Examining the Effectiveness of Nonprofit Groups' Expenditures on Species Recovery: The Case of Pacific Salmon and Steelhead[*]

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Abstract

The effectiveness and efficiency of environmental NGOs in recovering endangered and threatened species is not well studied in current literature. This paper provides the first estimation of the effect of environmental NGOs and government spending on the abundance of threatened Pacific salmon and steelhead. We develop a two-way fixed effects identification strategy that leverages salmon's biological features and exploits substantial within watershed variation in spending and species abundance. Our results show that both NGO and government conservation spending have a positive impact on the abundance of these species. We combine our main results with non-market benefit estimates and show that the benefits of recovering Oregon Coast Coho salmon exceed the costs.

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1 Introduction

Environmental groups actively devote resources to threatened species recovery. For example, over the period 1954-2004 the Nature Conservancy spent $5.3 billion on land acquisition to promote biodiversity (Davies et al., 2010). Smaller regional and local groups, including conservation organizations, land trusts, and riverkeepers, play a significant role as well. They coordinate advocacy for conservation policies, file lawsuits to force government action on behalf of wildlife, lobby state legislatures, monitor wildlife populations and water quality, restore habitat, and work with local landowners to promote conservation. Groups in our study area (Washington, Oregon, California, and Idaho) spent $80.5 million per year on average during the period 1995 - 2014.

Examining the impact of environmental non-governmental organizations' (NGOs) expenditures on species populations can help us assess the effectiveness of conservation efforts and the cost of species recovery, and to understand the role of NGOs in this process. However, the effectiveness of these efforts remains unclear and has not been subject to rigorous empirical assessment. Data limitations and the non-random nature of spending decisions have thus far precluded a rigorous analysis of the impacts of NGOs on threatened species (Langpap et al., 2018) . There is no centralized database of these organizations' expenditures on species recovery. Additionally, the impact of NGOs' efforts likely accumulates over time with durable habitat investments, and detailed population counts covering sufficiently long periods are not available for most species. Finally, the temporal and spatial scales of many ecosystems are too broad to be experimentally controlled (Butsic et al., 2017) .

This paper overcomes these challenges by combining data on threatened and endangered Pacific salmon and steelhead in the four states in our study area with information on expenditures by environmental NGOs and government resource management agencies located in the region. Distinct population segments of Pacific salmon and steelhead have been listed as endangered or threatened under the Endangered Species Act (ESA) over the last 30 years, and population counts are available for each segment. Leveraging the detailed population data and biological features of salmonids, we use a quasi-experimental approach for identification.

Environmental groups have actively advocated for Pacific salmon and steelhead by filing petitions and lawsuits to compel listing decisions (*Oregon Natural Resources Council, Inc. v. Kantor*, 1996; *Natural Resources Defense Council v. Kempthorne*, 2007; *WildEarth Guardians v. Jeffries*, 2019). They have also directly participated

in planning and implementation of habitat restoration projects over several decades (NMFS, 2016). Their reported program expenditures reflect these advocacy and management efforts. Using these data, we examine whether NGO investments have increased salmon and steelhead abundance in the region. Further, we study the mechanism through which these efforts help salmon recover. We use our findings to conduct a cost-benefit analysis of recovering a specific population in a federally defined evolutionarily significant unit, Oregon Coast Coho salmon.

This paper makes contributions to two strands of literature. First, it contributes to the economics literature on endangered species conservation. While both government agencies and NGOs invest substantial amounts on threatened and endangered species, to date the economics literature has only studied the effect of government expenditures on discrete measures of species recovery (Ferraro et al., 2007; Kerkvliet and Langpap, 2007; Langpap and Kerkvliet, 2010) . We are not aware of any previous empirical studies that estimate the impact of NGOs' expenditures. We fill this gap by estimating the effect of NGOs' expenditures on the abundance of threatened Pacific salmon and steelhead. This paper is also the first econometric analysis to use species abundance data to examine the effect of conservation efforts on species recovery; previous studies use discrete recovery status categories (Ferraro et al., 2007; Kerkvliet and Langpap, 2007; Langpap and Kerkvliet, 2010).

