What Will Be the Most Abundant Anadromous Species in the Columbia River Basin in 2100 as Predicted by Scientific Experts?

by

Jessica A. Heppler

A Capstone Final Report

Submitted to

Oregon State University

In Partial Fulfillment of

The Requirements for the

Degree of

Professional Science Masters in

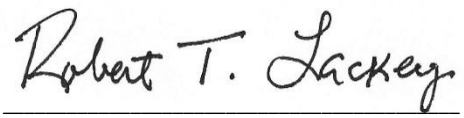
Fisheries and Wildlife Administration

Presented and Defended: *June 25th, 2026*

buckskinmare@gmail.com

APPROVED:

Representing the Department of Fisheries, Wildlife, and Conservation Sciences, Oregon State University.



Robert T. Lackey, Major Professor

I understand that my final report will become part of the permanent collection of the Oregon State University Libraries. My signature below authorizes the release of my final report to any reader upon request.

Jessica A. Heppler, Student

Disclaimer

This report was written to fulfill part of the requirements of a graduate degree at Oregon State University. Nothing in this report should be construed to necessarily represent the policy positions of my current employer, my past employers, or Oregon State University.

Abstract

This study determined which anadromous fish species Columbia River Basin (CRB) expert salmon scientists predict will be most abundant in the CRB in 2100. I vetted and invited 170 Columbia River Basin anadromous fish experts, of which 79 agreed to participate. Experts invited to participate were defined as those with at least 5 years' experience, as assessed by publications and curricula vitae. Survey responders were assured anonymity to encourage candid answers. A majority (68%) of surveyed experts predicted American Shad (*Alosa sapidissima*) as likely being the most abundant anadromous fish species in the CRB in 2100. Second was Chinook salmon (*Oncorhynchus tshawytscha)* at 8%. Eulachon (*Thaleichthys pacificus)* was predicted by 6% of the respondents. All other species represented 4% of the respondents' predictions or less. Of the 79 responding experts, a fifth (20.5%) predicted that salmon (*Oncorhynchus spp.)* or steelhead (*Oncorhynchus mykiss)* would be the most abundant species in the CRB by 2100. Shad are currently the most abundant anadromous fish species in the CRB, and the surveyed experts predicted that the situation is unlikely to change through 2100. Past CRB salmon recovery programs, although costing billions in direct and forgone economic opportunity costs, have not restored salmon runs to being the most abundant anadromous fish species, nor do the experts predict that this will happen by 2100.

Introduction

Over the past 35 years, over 9 billion USD have been spent by the United States (Jaeger and Scheuerell 2023) on restoration efforts for salmon and steelhead in the CRB. This estimate does not include foregone economic opportunity costs. Before 1850, salmon and steelhead were the dominant anadromous fish species in the CRB with runs estimated to be 7.5 to 16 million fish (Alldredge et al. 2015). With the arrival of many immigrants from the eastern United States to the CRB starting in the 1840s, the downward trend in salmonid abundance began.

Dams and associated landscape alterations, initially used for agriculture and mining, eventually evolved into a massive modern network of mainstem and tributary dams utilized primarily for power generation, transportation, and flood control. These dams hindered the migratory movements of anadromous fish, including posing substantial impediments to young fish migrating downstream to estuarine and marine habitats and upstream migration of adult fish to spawning habitats (Raymond 1988, Booth 1989, Rechisky et al. 2013). Increased sediment loads from mining and timber activities further reduced salmon numbers by smothering gravel beds used for spawning (Robbins 2002). Starting in the 1990s, a dozen salmon runs (also called stocks, evolutionarily significant units, or distinct population segments) had declined to the point of warranting protection under the Endangered Species Act (Harrison 2011, United States National Marine Fisheries Service 2022). Some runs are likely to have been extirpated in the interim (Gustafson et al. 2007).

Except for a single run listed in 2005, all others were listed in the 1990s (Table 1). Despite the decades that have elapsed since the listing of all of these CRB salmon and steelhead runs, there are no runs that have improved to a level where delisting would be warranted (United States National Marine Fisheries Service, West Coast Region 2022*a*, *b*, *c*, *d*, 2024). In more than 3 decades since the first CRB salmon and steelhead ESA listings, billions of dollars have been spent in attempting to recover salmon numbers without much success (Rice and Lackey 2019). Jaeger and Scheuerell (2023) conducted a Return on Investment (ROI) analysis and determined that despite the billions spent on salmon recovery, there has been no statistically significant improvement.

Table 1. CRB Salmon and Steelhead populations listed for protection under the ESA by year.

Common Name	Species	Threatened or Endangered	Year Listed
Snake River Sockeye	*Oncorhynchus nerka*	Endangered	1991
Snake River fall run Chinook	*Oncorhynchus tshawytscha*	Threatened	1992
Snake River spring/summer run Chinook	*Oncorhynchus tshawytscha*	Threatened	1992
Upper Columbia River Steelhead	*Oncorhynchus mykiss*	Endangered (Reclassified to Threatened in 2006)	1997
Snake River Basin Steelhead	*Oncorhynchus mykiss*	Threatened	1997
Lower Columbia River Chinook	*Oncorhynchus tshawytscha*	Threatened	1999
Upper Willamette River Chinook	*Oncorhynchus tshawytscha*	Threatened	1999
Upper Columbia River spring run Chinook	*Oncorhynchus tshawytscha*	Endangered	1999
Columbia River Chum Salmon	*Oncorhynchus keta*	Threatened	1999
Lower Columbia River Steelhead	*Oncorhynchus mykiss*	Threatened	1999
Upper Willamette River Steelhead	*Oncorhynchus mykiss*	Threatened	1999
Middle Columbia River Steelhead	*Oncorhynchus mykiss*	Threatened	1999
Lower Columbia River Coho	*Oncorhynchus kisutch*	Threatened	2005

The decreasing numbers of anadromous salmonids (Figure 1) are unacceptable to angling interests that find salmonids in the CRB to be a highly desirable species to catch. To satisfy the need for more harvest than what the wild runs could provide, hatcheries were and are utilized to supplement the salmonid run levels to satisfy the harvest demand. Early (1860s onward) demand was from canneries, but more recently from anglers and tribal interests (Dammerman et al. 2017). Hatchery efforts to bolster salmonid runs however have added and compounded problems to the low numbers of wild CRB salmonids including issues with the stocks being utilized (Reisenbichler and McIntyre 1977, Tipping and Busack 2004), and performance of hatchery reared fish (Chilcote et al. 1986, Ebel et al. 2022) among others (Buchanan et al. 1983, Nickelson et al. 1986, Bottom et al. 2021). While it is likely that the large numbers of hatchery-origin fish have sustained CRB salmonid fisheries to protect the extant wild runs, much political controversy remains over how to proceed with continued hatchery operations to best support declining salmonid runs (Brannon et al. 2004, Alen 2025).

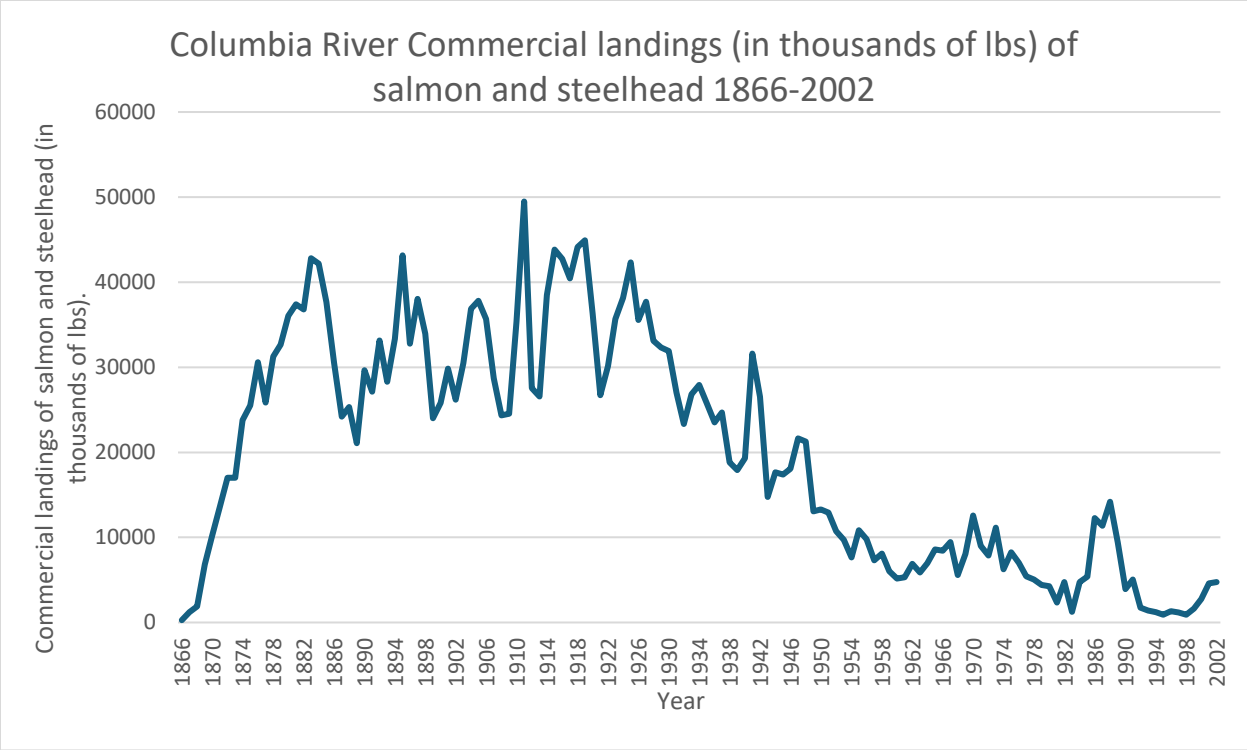


Figure 1. Estimated Columbia River Salmon and Steelhead Landings from 1866 – 2022 (in pounds). Data taken from Status Report: Columbia River Fish Runs and Fisheries 1938-2002. (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2002).

