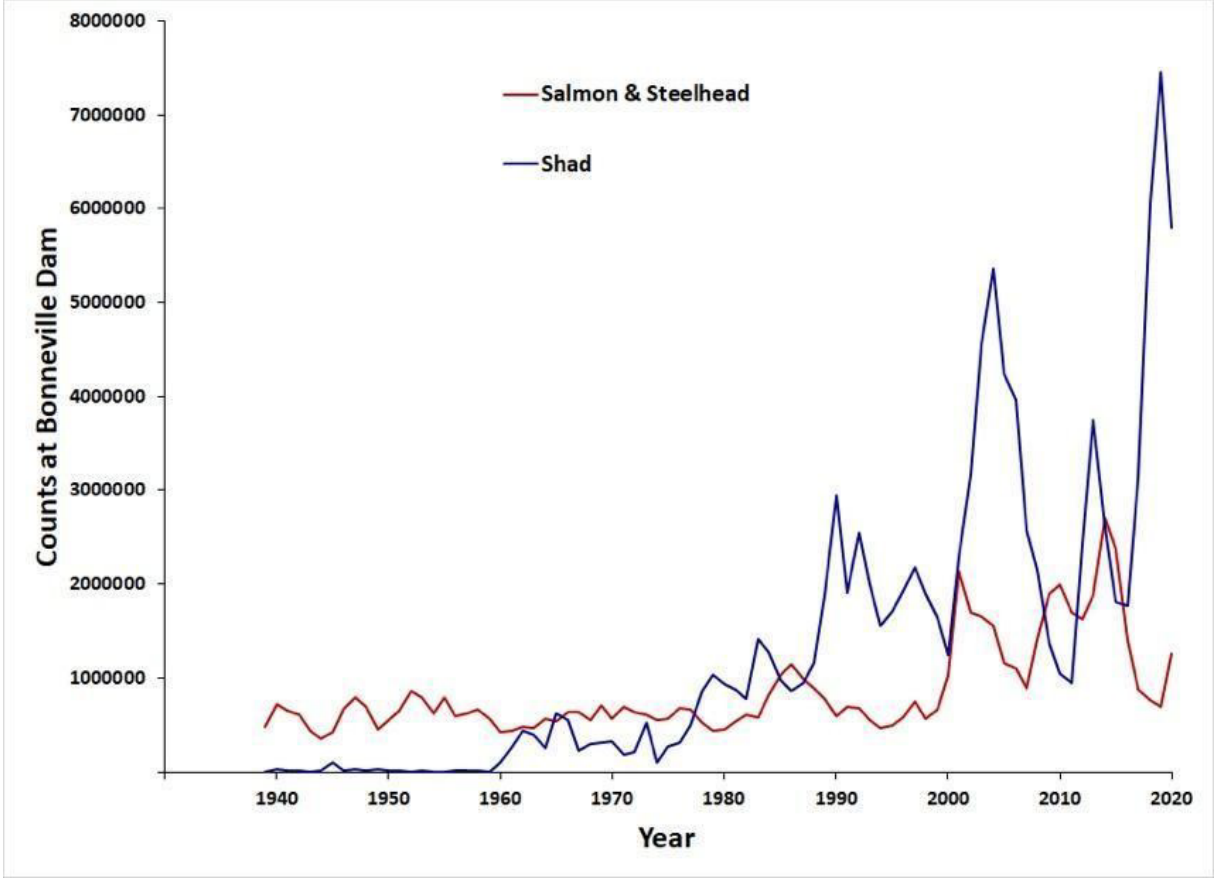


Figure 1. Counts at Bonneville Dam of all adult salmon and steelhead combined (red) compared to counts of shad (blue). Data from Columbia River DART (2021).

For the full report by the Independent Scientific Advisory Board of the Northwest Power and Conservation Council (*American Shad in the Columbia River: Past, Present, Future*), see https://www.nwcouncil.org/reports/american-shad-columbia-river-past-present-future. The author acknowledges the assistance of Peter Moyle, John Epifanio, Tom Quinn, Tom Wainwright, Cynthia Jones, and Erik Merrill in this presentation.

## LIST OF REFERENCES

Hasselman, D.J., R.A. Hinrichsen, B.A. Shields and C.C. Ebbesmeyer. (2012). The rapid establishment, dispersal, and increase in abundance of invasive American shad in the Pacific Northwest. *Fisheries,* 37(3), 103-114.

Hinrichsen, R.A., D.J. Hasselman, C.C. Ebbesmeyer and B.A. Shields. (2013). The role of impoundments, temperature, and discharge on colonization of the Columbia River basin, USA, by nonindigenous American Shad. *Transactions of the American Fisheries Society,* 142, 887-900.

Quinn, T.P. and D.J. Adams. (1996). Environmental changes affecting the migratory timing of American shad and sockeye salmon. *Ecology.* 77, 1151-1162.