Second, the paper contributes to the literature on the relationship between non-profits, especially environmental nonprofits, and the provision of public goods. The topic of nonprofits and public good provision has long been of interest (Kingma, 1989; Ribar and Wilhelm, 2002; Duquette, 2017). There is a growing body of literature on the economics of environmental groups (see Grant and Langpap (2023) for a review). Sundberg (2006) analyzes the relationship between land trust membership and public goods generated by land conservation. Grant and Grooms (2017) examine the relationship between environmental group activity and regulatory inspections and compliance with the Clean Water Act. Grant and Langpap (2019) find that expenditures by environmental groups in a watershed improve water quality. This paper is the first to examine the impact of environmental group activity on endangered and threatened species.

The paper proceeds as follows. Section 2 provides background on Pacific salmon and steelhead and environmental groups. In section 3, we describe our data. Section 4 describes our empirical methodology and how it overcomes identification challenges. In section 5, we present our results, and in section 6 we use them to conduct a cost

analysis of species recovery. Section 7 tests the robustness of our results. The final section (Section 8) summarizes and concludes.

2 Background

2.1 Pacific Salmon and Steelhead

This study focuses on three species of Pacific salmon and steelhead in the U.S. states of Washington, Oregon, Idaho, and California: Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead trout (*Oncorhynchus mykiss*). Each species is further divided into two or more Evolutionary Significant Units (ESU) to identify distinct population segments for listing under the U.S. ESA.[1] Figure 1 shows the distribution of the three species and corresponding ESUs in the Pacific Northwest region.

Pacific salmon and steelhead have unique life cycles that stretch from freshwater rivers into the ocean and back, which is essential for our identification strategy. After emerging from eggs, juvenile salmon stay in cool, slow-moving stream reaches. After spending one summer and winter in these rearing areas, juveniles migrate towards the ocean. Each species remains in the ocean for a different length of time before returning to their original spawning ground (Hansen and Quinn, 1998). Coho spend 18 months in the ocean, Chinook one to five years, and steelhead trout two to three years. Chinook and Coho die after spawning.

2.2 NGOs and Spatial Scale

Determining the relevant spatial scale is an essential element for the quasi-experimental design in this paper. Our choice of spatial scale relies on the fact that NGOs' activities likely affect anadromous fish populations through their impact on habitat quality in creeks, streams, and rivers, which are interconnected through water flow within a watershed. Hence, we account for factors impacting salmon habitat quality by using watersheds as the unit of observation. Furthermore, the groups in our data tend to operate at a local scale. For example, Trout Unlimited is a cold-water fisheries NGO that has multiple local chapters throughout the pacific coast states. Each chapter's