In addition to anadromous salmonids, there are other anadromous species present in the CRB. The abundance of non-native American Shad (Shad*)* has greatly increased since they first became established in the late 1800s. They are observed in large numbers migrating through the Bonneville Dam fish ladder (Petersen et al. 2003, Carothers et al. 2021).

Pacific Lamprey (*Entosphenus tridentatus)* and White Sturgeon (*Acipenser transmontanus)* are both present in the CRB, and while they are not listed for protection under the ESA, similar to the CRB salmonids, they are also species targeted by large-scale recovery efforts.

Eulachon are also present in the CRB, which were listed as threatened under the Endangered Species Act in 2010 (National Marine Fisheries Service 2017a). Reports of Striped Bass *(Morone saxatilis)* appear to be increasing in frequency and fishing guides have begun advertising fishing for this introduced anadromous species in the lower reaches of the CRB (FiveCrows 2013, Enns 2020, Pollock 2023).

Not all anadromous fish species are declining in the CRB. Shad, for example, prosper in the currently highly altered CRB. Many other non-native and non-anadromous species (Walleye, Smallmouth Bass, Largemouth Bass, Northern Pike, and others) are doing very well and generally appear to be increasing in abundance. Although some anadromous species are currently doing better than salmon and steelhead, the question remains: Even with all the salmon and steelhead recovery efforts underway, what will be the most abundant species by 2100?

Methodology

Through an evaluation of the peer-reviewed scientific literature and American Fisheries Society membership, I initially identified 130 scientists on CRB salmon that I determined to be experienced and knowledgeable scientists about anadromous fish species in the CRB. Experience was assessed by reviewing initial candidates' publications, curricula vitae, and other professional information available on the internet. Not considered to be scientific experts were those individuals who did not appear to have documented substantial experience in mid- or high-level science or salmon management activities. For example, field and hatchery technicians or those in supporting science or management roles were not included in the target pool. Candidates lacking the requisite 5 years of experience and at least 5 scientific publications about salmon or other CRB species were excluded.

In an effort to avoid real or perceived policy pressure on the selected scientists to advance their employers' policy positions, all candidates were assured anonymity. This assurance ideally encouraged forthright answers and reflected what they actually think about future anadromous species abundance. Anonymity assured that there is no way for anyone to link a specific comment or vote to a name, minimizing any potential occupational or personal ramifications.

To address the potential bias of responses to certain employment types of salmonid scientists, I categorized the candidates into groups based on employment. These groups included groups like Tribal, Federal Government, State Government, Private entities, and Academia. It was common to find candidates who had occupations of more than one type in reviewing their experience, so I opted to use the most current place of employment as the category I placed them in. I then selected an equal number of experts from the areas of Washington, British Columbia, Oregon, Idaho, and Montana. Some types of experts proved to be difficult to find enough candidates to fill my sample sizes (e.g., Tribal), or it was impossible to discern the level of expertise. In such cases, I included as many of that particular expert type as I could find and filled the balance with experts equally distributed among other occupational

categories. Ultimately, I could not find enough tribal experts to balance against the other types of experts, and this may represent a bias in the data sample.

Recruitment of respondents began first with emails to scientists who met the minimum expertise standard, asking them if they would participate. Respondents to the initial recruitment email were then emailed the survey question (Appendix 1). Unfortunately, at the time of the survey, several U.S. Government natural resource and fisheries agencies shut down, rendering some of the survey participants unable to receive the survey question. To ensure a sufficiently large pool of survey participants, I selected an additional group of candidates vetted using the same selection criteria. In total, 170 experts were contacted, with 79 providing an answer to the question (Appendix 2), a response rate of 46.5 percent.

Some candidates provided succinct, direct responses with a single species. Others provided a species (or several species) but added rationales behind their answer. Information volunteered by respondents above and beyond the immediate question response requirement was reviewed thoroughly and carefully considered for policy implications presented in the Discussion section. All responses and all narrative text are provided in Appendix 2.

Results

The principal result (Table 2) is that 68% of respondents predicted American Shad as the fish likely to be most abundant in 2100. Shad was followed by Chinook salmon at 8%. Eulachon was listed by 6% of the respondents. All other species were at 4% of respondents or less.

Table 2: Summary of Responses to the survey question of Which anadromous fish species will most likely be the most abundant in the Columbia River Basin in 2100?

Results: Predictions for most abundant species in the Columbia River Basin by 2100
American Shad - 68%
Chinook Salmon - 8%
Eulachon - 6%
Coho Salmon - 4%
Steelhead - 3%
Striped Bass - 3%
Lamprey - 2.5%
Salmon spp. - 2.5%
Sockeye Salmon - 2%
Pink Salmon - 1%

About 80% of the respondents predicted that an anadromous fish species other than a salmonid would be the most abundant in the CRB in 2100. Broadly, they predicted that the anadromous fish situation in 2100 will most likely roughly follow the current state.

American Shad

Considering the many narrative comments (Appendix 2), the 68% of respondents who predicted American Shad as the most likely to be the most abundant in 2100 had several points in common. Many recognized that Shad were well adapted to the human-created lake-like and segmented sections of the CRB created by the lock-and-dam hydroelectric system (Hasselman et al. 2012). Respondents also frequently highlighted that Shad are relatively tolerant of warmer water conditions in both the ocean and river (Chittenden 1972, Carothers et al. 2021) and that these altered conditions are suboptimal for most other anadromous species in the CRB (Van Wert et al. 2023). Many respondents also emphasized that CRB Shad already dwarf other runs, and continue to increase today. Looking forward, the majority of the commenters predicted that shad runs will continue to increase.

Native to the eastern coast of the United States, Shad were introduced to the West Coast in the late 1800s as part of an effort to introduce fish species considered economically valuable (Smith 1895). Specifically, American Shad were introduced in the Sacramento and Willamette Rivers as part of this early range expansion effort (Hasselman et al. 2012). These introductions led to American Shad colonizing rivers on the western coast of North America from Mexico to Alaska. Many scientific studies over the years have documented the striking population increases occurring in the CRB (Petersen et al. 2003, Carothers et al. 2021). For example, in 2019, the number of American Shad that passed through the Bonneville Dam (lower Columbia River) fish ladder set a new record of 7.7 million Shad, with the second biggest run to date in 2022 with 6.4 million shad (Washington Department of Fish and Wildlife 2023).

Anadromous Salmonids

The 20.5% of respondents who predicted some species of anadromous salmon or steelhead likely to be most abundant by 2100 (Appendix 2) were in the minority. Of the total responses received, 8% predicted Chinook Salmon as most abundant in 2100, 4% predicted Coho Salmon, 3% predicted Steelhead, 2% predicted Sockeye Salmon, 1% predicted Pink Salmon, and the respondents who predicted salmonids without specifying a species represented 2.5% of respondents. Participants were not constrained to respond with wild-fish (non-hatchery) returns only, but to include *any* returning salmon regardless of origin. Hatchery-reared fish were generally not addressed by respondents in the narrative comments, except in

the context of raising fish to bolster populations. Currently, roughly 80% of the CRB aggregate salmon run is supported by hatchery releases (Williams 2005, Paquet et al. 2011). Shad are not grown in hatcheries in the CRB, so their runs comprise 100% wild-origin fish.

In the narrative responses, respondents who predicted that a salmon species would be the most abundant in 2100 pointed to restoration efforts, both ongoing and completed, continued strong and focused funding for salmon recovery goals, and numerical bolstering with hatchery-reared fish. Two respondents in particular noted the resiliency of Coho salmon, calling out certain populations as showing promise for further population increases with additional restoration actions. Some answers indicated optimism in innovations in hydropower or other power generation methods in addition to new technologies that would allow fish to circumnavigate dams with less mortality. Several expressed optimism for new or improved invasive species control methods and/or a political willingness to reduce invasive species competition with the native salmonid species.

Eulachon, Striped Bass, and Pacific Lamprey

Relatively few selected Eulachon, Pacific Lamprey, and Striped Bass as likely to be the most abundant in 2100 (Appendix 2).

Approximately 6% of all respondents selected Eulachon as the most abundant anadromous species in 2100. Although the literature is limited, Eulachon likely exist in the tens to hundreds of millions, easily dwarfing the numbers of both salmon and shad combined *numerically* (National Marine Fisheries Service 2017b), a possibility identified by two survey respondents. Individual Eulachon are very small relative to salmonids, and not much is known about their numbers (or total weight) in the CRB, as run sizes are estimated from pounds of fish caught (Gustafson et al. 2010). Depending upon the individual size in a pound, there could be a large *number* of Eulachon. Thus, estimating their precise overall numerical abundance is difficult, and the range of error is potentially immense.

Despite this lack of numerical precision, in 2012 the southern Distinct Population Segment (DPS) of eulachon was listed for ESA protections following several years of poor commercial catch. The southern DPS is the same population of Eulachon that inhabits the CRB and is estimated to likely represent the largest run (numerically) of these fish within the southern DPS (National Marine Fisheries Service 2017a). Eulachon have not been observed utilizing fish ladders, and the extent to which they spawn beyond Bonneville Dam is unknown, but occasionally documented (Gustafson et al. 2010).