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[1]An ESU is a population that is "substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species" https://www.fisheries.noaa.gov/laws-and-policies/glossary-endangered-species-act (accessed 4/18/2023).
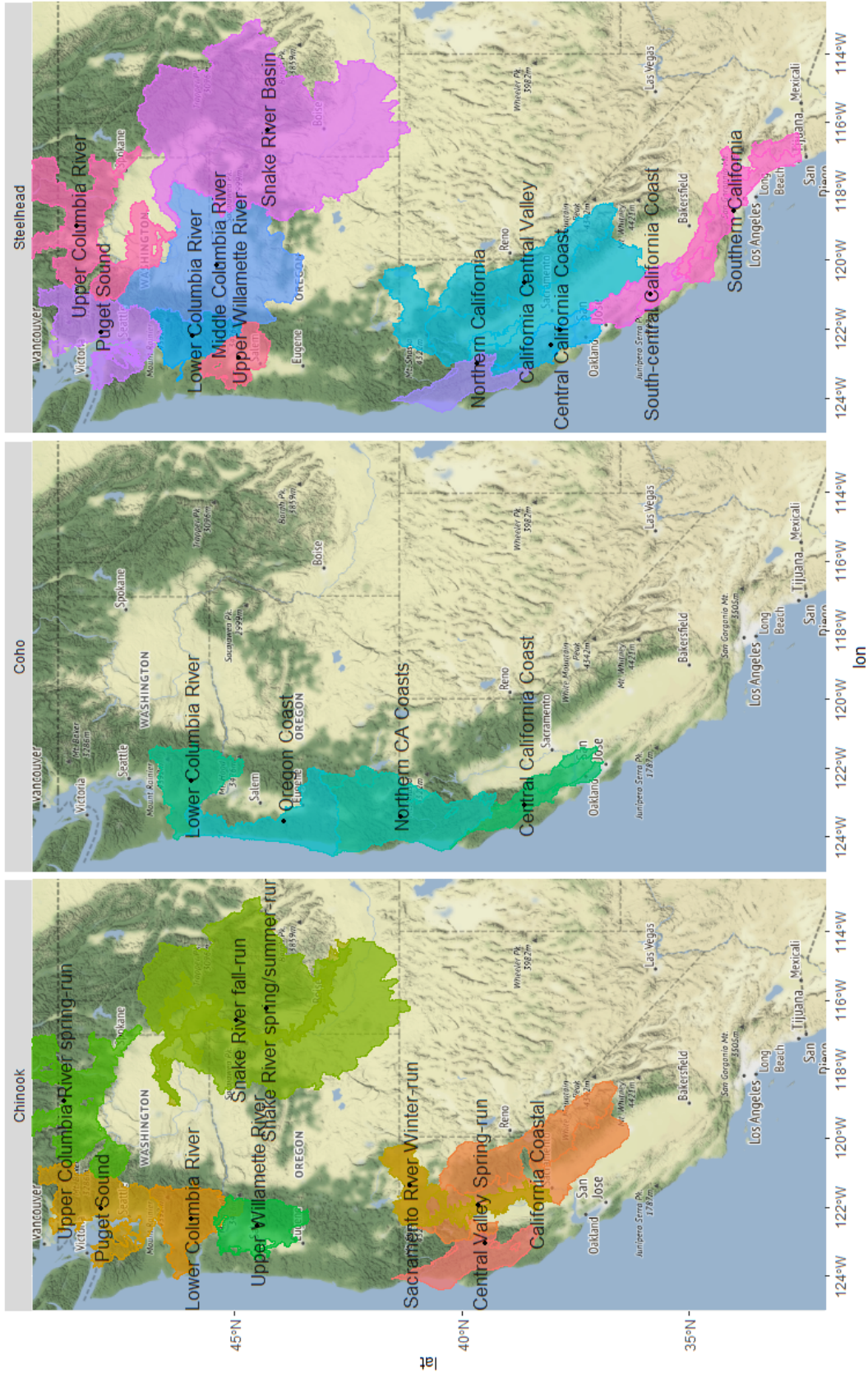
Figure 1. The Distribution of Endangered and Threatened Pacific Salmon and Steelhead

This figure shows the endangered and threatened Pacific salmon and steelhead ESUs categorized by species, namely Chinook, Coho, and steelhead. Each color represents a different ESU, and some species may have overlapping habitats (e.g., Snake River Chinook spring/fall run and Snake River Basin steelhead).

activities occur near their local headquarters. Hence we follow Grant and Langpap (2019) in using HUC8 watersheds as the unit of observation, which is the smallest area that a single NGO can affect.[2]

2.3 Mechanism for Impact of Recovery Expenditures

Biologists have long held that habitat degradation and loss, hydroelectric dams and impoundments, harvest practices, and hatchery misuse (the four Hs) are the major factors contributing to salmon decline (Ruckelshaus et al., 2002). They have been the primary focus of salmon recovery research and conservation efforts.

Anecdotal evidence suggests that NGOs influence salmon populations mainly through the habitat channel. Individual NGOs improve habitat quality directly through restoration efforts, and indirectly through water quality monitoring and litigation.[3] The government's conservation efforts, on the other hand, cover a broader scope. Salmon ESUs in our paper are listed as endangered or threatened under the ESA. Once listed, substantial resources are devoted to recovering species and their critical habitat, including investments in research, land acquisition, monitoring, propagation, and law enforcement. As a result, government recovery efforts are likely to improve salmon populations through all four channels.

3 Data

We collect data from multiple sources, constructing a panel of 115 watersheds in Washington, Oregon, California, and Idaho for the years 2000 to 2018. We focus on this time period because the 1990s saw exceptionally poor ocean conditions, which were widely considered the main cause for the low productivity of Pacific salmon and steelhead (Hare et al., 1999; Kilduff et al., 2015; Mantua et al., 1997; Ohlberger et al., 2016). We want to avoid the influence from extreme ocean conditions, which would overwhelm the effects we seek to measure. Table 1 shows descriptive statistics.

Salmon population data are collected by local agencies. They conduct annual surveys of streams and record the number of carcasses as the spawner population, since salmonids die after spawning. These counts are commonly used as an indicator of

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[2]The United States Geological Survey (USGS) uses a hierarchical system of hydrologic units to categorize watersheds. Each unit is assigned a unique Hydrologic Unit Code (HUC), named with 2-14 digits based on decreasing size class.