Only 2.5% of respondents predicted Pacific Lamprey would be most abundant in 2100. Pacific Lamprey is an anadromous fish species that is native to the CRB. This fish is influenced

by some of the same problems and conditions that overlap with salmon, including dams and climate change (Clemens et al. 2017, Wang et al. 2020). While not listed for ESA protection and, similar to salmonids, this fish has been the focus of recovery actions in the CRB (Close et al. 2002, Luzier et al. 2011, Clemens et al. 2017).

Similarly, only 3% of survey respondents predicted Striped Bass as most abundant in 2100. As with American Shad, Striped Bass are a species introduced to the West Coast in the late 1800s (Smith 1895). It is known to be established (FiveCrows 2013) in the CRB below Bonneville Dam. While it is unknown how far Striped Bass have migrated into the CRB, only a single individual was observed passing through the Bonneville Dam fish ladder in 2013 (Landers 2013). Population numbers for Striped Bass in the CRB are currently unknown.

Discussion

Nearly 7 in 10 of the surveyed experts predicted that American Shad, currently the most abundant anadromous fish in the CRB, will remain so through 2100. Using an anonymous survey of scientific experts, nearly 70% of respondents, while not asked to account for recovery actions explicitly, in the narrative comments, many did, and implicitly predicted that salmonid recovery efforts will continue to occur, but the outcome is that those actions will not restore salmonids to the most abundant species in the CRB.

The sampled scientific experts are a sample of the most knowledgeable scientists about the current anadromous runs in the CRB, and presumably they could best predict future conditions. The survey results showed that nearly 70% of them predicted that American shad (currently the most abundant anadromous species in the CRB) would remain so through at least 2100. By implication, they also predict that the salmon recovery activities most likely (in their expert opinion) would continue to take place through this century without any apparent change in salmonid abundance.

There is no lack of peer-reviewed and published studies documenting the dwindling numbers of salmonid runs both past and present (Ashley 2006). The choices and actions that would make a difference in salmonid run recovery are similarly well known by experts, but would be difficult to implement (Bilby et al. 2024), in many cases unpopular from a policy standpoint (Lackey 2000, 2013), and unlikely to happen by 2100 as the survey participants implied with their predictions. Conversely, some of the effects, such as warming waters and a river that behaves like a series of reservoirs, that have proven detrimental to salmonids have contributed to the success of shad in the CRB (Chittenden 1972, Hinrichsen et al. 2011).

Despite listing individual distinct population segments for ESA protections, salmon runs have failed to rebound. Since the first listing of CRB salmon runs in the early 1990s, there has

been no indication of broad-scale recovery of any of the CRB runs listed as endangered as of 2026 (Ford et al. 2025). As noted by NOAA in 5-year reviews, bolstered by numerous peer-reviewed and published studies, all runs listed for protection under the Endangered Species Act in the CRB remain listed today (United States National Marine Fisheries Service, West Coast Region 2022*a*, *b*, *c*, *d*, 2024). This status exists despite billions of dollars being spent on recovery and conservation actions in the decades since listing. By implication, the experts agreed that this status was likely to continue.

Furthermore, studies (Rice and Lackey 2019, Bilby et al. 2024) have observed that a considerable amount of money has been spent on attempting to reverse the decline of CRB salmonid runs with no evidence that the efforts made a major difference in the longterm trend. Jaeger and Scheuerell (2023) documented the failure to see *any* returns on the billions of dollars spent for the improvement in salmon runs. Bilby et al. (2024) discussed reasons (including recovery efforts not being in place for a sufficient time to show results, not doing the correct actions at the appropriate time, etc.) why there have not been many, if any, improvements. The survey of experts reported here was broadly consistent with those conclusions. Additionally, results of surveyed salmonid experts by Lackey (2022) also are broadly consistent with this study and imply that the current status quo in terms of CRB anadromous salmonid species abundance will remain unchanged in 2100 (Lackey 2022).

While some efforts have been made to forecast the likely status of CRB salmonids in the future (Duncan et al. 2006, Lackey et al. 2006), no other study to date has *anonymously* surveyed salmon science experts to predict the future status of salmonid abundance in the CRB. To date, despite extensive and sustained efforts to restore CRB runs of salmon, American shad have thrived, as have some other nonnative fish species (walleye, smallmouth bass, largemouth bass, Northern pike, and others) (Hasselman et al. 2012, Carothers et al. 2021, Washington Department of Fish and Wildlife 2023).

While few of the scientific experts in this study predicted salmonids to be the most abundant in 2100 in the CRB, they also implied in narrative comments that there does not appear to be much motivation to reduce expenditures on salmonid restoration programs. Lawsuits over CRB salmon issues range from possible adverse effects of hatchery-origin salmon on wild salmon to, more generally, failure to protect and recover wild populations. Thus, it seems likely that lawsuits and the activities of many advocacy organizations will continue to require the Federal government to continue spending money on the CRB salmon restoration (McCall 2008, Beaver 2025, Rush and Johnson 2026). One substantial but uncertain policy driver is whether some (or all) CRB salmon runs will be exempted from ESA. Exempting salmon in the CRB from the ESA would greatly change the salmon recovery policy dynamic, but the likelihood of such a change is speculation at this point (Clarke 2014).

The majority of experts in this study predicted that anticipated recovery and restoration efforts through this century will not recover or restore salmonid populations by 2100 to the point where they would be most abundant. However, based on the implications of narrative comments, recovery actions will likely continue, although there was little explicit elaboration about whether spending would be increased. Based on the narrative comments, the overall failure of salmon recovery efforts is nearly universally acknowledged.

In summary, considering the totality of the survey results and the volunteered narrative comments, the status of the currently most abundant CRB anadromous fish species, the non-native American Shad, will remain most abundant at least through 2100, and the runs of salmon will continue to be very low compared to historical abundance.

Acknowledgements:

I would like to thank my advisor, Dr. Robert Lackey, for all of his advice, reviews, and willingness to simply stop and talk me through this process, especially with the challenges and sensitivities that salmonid policy can represent. This effort quite simply would not have been possible without his patience, insight, and willingness to coach me through a topic rife with policy conundrums and political disputes.

I also thank the other members of my graduate committee (Drs. James Peterson, Erika Wolters, and Susie Dunham) for their insightful and frank comments and discussion. Their combined efforts made this capstone project possible, and I thank them for regularly providing their perspectives on all aspects of this project.

I would also like to acknowledge the surveyed scientific experts who provided answers to my survey question. In addition to answering the single survey question, many provided extensive, well-written, and thoughtfully rationales justifying their answer. These narrative answers provided invaluable insight into the difficult task of assessing the ecological and policy factors relative to CRB salmon issues.

Finally, I would like to thank my husband and my parents for their support throughout the entire Capstone process. Their endless encouragement kept me moving forward and past the many obstacles that arise during a Capstone Project.

References

Alen, B. W. V. 2025. Hatchery Salmon and Ecological Overshoot. Aquaculture, *Fish and Fisheries* 5:e70103.

Alldredge, R., K. Fausch, A. Maule, R. Naiman, G. Ruggerone, L. Saito, D. Scarnecchia, S. Schoder, C. Schwarz, and C. Wood. 2015. *Density dependence and its implications for fish management and restoration*. Northwest Power and Conservation Council, Portland, Ore.

Ashley, K. 2006. Wild salmon in the 21st century: energy, triage, and choices. *Salmon 2100: The Future of Wild Pacific Salmon* 71–88.

Beaver, T. 2025. Lawsuit argues BPA's energy market move violates federal, environmental laws. *Tri-Cities Area Journal of Business*. 14 December 2025.

Bilby, R. E., K. P. Currens, K. L. Fresh, D. B. Booth, R. R. Fuerstenberg, and G. L. Lucchetti. 2024. Why Aren't Salmon Responding to Habitat Restoration in the Pacific Northwest? *Fisheries* 49:16–27.

Booth, D. E. 1989. Hydroelectric Dams and the Decline of Chinook Salmon in the Columbia River Basin. *Marine Resource Economics* 6:195–211.

Bottom, D. L., S. A. Hinton, D. J. Teel, G. Curtis Roegner, L. L. Johnson, and B. P. Sandford. 2021. The Abundance and Distribution of Hatchery and Naturally Produced Chinook Salmon in Columbia River Estuary Nearshore Habitat. *North American Journal of Fisheries Management* 41:1549–1571.

Brannon, E., D. Amend, M. Cronin, J. E. Lanna, S. LaPatra, W. McNeil, R. Noble, C. Smith, A. Talbot, G. Wedemeyer, and H. Westers. 2004. The controversy about hatcheries: The use of hatcheries in supplementation and recovery of wild salmon and steelhead: resolving the confusion of hatchery fish performance with fisheries management. *Fisheries* 29:12–31.

Buchanan, D. V., J. E. Sanders, J. L. Zinn, and J. L. Fryer. 1983. Relative Susceptibility of Four Strains of Summer Steelhead to Infection by *Ceratomyxa shasta*. *Transactions of the American Fisheries Society* 112:541–543.

Carothers, C., J. Epifanio, S. Gregory, D. Infante, W. Jaeger, C. Jones, P. Moyle, T. Quinn, K. Rose, and T. Turner. 2021. *American Shad in the Columbia River: Past, present, future*. Report 2021Y4. Independent Scientific Advisory Board, Northwest Power and Conservation Council, Portland, OR.