[3]Of 53 lawsuits directly advocating for Pacific salmon and steelhead since 2000, 33 are about habitat protection and 6 about dam removal or management.

salmon abundance (Forest Science Project, 2000). The data are gathered and reported by StreamNet project, CalFish project, and State of Salmon in California project. The three projects collect and organize salmon abundance estimates from Oregon Fish and Wildlife Service, Washington Fish and Wildlife Service, Idaho Department of Fish and Game, and California Department of Fish and Wildlife. StreamNet data includes salmon abundance in Washington, Oregon, and Idaho. CalFish and State of Salmon in California provide similar data for California.

We aggregate the annual salmon abundance data from each stream to the HUC8 level. We use only the naturally spawning salmon population, and do not include salmon released from hatcheries.[4] The biological literature has found that hatchery-released fish can negatively impact the wild population (Hilborn and Winton, 1993; Waples, 1999; Myers et al., 2004; Jones et al., 2018) and recent research finds that the two populations are genetically different(Christie et al., 2016).

We use spawners per river mile, a measure commonly used in the biology literature, to measure salmon abundance. Using shapefiles of salmon distribution from the National Oceanic and Atmospheric Administration (NOAA), we divide the total salmon population by total river miles within each watershed.[5] Fish per river mile measures the density of species, taking into account the carrying capacity of the habitat. For this reason, it is preferred to total number of fish to quantify abundance.[6] Our dataset covers all species and their corresponding ESUs in the study region.

Our sample includes all the NGOs that could impact salmon through direct channels (i.e., monitoring) or indirect channels (i.e., restoring habitat), but does not include groups whose activities are unlikely to impact salmon. We select groups on the basis of their National Taxonomy of Exempt Entities (NTEE) codes, which are used by the Internal Revenue Service (IRS) to classify nonprofit organizations according to their focus areas. Specifically, we start with organizations with codes C (Environment) and D (Animal-Related), and then further narrow down our choice to the ten categories with activities most likely to directly impact salmonids and their habitats.[7] Then we collect individual NGOs' information from the National Center

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[4]Wild salmon and hatchery salmon can be distinguished by the presence or absence of the adipose fin. A hatchery fish has its adipose fin removed, while a wild salmon has an intact adipose fin. The StreamNet data include both wild salmon and hatchery salmon populations, but we only utilize the data on wild salmon population in this paper.

[5]https://www.fisheries.noaa.gov/resource/map/critical-habitat-maps-and-gis-data-west-coast-region

[6]We check for robustness to using total number of fish in Appendix C.

[7]The 10 NGO categories selected in this paper are: C01 (Alliances Advocacy), C20 (Pollution Abatement Control), C30 (Natural Resources Conservation Protection), C32 (Water Resources,

for Charitable Statistics (NCCS) Data Archive. We obtain each nonprofit group's Employer Identification Number (EIN), address, NTEE code, and annual total expenditures net of fundraising. Based on their addresses, we use the Google Map API to request the longitude and latitude of each organization. Finally, we adjust for inflation and aggregate annual expenditures to the HUC8 level. Our sample covers all 2,323 environmental and animal-related organizations in the four states.

An important control variable is government investment in endangered and threatened salmon. We obtain annual government expenditure data from the U.S. Fish and Wildlife Service Annual Expenditure Report. The report tracks all federal and state government expenditures towards every listed species in each ESU. As shown in Figure 1, a ESU is equivalent to a HUC4 or a HUC6, which is much larger than a HUC8. The expenditures include spending on "habitat management or acquisition, research, propagation (including surrogate species), recovery plan development or implementation, and mitigation".[8] In the case of salmonids, this includes expenditures on hatcheries. We adjust for inflation. To draw a fair comparison to NGO spending, we calculate the number of HUC8 watersheds within each ESU. Government spending at each ESU is divided by the number of HUC8s.

We also control for two key time- and spatial-varying limiting factors for salmon: dam removal and water temperature. Dam removal history comes from the USGS National Dam Removal Database, which includes final dam removal year and latitude-longitude of the dams.[9] We calculate the number of dams removed within each HUC8 each year.

Excessively high freshwater temperature is fatal for both young fish and spawners. We obtain water temperature data from the National Water Information System Water Quality Portal, which provides temperature readings from 360,000 monitoring locations across the four states.[10] To reduce the impact of outliers, we winsorize the data at the 99th percentile. We also eliminate all non-routine hydrologic events, such as floods. For each HUC8, we calculate the annual average water temperature for all monitors located in the watershed.