Chilcote, M. W., S. A. Leider, and J. J. Loch. 1986. Differential Reproductive Success of Hatchery and Wild Summer-Run Steelhead under Natural Conditions. *Transactions of the American Fisheries Society* 115:726–735.

Chittenden, M. 1972. Responses of Young American Shad, *Alosa sapidissima*, to Low Temperatures. *Transactions of the American Fisheries Society* 101:680–685.

Clarke, C. 2014. *Northwest Water Users Want Exemption from Salmon Protection*. Public Broadcasting Service, Southern California 23 April 2014.

Clemens, B., R. J. Beamish, K. Coates, M. Docker, J. Dunham, A. Gray, J. Hess, J. Jolley, R. Lampman, B. McIlraith, M. Moser, J. Murauskas, D. Noakes, H. Schaller, C. Schreck, S. Starcevich, B. Streif, S. van de Wetering, J. Wade, and L. Wyss. 2017. Conservation Challenges and Research Needs for Pacific Lamprey in the Columbia River Basin. *Fisheries* 42:268–280.

Close, D., M. Fitzpatrick, and H. Li. 2002. The Ecological and Cultural Importance of a Species at Risk of Extinction, Pacific Lamprey. *Fisheries* 27.

Dammerman, K., B. Silver, D. Hand, D. Olson, J. Rivera, T. Gilmore, and D. Hines. 2017. *Monitoring and Evaluation of Mitchell Act-Funded National Fish Hatcheries in the Columbia River Gorge Complex.* USFWS, Vancouver, WA.

Duncan, S., D. Lach, and R. Lackey. 2006. Without a Change in Direction, We'll Get Where We're Going: Writing a Future for Wild Salmon. Pages 619–627 *in*.

Ebel, J. D., D. A. Larsen, K. R. Conley, and M. A. Middleton. 2022. A Fish Out of Basin: Increased Stress Physiology and Reduced Performance of Salmon River Hatchery Chinook Salmon. *North American Journal of Fisheries Management* 42:741–757.

FiveCrows, J. 2013. Striped Bass in the Columbia River?! CRITFC. <https://critfc.org/2013/12/05/striped-bass-in-the-columbia-river>. Accessed 27 May 2025.

Ford, M. J., S. T. Lindley, K. A. Barnas, A. O. Shelton, B. C. Spence, L. A. Weitkamp, D. M. Holzer, D. A. Boughton, E. E. Holmes, J. M. Myers, C. E. Jordan, H. Fish, M. Liermann, M. R. O'Farrell, N. J. Mantua, R. C. Johnson, W. H. Satterthwaite, and T. H. Williams. 2025. Abundance Trends of Pacific Salmon During a Quarter Century of ESA Protection. *Fish and Fisheries* 26:1087–1106.

Gustafson, R. G., M. J. Ford, D. J. Teel, and J. S. Drake. 2010. *Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California*. NOAA.

Gustafson, R. G., R. S. Waples, J. M. Myers, L. A. Weitkamp, G. J. Bryant, O. W. Johnson, and J. J. Hard. 2007. Pacific Salmon Extinctions: Quantifying Lost and Remaining Diversity. *Conservation Biology* 21:1009–1020.

Harrison, J. 2011. *Endangered Species Act and Columbia River Salmon and Steelhead.* Northwest Power and Conservation Council. <https://www.nwcouncil.org/news/endangered-species-act-and-columbia-river-salmon-and-steelhead/>. Accessed 23 June 2025.

Hasselman, D., R. Hinrichsen, B. Shields, and C. Ebbesmeyer. 2012. The Rapid Establishment, Dispersal, and Increased Abundance of Invasive American Shad in the Pacific Northwest. *Fisheries* 37:103–114.

Hinrichsen, R., D. Hasselman, C. Ebbesmeyer, and B. Shields. 2011. Temperature and the upstream distribution of adult American Shad in the Columbia River basin.

Jaeger, W., and M. Scheuerell. 2023. Return(s) on investment: Restoration spending in the Columbia River Basin and increased abundance of salmon and steelhead. *PloS one* 18:e0289246.

Lackey, R. 2000. Restoring Wild Salmon to the Pacific Northwest: Chasing an Illusion? Pages 91–143. *What We Don't Know about Pacific Northwest Fish Runs: An Inquiry into Decision-Making.*

Lackey, R. T. 2013. Saving wild salmon: a 165-year policy conundrum. Pages 3–4. Dubach Workshop: *Science and Scientists in the Contemporary Policy Process*.

Lackey, R. T. 2022. What Would Happen to Columbia River Basin Wild Salmon Runs If Hatchery Stocking and Fishing Ended. Published in an *Oregon State University Blog*, September.

Lackey, R. T., D. H. Lach, and S. L. Duncan. 2006. Wild salmon in western North America: forecasting the most likely status in 2100. Salmon 2100: 57–70.

Landers, R. 2013. Striped bass moving over Bonneville Dam? *Spokesman.com*. <https://www.spokesman.com/stories/2013/jun/28/striped-bass-moving-over-bonneville-dam-see-photo/>. Accessed 5 Dec 2025.

Luzier, C. W., H. Schaller, J. K. Brostrom, C. Cook-Tabor, D. Goodman, R. D. Nelle, K. Ostrand, and B. Streif. 2011. *Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation Measures.* U.S. Fish and Wildlife Service, Portland, Oregon. 282 pp.

McCall, W. 2008. BPA, tribes reach $900 million deal to help Columbia River salmon. *The Seattle Times.* 7 April.

National Marine Fisheries Service, editor. 2017a. *Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus)*. National Marine Fisheries Service. West Coast Region, Portland, OR.

National Marine Fisheries Service. 2017b. *Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus)*. National Marine Fisheries Service. West Coast Region, Portland, OR 132.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. Use of Hatchery Coho Salmon (*Oncorhynchus kisutch*) Presmolts to Rebuild Wild Populations in Oregon Coastal Streams. *Canadian Journal of Fisheries and Aquatic Sciences* 43:2443–2449.

Paquet, P. J., T. Flagg, A. Appleby, J. Barr, L. Blankenship, D. Campton, M. Delarm, T. Evelyn, D. Fast, J. Gislason, P. Kline, D. Maynard, L. Mobrand, G. Nandor, P. Seidel, and S. Smith. 2011. Hatcheries, Conservation, and Sustainable Fisheries—Achieving Multiple Goals: Results of the Hatchery Scientific Review Group's Columbia River Basin Review. *Fisheries* 36:547–561.

Petersen, J. H., R. Hinrichsen, D. M. Gadomski, D. H. Feil, and D. Rondorf. 2003. American shad in the Columbia River. *American Fisheries Society Symposium* 2003:141–155.

Raymond, H. 1988. Effects of Hydroelectric Development and Fisheries Enhancement on Spring and Summer Chinook Salmon and Steelhead in the Columbia River Basin. *North American Journal of Fisheries Management* 8:1–24.

Rechisky, E. L., D. W. Welch, A. D. Porter, M. C. Jacobs-Scott, and P. M. Winchell. 2013. Influence of multiple dam passage on survival of juvenile Chinook salmon in the Columbia River estuary and coastal ocean. *Proceedings of the National Academy of Sciences of the United States of America* 110:6883–6888.

Reisenbichler, R. R., and J. D. McIntyre. 1977. Genetic Differences in Growth and Survival of Juvenile Hatchery and Wild Steelhead Trout, *Salmo gairdneri*. J*ournal of the Fisheries Research Board of Canada* 34:123–128.

Rice, R., and R. Lackey. 2019. Annual Costs of Wild Salmon Restoration Efforts in the Columbia River Basin.

Robbins, W. 2002. *Timber and Salmon*. Oregon History Project. <https://www.oregonhistoryproject.org/narratives/this-land-oregon/political-and-economic-culture-1870-1920/timber-and-salmon/>. Accessed 23 June 2025.

Rush, C., and G. Johnson. 2026. *Judge orders changes to Columbia and Snake River dam operations to help 'disappearing' salmon*. Associated Press. 26 February 2026.

Smith, H. 1895. *A Review of the History and Results of the Attempts to Acclimatize Fish and other Water Animals in the Pacific States*. United States Fish Commission.

Tipping, J. M., and C. A. Busack. 2004. The Effect of Hatchery Spawning Protocols on Coho Salmon Return Timing in the Cowlitz River, Washington. *North American Journal of Aquaculture* 66:293–298.

United States. National Marine Fisheries Service, editor. 2022. *Rebuilding Interior Columbia Basin Salmon and Steelhead.*

United States. National Marine Fisheries Service. West Coast Region, editor. 2022*a*. *2022 5-Year Review: Summary & Evaluation of Middle Columbia River Steelhead.* https://doi.org/10.25923/63dr-dw24.

United States. National Marine Fisheries Service. West Coast Region, editor. 2022*b*. *2022 5-Year Review: Summary & Evaluation of Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, Lower Columbia River Coho Salmon, and Lower Columbia River Steelhead.* https://doi.org/10.25923/431f-fc96.

United States. National Marine Fisheries Service. West Coast Region, editor. 2022*c*. *2022 5-Year Review: Summary & Evaluation of Upper Columbia River Spring-run Chinook Salmon and Upper Columbia River Steelhead.* https://doi.org/10.25923/p4w5-dp31.

United States. National Marine Fisheries Service. West Coast Region, editor. 2022*d*. *2022 5-Year Review: Summary & Evaluation of Snake River Basin Steelhead.* https://doi.org/10.25923/pxax-h320.

United States. National Marine Fisheries Service. West Coast Region, editor. *2024. 2024 5-Year Review : Summary & Evaluation of Upper Willamette River Steelhead, Upper Willamette River Chinook Salmon.* https://doi.org/10.25923/dxwv-8d59.

Van Wert, J., B. Hendriks, A. Ekström, D. Patterson, S. Cooke, S. Hinch, and E. Eliason. 2023. Population variability in thermal performance of pre-spawning adult Chinook salmon. *Conservation Physiology* 11.

Wang, C., H. Schaller, K. Coates, M. Hayes, and R. Rose. 2020. Climate change vulnerability assessment for Pacific Lamprey in rivers of the Western United States. *Journal of Freshwater Ecology* 35:29–55.

Washington Department of Fish and Wildlife. 2023. *Columbia River shad run tops 1.5 million with more streaming toward Bonneville Dam for excellent fishing along the lower mainstem.* <https://wdfw.medium.com/columbia-river-shad-run-tops-1-1-9ac9d53c8675>.

Washington Department of Fish and Wildlife, ODFW. 2002. *Status Report Columbia River Fish Runs and Fisheries 1938-2002 - Tables Only* | Washington Department of Fish & Wildlife. <https://wdfw.wa.gov/publications/00931>. Accessed 15 Feb 2026.

Williams, R. N. 2005. *Return to the river: restoring salmon back to the Columbia River*. Elsevier.

Appendix 1. Letter sent to Participants

Using several different approaches, I have identified salmon experts who have documented credentials as professionals in the field. You are one of those individuals. These individuals are (or were) employed by Federal, State, Tribal, private, university, advocacy, and other organizations. I tried to have various academic disciplines and employing organizations represented.

For each survey participant (you), I am asking a single question about the future of Columbia River Basin anadromous fish species. ***All survey participants (and their employers) will remain entirely anonymous****. Further, the participating individuals will not be identified in any manner that will infer their identity, nor will their employer (except in very general categories).*

Here is some background to the question you will be answering. For this survey, what counts as an anadromous fish species in the Columbia River Basin? Here is a possible list in alphabetical order:

American Shad
Chinook (King Salmon)
Coho (Silver Salmon)
Eulachon (Candlefish)
Pacific Lamprey
Pink (Humpback Salmon)
Sockeye (Red Salmon)
Steelhead
Striped bass
White Sturgeon

Some of these species were established in the Columbia River Basin pre-1850. Others have become established since then. If I have missed any anadromous fish species (including any which are likely to be established later this century), please feel free to consider them in your prediction!

Here is your question to answer:

Which anadromous fish species will most likely be the most abundant in the Columbia River Basin in 2100?

To help me with my analysis, please constrain your formal answer to one sentence. However, also feel free to add narrative comments justifying or expanding on your answer!

Appendix 2. Survey Participant Answers

Respondent	Answer
1	My answer is American Shad.
2	I believe American Shad will likely remain the most abundant species (numerically) within the Columbia River Basin. I believe that because this species seems to be thriving when other species are struggling with changing ocean conditions. Since the 1970s, the American Shad have been the most abundant species counted at Bonneville Dam.
3	Based on current trends, I believe that American Shad will be the most abundant fish species in the Columbia River Basin in 2100; however, I also think Coho may have a chance to continue increasing abundance into the future, and while I wouldn't bet on them surpassing American Shad, I would be rooting for them to win the race.
4	My answer is American Shad. It is already the most abundant anadromous species in the Columbia River basin and seems better able to adapt to likely climate change-induced changes to the basin's ecosystem. I wish I could say it was one of the native species, but while American Shad numbers continue to increase in recent history, I have a hard time imagining that many of the native salmon, steelhead, or sturgeon populations will experience a dramatic upward shift in their population trajectories.
5	American shad will likely be the most abundant anadromous fish species in the Columbia River in 2100 as they are already far and away the most abundant (2-7 million per year vs approx. 2 million per year for all salmon & steelhead combined)1 and prospects for significant salmon improvements are highly uncertain given climate trends, declining hatchery funding and a demonstrated lack of commitment to address fundamental salmon habitat and mainstem hydropower-related impacts.
6	I believe that the American Shad will be the most abundant anadromous fish species in the Columbia River System in 2100, mostly due to its fecundity and low levels of harvest, combined with anticipated fisheries management failures for native species.
7	American Shad will likely be the most abundant anadromous fish species in the Columbia Basin in 2100, followed by Pacific lamprey because of their ecological flexibility, steelhead, and possibly Chinook salmon at the lowest abundance. Comments 1) Climate change and deteriorating ocean conditions will continue to degrade conditions for cold-water anadromous species, particularly salmon and steelhead. 2) Hydrosystem effects will likely continue to degrade the relative abundance of anadromous salmonid species, considering that the demand for energy and power will continue to increase in the future. 3) Salmon and steelhead abundance may be kept artificially high by hatchery production if it is continued and managed to support them. 4) Fisheries management actions will continue to evolve over the next 75 years and may have an effect on the relative abundance of anadromous species in the Basin. 5) Striped bass could possibly be present in the Basin by 2100 if they were introduced in sufficient numbers to establish a reproducing population.
8	My answer would be American Shad. This is based on the fact that exotic species tend to take over freshwater ecosystems

9	Using numbers rather than biomass, I'd put my money on shad being the most abundant (numerous) anadromous species in the Columbia River Basin in 2100. I'm making a lot of assumptions in making that call, not the least of which is that the Columbia River will be able to support ANY anadromous fish 75 years from now. Additional short list of assumptions off the top of my head: some anadromous fish species that aren't already in the Columbia River show up and proliferate. Managers (Canada, ID, WA, OR) have already reached our capacity for artificially producing or naturally boosting native anadromous fishes. Managers don't take additional measures to reduce shad abundance. I'm sure there are many others. Some of these assumptions are likely to be violated; for example, we're in the middle of lamprey recovery, and we're expanding the range of salmonids back to the pre-dam anadromous range, so my second bullet assumption is probably violated.
10	American Shad; their abundance is orders of magnitude above other native fishes, and the ISRP did a report on this.
11	American Shad – Should increase greatly (op. cit.). Chinook (King Salmon) – Likely further declines, especially for the spring and summer runs that SRKWs aren't getting enough of. Hatchery fall Chinook might maintain themselves, though (op. cit.). These three runs would do better if the lower Snake River (LSR) dams got breached by 2100 (Storch et al. 2022; Winters 2023), depending on whether harvest strategy allows more escapement and thus carcass MDNs (Michael et al. 2025). The reintroduction of Chinook above Grand Coulee Dam is encouraging, though. Coho (Silver Salmon) – As recovery is occurring in the lower to mid-Columbia, they might maintain themselves, especially if the LSR dams got breached. Indeed, they haven't done well with damming. Eulachon (Candlefish) – Likely further declines in the lower Columbia, as oceanic conditions worsen from climate change. Pacific Lamprey – As recovery (e.g., translocation) is occurring in the lower to mid-Columbia, they might maintain themselves (op. cit.; Vadas 2024), perhaps even increasing if the LSR dams got breached. Indeed, they haven't done well with damming (Michael et al. 2025), although they have some flexibility to landlock (Vadas 2024). Pink (Humpback Salmon) – Likely continue to be seen in low numbers in the lower Columbia. They much prefer the fjord-like Salish Sea over the outer coast in the Pacific Northwest. Steelhead – As they're warmer-adapted and can residualize/landlock better than other larger-bodied, Pacific salmonids, they have a better chance of maintaining themselves, including the downriver winter run and upriver summer run, but there should be delayed harvesting to allow more iteroparity to prevent further population declines. The summer run might benefit if the LSR dams got breached. Coastal Cutthroat Trout – Likely continue to maintain themselves in the lower Columbia, but further removal of tributary-passage barriers might allow some increase. Striped bass – Unlike south of the Columbia River, stripers haven't colonized the lower Columbia much yet, although a modest increase might occur as climate change proceeds. Western River Lamprey – Likely continue to be seen in low numbers in the lower to mid-Columbia. They're now recognized as the sea-run morph of Western Brook Lamprey, which are more abundant in the Columbia River Basin, is not fish-passage limited. But further research is needed on this sea-run fish. White Sturgeon – Likely further declines given their intolerance of landlocking via damming. These three runs might do better if the lower Snake River (LSR) dams got breached. Despite some uncertainty, I tend to agree with Dr. Paul Ehrlich, who once noted that he was optimistic about what people can do, but pessimistic about what they'll actually do.
12	I expect that American Shad will continue to be the most common anadromous fish in the Columbia River because key lower river dams creating spawning habitat are unlikely to change before 2100 and projected climate warming will maintain or improve the thermal habitat for the species in the region.
13	Against all my desires, as I've worked on CRB salmon and steelhead recovery for more than 30 years, I believe it likely that American shad will be the most abundant anadromous fish in the Columbia River system by 2100, if not much sooner.