Summary statistics for the data are shown in Table 1. Expenditures are cumu-

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Wetlands Conservation Management), C34 (Land Resources Conservation), C36 (Forest Conservation), D01 (Alliances Advocacy), D30 (Wildlife Preservation Protection), D31(Protection of Endangered Species), and D33 (Fisheries Resources).

[8]https://www.fws.gov/library/collections/endangered-and-threatened-species-expenditures-reports

[9]https://data.usgs.gov/drip-dashboard/

[10]https://www.waterqualitydata.us/

lative; that is, NGO and government spending in time t include the corresponding cumulative conservation expenditures up to time t.[11]

Table 1. Summary Statistics

	Observation	Mean	SD	Min	Max
Fish per Mile	2000	2.176	(5.347)	0	71.962
Cumulative NGO (Mill. $)	2000	8.374	(37.475)	0	648.228
Cumulative GOV (Mill. $)	2000	20.311	(29.575)	0	161.816
Water Temperature ($°C$)	1421	12.299	(3.640)	1.407	25.2
No. Dams removed	2000	.004	(.059)	0	1

4 Methodology

The quasi-experimental design of this research builds off the scope of NGOs' activities and the biological features of salmonids. Since the NGOs in our data conduct their activities at a local scale, the impact of these local organizations is likely limited to areas no larger than the HUC8 watershed, which we define as the unit of observation(Grant and Langpap, 2019). Conservation spending will only impact the local freshwater ecosystem within the watershed where the spending occurs, rather than ocean conditions, which are driven by larger scale global processes. The levels of NGO spending vary across watersheds and over the 18-year study period, and some watersheds never receive NGO expenditures. This large spatial and temporal variation in salmon abundance and NGO spending drives identification in our model. Figure 2 displays the substantial spatial variation in both salmon abundance and NGO spending, using 2015 as an example year. Government spending is not included in the figure because the scale of government spending is larger than the HUC8 level. Figure 3 shows the large temporal variation in salmon abundance, NGO spending, and government spending.

A key feature of salmonid biology is that salmonids return to their native streams to spawn after spending several years in the ocean, and it is returning adult salmonid abundance that is measured, not abundance of juveniles. However, since NGO and government spending affect the local freshwater ecosystems rather than ocean conditions, we expect the impact of conservation spending on salmonid abundance to