14	The species most likely to be the most abundant anadromous species in the Columbia River basin in 2100 is American shad; this metric is, of course, one of many that indicate the state of the Columbia basin ecosystem and would not alone be indicative of success or failure of efforts towards salmon recovery. American shad are the most abundant anadromous species in 2025, and it seems likely that will continue in the future. Regardless, the success of efforts towards salmon recovery will depend on a number of factors: the level of climate change impacts that is realized (freshwater and ocean), how much large landscape- and floodplain-scale habitat restoration can be effectively and extensively implemented (including dam removal), and at what level the likely need continues for hatchery production to meet abundance and harvest goals.
15	In 2100, American Shad will continue to be the most abundant anadromous fish in the Columbia Basin. It was introduced in the 1800s, and the population continues to grow! ISAB recently reported that in some recent years, shad represented 90% of all upstream migrants in the Columbia, and the population is still growing. I like to follow the data in making this prediction. So, shad will continue to be the most abundant anadromous species. I have captured many, many shad in the Duwamish waterway near Seattle, but few people know about their abundance.
16	I suspect that all anadromous species will still occur (in low numbers) in the Columbia R. in 2100, but American Shad will be most abundant.
17	I am predicting the most abundant anadromous species in the Columbia River basin in 2100 will likely be shad. They are doing very well, and salmonids, except for coho, continue to struggle with the dams in place.
18	I believe the American Shad will be the most abundant in the Columbia River Basin in 2100. With the proliferation of shad despite mounting efforts to keep numbers down, I suspect that being a non-native and thriving in the basin will only allow shad numbers to grow in the coming decades.
19	American shad are the most abundant anadromous species in the Columbia River and are increasing in abundance—a trend that is likely to continue into the foreseeable future given climate-change effects such as warming water temperatures on freshwater, estuary, and ocean habitats.
20	I know from work in the Columbia that the American Shad are increasing, but defer to the natural scientists in your sample to make those predictions!
21	American shad, by far.
22	American shad will most likely be the most abundant in the Columbia River Basin in 2100. American shad were introduced to the Sacramento River in the 1870s and made their way to the Columbia River soon thereafter. Today, shad are the most abundant anadromous fish in the Columbia. Their success stems from high fecundity, broad habitat tolerance, and the ability to exploit reservoir environments and fish passage structures originally built for salmon. Hydrosystem modifications, consistent plankton availability, and minimal directed management have allowed shad populations to expand unchecked. Given these enduring advantages and the stability of their established life cycle in a regulated river system, I estimate that American Shad will be the numerically dominant anadromous species in the Columbia River well into the next century.
23	American shad already are numerically more abundant crossing Bonneville Dam than all salmon species combined, and that trend seems to be building and moving upriver. This statement is easily verified by looking at dam counts.
24	My vote goes to American Shad. Barring any large-scale disease outbreak, this invasive species seems to me to already have a big numerical advantage over the other anadromous fishes in the Columbia, and there is lots of habitat they can still exploit.
25	American Shad
26	Given the continuing habitat modifications of the Columbia River by dams, it seems that the most abundant anadromous fish species in the river by the year 2100 is likely to be American Shad.
27	In my professional opinion, American Shad will likely be the most abundant anadromous fish species in the Columbia River Basin in 2100.

28	American shad are (and have been for years) the most numerous anadromous fish in the Columbia River and will continue to be through the year 2100.
29	Shad will be the most abundant anadromous fish species in 2100. I am pretty sure they already are the most abundant, and climate-driven declines in native anadromous species, plus a failure to remove dams or robustly address their impacts on migrations of salmon and sturgeon, will likely contribute to an ongoing shift in species abundance away from salmon and towards more warm water-tolerant species like shad.
30	I think American Shad will most likely be the most abundant in the Columbia River Basin in 2100, based primarily on their diverse diet and broad habitat requirements.
31	My formal answer: American shad will be most abundant numerically. Shad are less dependent on long upstream migrations and complex life histories and likely less impacted by climate change. Chinook and/or sockeye salmon could dominate, but that is dependent on significant environmental and management (river system) changes to improve their survival.
32	My answer to the question is: The anadromous species most likely to have the greatest abundance in the Columbia River Basin in 2100 is American Shad. Rationale: I came to the conclusion that American Shad will have the greatest abundance in 2100 based on the factors in the accompanying Table 1. They are an introduced species that has taken root in the Columbia River Basin. Their positive population trend is based on natural reproduction and has already resulted in their being the most abundant species in the basin. The second most abundant species, Chinook Salmon, is hatchery supported with low natural reproduction. While hatcheries can potentially increase Chinook Salmon, Coho Salmon, and Steelhead abundance above current levels, economic and political factors make this unlikely. Given the temperature changes in their native habitat, American Shad would seem better preadapted to a warming environment than Pacific Salmon. The increasing national need for electric power suggests the mainstem dam removal necessary for anadromous recolonization of White Sturgeon historical habitat is unlikely. Without knowing a clear reason for Eulachon abundance declining, I do not expect this trend to reverse by 2100. While having the opportunity to colonize the Columbia River Basin, Striped Bass have shown meager progress since their introduction. The abundance estimates for Pacific Lamprey may be underestimated based on one paper I skimmed. As I am unaware of the dam screen issue being resolved, I do not expect their abundance to increase. Although I did not consider them in Table 1, anadromous Cutthroat and Bull trout also live in the Columbia River Basin. Their abundance, like the other Salmonids, will probably diminish between now and 2100.

33	In the year 2100, the most abundant anadromous fish species in the Columbia River watershed will be the American Shad. That was easy, as it is currently the most abundant because of the habitat modifications, mostly dams. They are the only anadromous species reasonably well adapted to the current conditions, and those conditions are unlikely to change in any way meaningful to anadromous salmonids. Salmonid numbers will likely decline as money for hatcheries becomes tighter. There may be some minor increases in wild salmonid numbers as restoration efforts continue, but managers are unwilling to restore the runs to ecologically meaningful numbers. The "goals" for restoration are pitifully small (see Williams and Lichatowich). The increasing human population, which we have no intention of constraining, will have increasing demands for water, food, fiber, minerals, and electricity. All of these will further stress salmonids. Couple this with Climate Change, and the warming conditions are also damaging. ... I have stated, at meetings, that the only way to restore CR salmon is to remove all the dams in the anadromous zone. Doing this, coupled with harvest reductions sufficient to allow recovery, might give salmonids a chance. But even then, the shad would have a lot of usable river, and they are naturally more abundant than the salmonids. Time is of the essence. I worked in Fraser River sockeye management, and when the International Pacific Salmon Fisheries Commission disbanded, after 50 years, they had restored many stocks. The Horsefly went from 1,000 spawners cumulative in the first four years to well over a million (I think almost 2) in the last 4. But it took 50 years. In 50 years, it will be 2075 on the Columbia, and the dams are still in.
34	Answer: In 2100, I would assume that non-native Shad will continue to be the most abundant anadromous species in the Columbia River, as they have been since the 1980s.
35	I predict American shad will be the most abundant anadromous fish in the Columbia in 2100. As far as rationale for this prediction, shad have had extremely high abundances in recent years (3-7 million adults counted over Bonneville, who knows how many going through the locks), with the highest abundance (7 million) during the blob (marine heat wave) years. This suggests to me that they benefit from unusually warm conditions both in the ocean and the river, and will continue to benefit from a warming world.

36	With a low level of confidence, I would guess that American shad will continue to be the most abundant anadromous fish in the Columbia River Basin over the next few decades and possibly to 2100. Comments: • My low level of confidence is because American shad life histories are well-suited for the currently configured Columbia Basin reservoir system and passage at dams (Bonneville to McNary) up to Priest Rapids Dam. So, their continuing, and perhaps increasing, abundance likely relies on the current configuration of the hydrosystem and passage structures. Based on historical observations at Priest Rapids Dam, migrating adult shad do not tend to pass sub-surface entryways to fish ladders, and a lack of surface entryways substantially limits their passage. Thus, if fish managers decided to make passage at some of the lower four Columbia River dams' fish ladders only sub-surface, that could potentially limit access to a significant amount of shad habitat and reduce their abundance, unless shad altered their behavior at the fish ladders. Similarly, if the dams became obsolete and were removed because of other power sources or expensive maintenance issues in the next 75 years, that could alter the hydrosystem as well. I don't have any predictions on that potential change. • It would be interesting to know which anadromous fish species' adult returns have the largest biomass and compare this with adult abundance. For example, eulachon (~2.5 ounces) can have large runs in numbers of fish, but the overall biomass of the run could be significantly less than a shad (~2 to 4 pounds) run, and there would be a similar comparison with shad and heavier Chinook (~20-35 lbs. for fall Chinook). Although with Chinook, the researcher would need to decide whether to lump hatchery and wild fish in the calculation. In terms of your question, I lumped hatchery and wild salmonids and thought shad would still be more abundant, as they are now. • Thanks for listing striped bass; it made me look them up to see their recent returns to the Columbia and the San Francisco Bay Delta. They have an extended southern range, and it will be interesting to see if their nominal abundance in the Columbia increases with climate change, but it appears their numbers have been declining in the Bay Delta area.
37	I believe shad will be the most abundant anadromous species in 2100.
38	American shad because it likes warm water, is a physiologically resilient species, is increasing in the Columbia Basin, and has low fishing pressure.
39	I think the American shad will continue to be the most abundant species in the Columbia by 2100. I believe that all of the other anadromous fishes will remain, but it's difficult to anticipate overall abundances. Dam removals and continued effects of changing climate would undoubtedly change conditions dramatically, leading to differences in abundances of other species, but I suspect shad would be favored most by those changes and still come out on top (unless actions were taken to reduce their numbers).
40	Of the Pacific salmon, pink salmon will likely do best (relative to their historical abundances) as they are "climate change winners" while Chinook will fare the worst. Sockeye, Chinook, and steelhead will persist due to their importance and the likelihood of continued biological enhancement. Coho will persist in low numbers. Non-native American shad will likely continue to be the most abundant species. Striped bass, another non-native species, will likely persist in low numbers. Pacific lamprey will exhibit minor increases in abundance, due primarily to enhancement efforts. Columbia eulachon are near the southern limit of their global distribution and will not thrive but likely persist, but in low and possibly decreasing numbers. Sturgeon will persist with lower Columbia populations likely faring better than upper Columbia (including Canadian) populations.

41	I would think that Shad would be the most abundant species by 2100. Rationale: assuming that climate change will continue more or less as predicted, fish species adapted to more southernly climates will shift their range further north, while colder water species range will retract along their southern boundaries. Shad numbers should rise above their abundance (low millions) in response. Striped bass will fare well, but their abundance will not come close to that of shad. Further, the presence of striped bass, in larger numbers, in the Columbia River estuary will be a significant additional predation source on out-migrating salmonid juveniles - this will also parallel the expanded range of freshwater invasive species (largemouth bass). Bad tidings for salmonids indeed.
42	I believe that 'American Shad' is the answer to your question.
43	My guess is that American shad will be the most abundant in 2100. This is based on their apparent ability to live in rivers that get pretty warm in the summer, and more generally that they evolved in the Atlantic where there is stronger seasonal temperature variation that might have pre-adapted them to the warming PNW.
44	"In the spirit of a 'thinking exercise', and based on the knowledge in my head at this moment, I predict that American shad will be the most abundant anadromous fish species in the Columbia River basin in 2100."
45	I believe that in 2100 the most common (by numbers of adult fish) anadromous fish in the Columbia River will be American Shad.
46	It is my opinion that American shad (*Alosa sapidissima*) will be the most abundant anadromous fish species in the Columbia River basin by 2100, as this species has experienced exponential growth since its introduction along the Pacific coast in 1871 and the species is known to tolerate warmer river temperatures, making the American shad more resilient to climate change than native anadromous species.
47	It is with sadness that I provide the following … as much as I'd like to think that we'll "turn a corner" for anadromous salmonids, a likely continued decline in salmonid-appropriate habitats (at all life history phases) as well as the obvious disparities in fecundity of female results in the following (we can hope I'm wrong, but the trends will likely continue): In my professional opinion, American Shad Alosa sapidissima will likely be the most abundant anadromous fish species in the Columbia River Basin in 2100.
48	American shad are most likely to be the most abundant anadromous fish in the Columbia River Basin in 2100 due to their current prevalence and the threatened or endangered status of most, if not all, native anadromous species.
49	Unless there are dramatic changes, I'm pretty sure it will be shad, as they seem to have adapted nicely to life in an impounded Columbia. The only way I could see this changing is if the Columbia is restored to something much closer to the historic Columbia river that would require significant dam removals not just in the Snake River, but in the Columbia River as well, which I don't see happening. A management action that could change this prediction would be to figure out a way to change fish ladders to preclude shad. From what I've heard, this could be possible. In this case, perhaps Chinook due to high hatchery production.
50	The anadromous fish species I believe will be most abundant in the Columbia Basin in 2100 is the species that is currently most abundant: American Shad. The combination of short, free-flowing stretches and reservoirs on the Columbia and lower Snake rivers is ideal for shad. They spawn in the flowing reaches, and the juveniles feed on the zooplankton in the reservoirs. And they are capable of dealing with increased water temperatures due to climate change better than salmonids. Prognosticating about the future of the salmonids is a bit more difficult. I think pessimism about these populations is warranted. But we have seen a few populations increase since ESA listing (Upper Columbia Sockeye and Snake River Fall Chinook). There also has been some success with the reintroduction of Coho above Bonneville. Whether Coho will establish naturally spawning populations, however, remains unclear. But I do not see how any of the salmonid species could achieve abundance levels rivaling the shad.

51	The American Shad will be the most abundant anadromous fish species in the Columbia River Basin in 2100. American shad abundances have been increasing in the Columbia River over the past several decades. Shad are better adapted for warmer, slower-moving water compared to salmon. As the climate warms, the Columbia River basin is most likely going to see increasing river temperatures, making it harder to recover salmon populations and more likely that shad will thrive.
52	I consider that coho salmon will be the most abundant species in the Columbia basin from the apparent early successes in recovery plans to address habitat degradation/loss and dams, and given the resilience of this species, can be leveraged through enhancing rearing populations by reconnecting surface drainage networks in floodplains.
53	I believe that Chinook will be the most abundant anadromous species in the Columbia River system in the year 2100. Currently, Chinook is the most abundant species returning to the Columbia River system, for both natural and hatchery origin fish. Historically, Chinook was the most abundant species (3.4–9.2 million annual return, depending on the source). For anadromous species, Chinook and Steelhead have the most ESA-listed stocks (n = 6). It is my opinion that the success of a given species will be a function, somewhat, of the level of funding available for mitigation. Chinook, as does Steelhead, occupy a large geographical area within the Columbia River system, providing mitigation opportunities. I've selected Chinook because that species is an icon of the Pacific Northwest, and as such, I believe that a great effort will be made to secure the species.
54	I predict that Coho (Silver Salmon) will be the most abundant naturally reproducing anadromous fish species in the Columbia River system in the year 2100. Reasoning: Coho don't travel as far from the Oregon and Washington coast in the ocean, so local fisheries management is more impactful. They have shown great resilience and recovery in coastal systems and seem to be taking hold in the upper Willamette, which historically was not accessible to them because of Willamette Falls. Improvements to downstream juvenile passage (operational and structural) at Columbia River dams have improved, and reintroduction efforts have been successful to the point that they again have access to farther reaches of the Snake River tributaries (ex., Grande Ronde River). In addition, they appear to be outcompeting Chinook salmon in Columbia Tributaries that were once occupied primarily by Chinook (ex., Deschutes River) under current environmental conditions. Coho are better adapted to survive higher water temps than most salmonids. I would add that Pacific lamprey would be #2, primarily because their distribution is greatly limited by Columbia River dams.
55	Chinook salmon will be the most abundant anadromous fish species in the Columbia River Basin in 2100.
56	Because the heart demands it, the mind and body will work toward opportunities and learning to ensure that Oncorhynchus sp. will be both abundant and diverse in 2100 for the benefit of my grandchildren's grandchildren.
57	Probably steelhead because they are more widely distributed.
58	Fall Chinook Salmon will be the most abundant anadromous fish in the Columbia River Basin in 2100.

59	In the span of 75 years between now and 2100 (just less than 20 generations of salmon), I suspect that the negative effects of climate change and the hydrosystem will continue to limit the potential abundance of large native anadromous fishes (salmonids, sturgeon and lamprey) for the next 10 generations while the factors that have increased abundance of non-native shad will continue to maintain and increase abundance; however by 2100 (the second set of 10 generations), key innovations in energy generation will remove reliance on the hydrosystem for power and improve conditions for salmonids in parallel with control measures directed at limiting shad enough so that chinook salmon (primarily fall run) will be the most abundant anadromous fish in the Columbia River. A close runner-up will be sockeye salmon with all the improvements to passage in the upper Columbia River; however, sensitivity to high temperatures will lead to wide swings in abundance. Key innovations will require a revolution in energy power generation like fusion; however, this will only allow salmonids to reach a fraction of their historic abundance potential due to the relentless increase in habitat development that will keep downward pressure on habitat capacities. Once the abundance of the salmonids returns to higher levels, Pacific lamprey will dominate abundance for a period of years as healthy cycles of predator-prey dynamics establish equilibrium.
60	The anadromous species likely to be most abundant in the Columbia River Basin in 2100 is Chinook Salmon. Chinook Salmon was historically the most abundant species in the Columbia River Basin with widespread stocks present from near the mouth to upstream tributaries. Several factors have caused the decline of all native anadromous species, including: overfishing in the 1800s and 1900s, habitat loss and fragmentation from dam construction, habitat alteration from creation of reservoirs, and introduction of non-native species. Most anadromous species and populations, especially salmonids, are now supported by hatcheries. Chinook still are the dominant salmonid species. Since it is unknown what future changes will occur to habitat, species presence, and climate, I assumed that restoration/hatchery efforts would continue. It is my opinion that some level of habitat restoration (both expansion of range and elimination of reservoirs) is needed to see substantial increases in anadromous populations. There are several recent habitat restoration/dam removal efforts that demonstrate the almost positive response of anadromous species. These include dam removal on the Elwha River in Washington and on the Klamath River in Oregon/California. Dam removal can also disadvantage non-native predators such as smallmouth bass and walleye. The reservoirs also can delay smolt outmigration in addition to the predation risks. It is my opinion that with continued restoration and focused management efforts, all anadromous species will benefit, but Chinook Salmon will be the most abundant.
61	I think Steelhead will be the most abundant anadromous fish in the Columbia by year 2100. I picked Steelhead because of the species' resilient life history and immense recreational preference (which helps fund restoration). I am pessimistic about salmon & sturgeon recovery in the Columbia.
62	I have a hard time imagining what our salmon-bearing freshwater ecosystems will look like in 75 years given the warming climate trajectory we are on, but if I had to guess or hypothesize which anadromous species will be most abundant or even present in 2100, I would say pink salmon because they seem to be resilient and are colonizing new areas where they have not been observed historically.
63	To answer your question: I would guess Coho salmon since they are more adaptable to smaller tributaries and have strong hatchery programs along with habitat restoration projects to help maintain their numbers.
64	“I believe that by the year 2100, the region and nation will have looked to examples like the Klamath and Elwha and will have moved to restore the lower Snake River to a free-flowing reach, as such Pacific salmon and steelhead – Chinook, steelhead, coho, and sockeye – will be the most abundant species in the Columbia River Basin.”