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[11]The number of observations for the variable *Water Temperature* is smaller than that of other variables. To address this issue, we estimate our main models with and without controlling for water temperature. Our main conclusions remain consistent regardless of model specification.
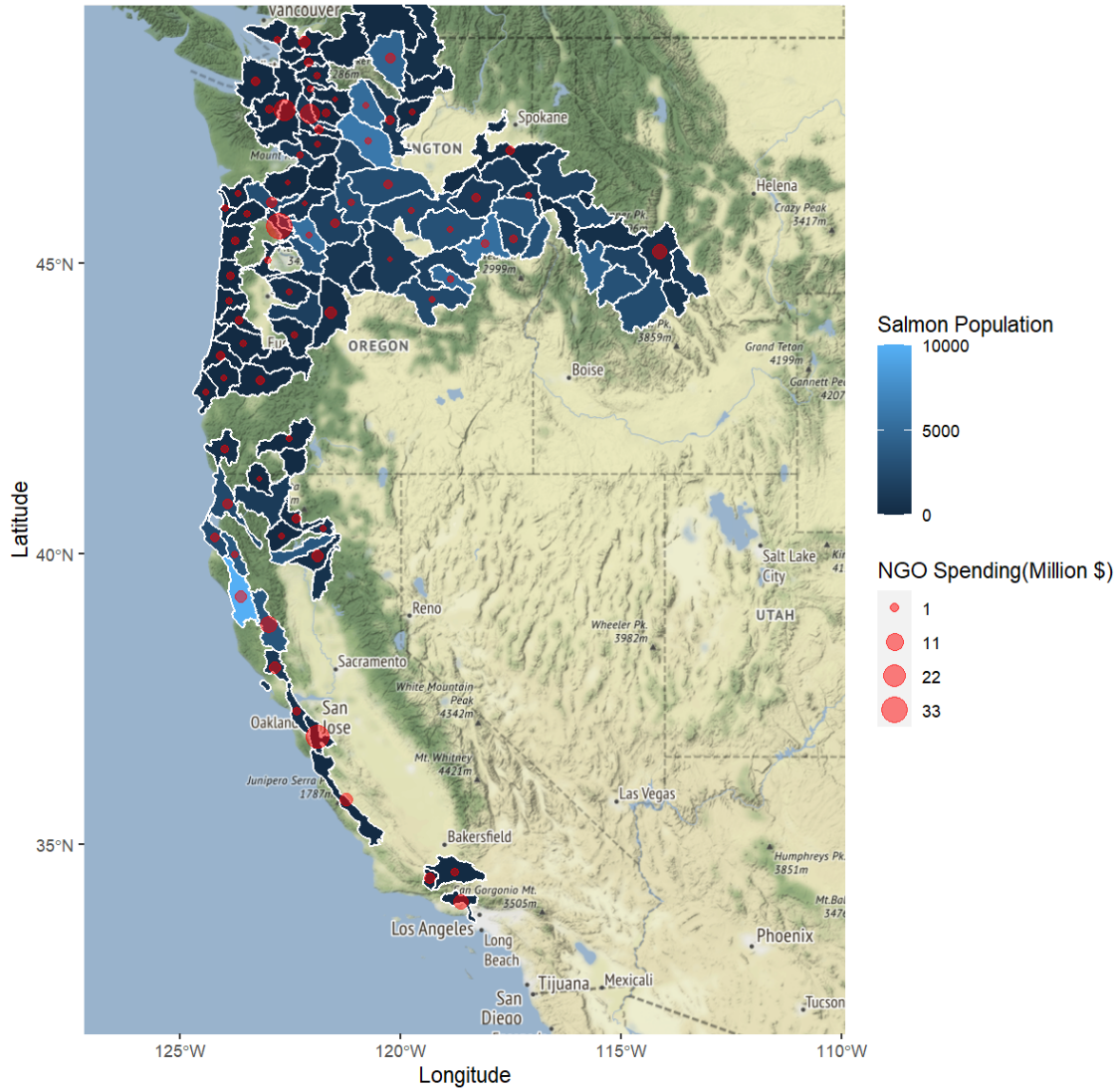
Figure 2. Spatial Variation of Salmon Population and NGO Spending
This figure displays the spatial variation of salmon population and NGO spending at the HUC8 level in 2015. Each HUC8 outlined by a white boundary is a unit of observation. The shade of each watershed indicates salmon abundance, and the size of the dots indicates the amount of NGO expenditures received in the watershed. Both salmon populations and NGO spending vary greatly across space.
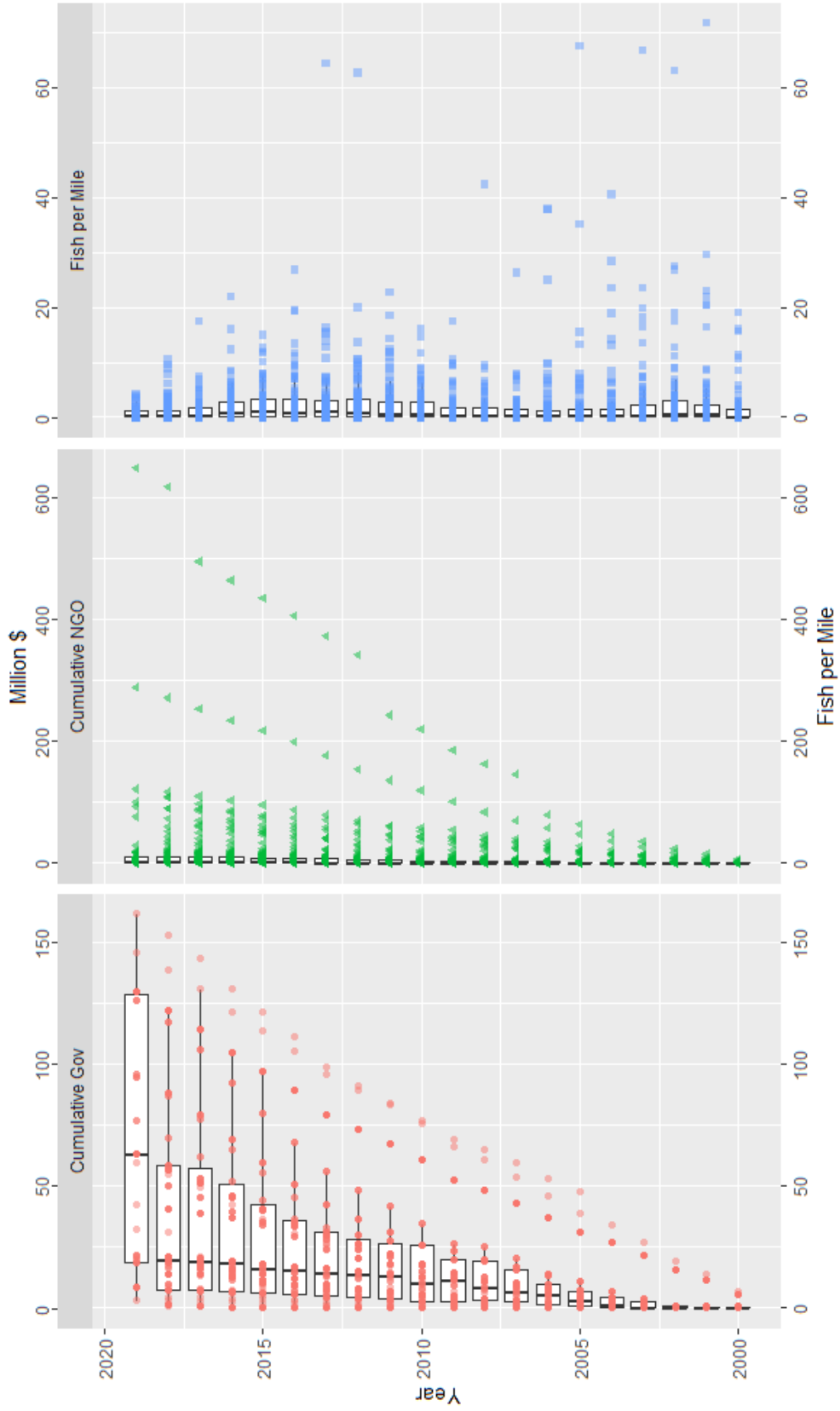
Figure 3. Temporal Variation of Salmon Population, NGO Spending, and Government Spending
This figure illustrates box plots of salmon population, NGO spending, and government spending per year. The three variables exhibit significant temporal variations.

operate through its effect on juvenile fish rather than the returning adult salmon, which spend relatively little time in freshwater. Therefore, in our model we use lagged NGO and government expenditures, as well as lags of other controls, to capture the fact that conservation spending impacts juvenile fish, while adult abundance is measured. The use of lags also mitigates joint causation concerns, since lagged expenditures are not affected by current salmon population counts. Further, given that different species spend different amounts of time in the ocean, we estimate several versions of the model with varying lag times.

Another important consideration that guides our empirical specification is the fact that conservation expenditures targeting habitat are likely to result in improvements in durable natural capital. Therefore, a conservation investment made in year t may have a lasting impact on salmonid abundance in all years following year t. As a result, we measure conservation spending as cumulative expenditures in our model, starting in the year 2000.

Finally, we use watershed fixed effects to control for time-invariant and spatially-varying factors, such as current and historical land use practices (e.g. splash dams) that can have long-term impacts on salmon abundance (Steel et al., 2017). We use year fixed effects to control for time-varying and spatially-invariant factors, the most important of which is ocean conditions in the Pacific. We explicitly control for dam removal and water temperature because they impact salmon survival and vary across both time and space.

Our main two-way fixed effects model is:

$$Salmon_{it} = \alpha_0 + \alpha_1 NGO_{i,t-m} + \alpha_2 GOV_{i,t-m}$$
$$+ \alpha_3 Water_{i,t-m} + \alpha_4 Dam_{i,t-m} + \mu_i + \nu_t + \epsilon_{it} \quad (1)$$

where $Salmon_{it}$ is the spawner population in watershed i and year t, $NGO_{i,t-m}$ is the cumulative expenditure (million dollars) of all the NGOs in watershed i up to year $t-m$, $GOV_{i,t-m}$ is government cumulative expenditures on listed ESUs within watershed i up to year $t-m$. $Water_{i,t-m}$ is the annual average water temperature in the watershed. $Dam_{i,t-m}$ is the number of dams removed in the watershed i in year $t-m$. μ_i are watershed fixed effects. ν_t are year fixed effects factor,and ϵ_{it} is the error term.[12]