65	My response to your question would be that I believe that Sockeye Salmon (O. nerka) will be the most abundant anadromous salmonid in the Columbia River system by the year 2100. My thoughts on this include: -Sockeye Salmon historically was the most abundant species in the Columbia/Snake River system, and numbers plummeted due to habitat alterations and alteration of nursery lakes. These lakes were converted to either reservoirs for power production and/or irrigation/water supply without providing upstream fish passage. -Many of these reservoirs are now being retrofitted with upstream fish passage facilities, while also providing for improved downstream fish passage. I am hopeful that these efforts to reestablish spawning/rearing areas for Sockeye (as well as the other anadromous species in the system) will result in Sockeye being able to utilize much more of their traditional areas that they are currently. -Although Chinook Salmon have historically had the greatest biomass in the system, unfortunately, even with the very welcome and necessary measures being taken in the Columbia/Snake River system, I don't believe that they will rebound to previous levels. This is due to the extensive level of habitat alterations that have occurred, many of which I don't believe will be corrected in the time period that is specified.
66	My professional guess would be Eulachon as the most numerous in 2100. I think that the limiting factors around bycatch are being addressed, and many of the other limiting factors they face from ocean conditions also exist for the other species. I would have predicted American Shad, but I foresee management actions to reduce shad numbers by creating commercial harvest and limiting their passage through the hydro system will be developed.
67	Numerically, I would suspect that Eulachon would be most abundant in 2100. Caveats: 1. Big unknowns are whether climate change will be effectively dealt with in the next 75 years, and the extent to which Snake and Columbia River dams remain. 2. My expertise is in Interior Columbia salmon (especially Chinook) and summer steelhead, not Eulachon.
68	Here is my tentative answer: Chinook: With 77% of the Spring/Summer Chinook populations in the Snake Basin estimated to reach quasi-extinction thresholds within the next 5-years and an estimated 19% decline in spawners each year, it may be expected that this species will be the least abundant by 2100. Chinook also have a narrower tolerance of habitat conditions compared to Steelhead and Lamprey, so are more susceptible to spawning/rearing area and passage habitat degradation. Steelhead: Steelhead are experiencing about an 18% decline in spawners each year, with 44% of the 7 distinct population groups in the Snake Basin predicted to be at or below the quasi-extinction threshold (50 spawners) within 5-years. However, their higher tolerance for habitat conditions and wider distribution in tributaries may contribute to them being in greater abundance by 2100 compared to Chinook. (Data for Chinook and Steelhead populations from: Snake Basin Chinook and Steelhead Quasi-Extinction Threshold Alarm and Call to Action, Nez Perce Tribe Department of Fisheries Resources Management, 2021. BP-24-E-YN-56). Pacific Lamprey: Lampreys appear to be increasing in abundance with recent returns above the 10-year average. Although currently adult returns are below those of steelhead and Chinook, the increased awareness of passage criteria and habitat conditions needed to sustain populations, coupled with the translocation of adults into watersheds where they had been extirpated, is contributing to the increases in the population, and this may lead to abundances greater than the other two species by 2100.
69	I know very little about Eulachon, but I see the recovery criteria range for the Columbia is 66 to 229 million spawners annually, whereas I believe shad are generally less than 10 million. What will those populations look like in 75 years? I will be an optimist: I believe Eulachon will remain the most abundant anadromous species in the Columbia River Basin in 2100.
70	I tried to answer this question by an analysis of growth and fecundity data in Fishbase https://www.fishbase.se/search.php. The database on these parameters for these species is not very thorough but could be followed up on. Anyway, I assumed that species with a high fecundity and growth rate would be the most abundant. Based on that angle, striped bass is the winner, but I think American shad is close behind.

71	My guess for which Columbia Basin anadromous fish species will be the most abundant in 2100 is Eulachon (smelt). Predictions of anadromous fish species composition and abundance in the Columbia Basin in 75 years (2100) are highly uncertain and primarily speculative. My logic path for picking smelt is: 1) Flow and water temperatures will be altered from current and historical conditions, 2) dams will still be present and operating in ways that don't maximize anadromous fish survival, 3) even if dams were removed, FW habitat restored, and climate change impacts curtailed salmon and steelhead would not exceed their historical abundance of 16+ million, 4) smelt habitat is constrained to lower Columbia, 5) smelt life history in FW avoids summer hot water, and 6) Smelt abundance is currently in 10+ million range and already the most abundant even in their ESA listed status.
72	I believe Pacific lamprey will be the most abundant in 2100.
73	In terms of numerical abundance of adult fish, I would anticipate that eulachon will continue to be (on average) the most abundant anadromous fish in the Columbia River Basin in 2100; on the other hand, if you are interested in adult biomass rather than numbers, without major changes to the hydropower system I expect that American shad will predominate in 2100 - with major improvements, I would expect Chinook salmon to have the highest biomass in 2100.
74	I'll go with striped bass.
75	American shad, fall Chinook ecotypes, and steelhead are likely to remain the most abundant species in the Columbia River Basin by 2100. However, this outcome depends heavily on how society adapts to growing energy demands, urbanization, water use, and access to historical spawning and rearing habitats. The future fish assemblage in the Columbia Basin will be shaped by society's response to ecosystem needs. Historical overexploitation, modification, and oversubscription of fisheries in Europe and the eastern U.S.—where Atlantic salmon, American eel, and other shad species are present—offer a cautionary tale for the Columbia Basin. Wild Atlantic salmon now struggle or are extirpated in many regions of their historic range. In the Columbia River, anadromous species with shorter juvenile residencies, like shad and fall Chinook, and those with documented genetic plasticity, such as steelhead, may show greater resilience to impacts on freshwater ecosystems. Nonetheless, climate change and the federal hydropower and flood control systems could lead to adaptations in fall Chinook's life histories, similar to the Sacramento River's winter-run life history, and variations in steelhead's freshwater residency (anadromous vs. resident) could occur. The abundance of native anadromous fish, including salmon, steelhead, lamprey, smelt, and sturgeon, is closely linked to the presence of sovereign Indigenous tribes. Columbia Basin tribes have co-evolved with salmon for over 16,000 years, adapting to significant ecological changes together, such as volcanic events, catastrophic floods, pandemics, and invasive species introductions. During periods when tribes were oppressed by U.S. policies (1800-present), salmon and steelhead populations struggled without tribal worldviews, ecosystem relationships, and advocacy. The continued existence of native anadromous fish in the Columbia Basin is inseparable from the ongoing presence of Indigenous people.

76	Assumption #1: Status quo water and fishery management continues with minor adjustments: American shad will be most abundant in 2100. The present basin management system has made incremental progress in habitat restoration efforts and, to some extent, hatchery management. However, many changes have occurred at the margins of what may be required to recover native anadromous species, including salmon. The impressive abundance of American shad in recent years may well be an ecological response to changing food webs (i.e., enhanced pelagic and diminished epibenthic and detrital-based food webs), elevated water temperatures, and an altered Columbia River hydrograph. Ecological changes in the basin have many sources but are driven to a large extent by the coordinated management of the dam and reservoir system, the replacement of historical salmon habitat with fish hatcheries, and underlying changes in the regional climate. Assuming the present management system does not respond significantly, I expect shad and warm-water resident species will continue to thrive while salmonid populations will diminish in abundance as temperatures approach and exceed lethal limits of many native cold-water species. Assumption #2: Coordinated conservation actions (e.g., habitat restoration, hatchery reforms, environmental flow regimes, Snake River dam removal, etc.) mimic "normative" ecological and hydrographic processes and help mitigate a warming climate: Chinook salmon will be most abundant in 2100. Salmonids, including Chinook salmon, are remarkably resilient in a region noted for unpredictable and catastrophic climatic and tectonic disturbance. Recent studies have documented surprising flexibility of anadromous salmonids to changing conditions and habitat opportunities. Restoration of diked estuarine wetlands, for example, has enabled re-expression of latent life histories by some Chinook and Coho salmon populations. Restoring life history variations, in turn, has enhanced population productivity and resilience. I believe salmon recovery is possible in the Columbia River basin, but it will require an alternative management framework to emulate the natural disturbance regimes to which Chinook salmon and other native aquatic fauna have adapted. This does not mean returning to a pre-developed state, but it will require a fundamental shift in the existing management approach to accommodate environmental variability. To the extent the present system is built around prediction and control of natural variations, it has established a novel stability to which salmonid species are ill adapted and where non-native fauna like American shad can thrive.
77	I believe American Shad and Sockeye will be the most abundant anadromous species in the Columbia River Basin in 2100. Assuming the Columbia and Snake Rivers continue to contain numerous reservoirs, these are the two species that are most likely to maintain somewhat stable (although highly variable year-to-year) populations over time. Young of both species prefer rearing in lakes even though they will be vulnerable to predation by introduced species. There have been considerable changes to planktonic food webs, including many plankton species introductions, that should benefit plankton feeders like shad and sockeye. Additionally, there is relatively little marine harvest of shad and sockeye, especially compared to ocean and in-river fisheries on other salmonids.
78	I think shad and striper will increase in abundance in the CR, while sturgeon and most salmonids will continue to decline, over the next 75 years.
79	American shad, Chinook salmon, and steelhead will make my most abundant list in part because of life history diversity and their ability to persist through times of severe change, and in part because of the continued high demand in tribal and sport fisheries, which will increasingly rely on hatchery production. Note that I selected three species because the most abundant species will switch from year to year.