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[12]Results are robust to estimating a density-dependent version of the model that includes lagged

5 Results

We estimate parameters in model 1 with different lag lengths ($m = 1, 2, \ldots, 5$). Table 2 displays our results. Standard errors are clustered at the watershed level. Estimated coefficients suggest that NGO spending has a positive and statistically significant impact on salmon populations for all the lag specifications considered. The coefficients of cumulative NGO spending indicate that a one million dollar increase in cumulative NGO expenditure in a HUC8 watershed will increase that watershed's salmon spawner population by between 0.005 and 0.0075 fish per river mile (0.25 to 0.38% relative to the mean, 1.97 fish per mile). However, a million dollar increase is not an empirically relevant change for this variable. NGO spending increases by 4.13%, or $3.33 million (given a mean of $80.49 million) per year on average during the study period. We therefore assess the impact of NGO spending by considering the effect of a $3.33 million increase in expenditures. This change leads to increases in salmon populations of 0.0167 to 0.025 fish per mile per year, or a growth of 0.85% - 1.27% relative to the mean. While these numbers are nominally small, we note that, after a large increase in the year 2000, between 2001 and 2018 salmon abundance decreased by 5.4% per year on average. Therefore, our results suggest that NGO spending mitigated a substantial proportion of the observed abundance decrease over this period.

As an alternative way to gauge the practical impact of NGO expenditures, we assess their effect on watersheds that did not receive any NGO investment during our entire study period. There are 28 such watersheds in our data (24% of the total). For these watersheds, we first calculate predicted counts of fish per mile when NGO expenditures are zero. Next, we calculate fish per mile for a counterfactual scenario in which these watersheds receive the average NGO spending every year. Finally, we calculate the difference in predicted fish per mile for every year. We find that, on average, salmon populations would increase by 1.83% - 2.92% per year in these control watersheds. Again, relative to an average annual decrease of 5.4% between 2001 and 2018, these effects are meaningful.

Government spending on conservation programs also has a positive and statistically significant impact – in particular, a $1 million increase in government spending raises salmon abundance by 0.02 to 0.0372 fish/mile (1 to 1.89%). The magnitude of the impact of government spending is larger than that of NGO spending. This is

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fish per mile. See table D1 in the Appendix.

Table 2. Main Results

Fish Per Mile	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.00558**	0.00565**	0.00672*	0.00569**	0.00545**	0.00515*	0.00533**	0.00590**	0.00633**	0.00646**
	(0.00260)	(0.00256)	(0.00345)	(0.00287)	(0.00226)	(0.00283)	(0.00257)	(0.00287)	(0.00297)	(0.00279)
$GOV_{i,t-m}$	0.0359***	0.0372***	0.0362**	0.0271**	0.0200**	0.0365***	0.0345***	0.0282***	0.0242**	0.0221**
	(0.0123)	(0.0123)	(0.0143)	(0.0125)	(0.00991)	(0.0112)	(0.0108)	(0.0104)	(0.0104)	(0.00997)
$Dam_{i,t-m}$	-0.0635	-0.101	-0.109	-0.664	-0.177	-0.0652	-0.0947	0.0399	-0.234	0.282
	(0.451)	(0.479)	(0.428)	(0.414)	(0.481)	(0.362)	(0.425)	(0.461)	(0.576)	(0.571)
$Water_{i,t-m}$	-0.100*	-0.0811*	-0.0392	0.0270	-0.0123	-	-	-	-	-
	(0.0526)	(0.0479)	(0.0352)	(0.0329)	(0.0188)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1278	1335	1398	1421	1615	1721	1828	1938	2000

[1] Statistical significance indicators: $* \; p < 0.10$, $** \; p < 0.05$, $*** \; p < 0.01$. Standard errors are clustered at the HUC8 level.
[2] m represents different lag lengths. The number of observations for each model varies depending on the lag length.

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probably because, as discussed in section 2, government spending is more directly tied to listed species and government recovery efforts impact salmon populations through a broader set of channels, including habitat restoration, propagation, monitoring, and law enforcement. On the other hand, NGO expenditures, as measured in our data, are less specifically focused on salmon, and likely only have direct impact through habitat maintenance and restoration. The average annual increase in government spending over our period 2000-2018 is $6.15 million/year, which would increase salmonid abundance by 0.123 to 0.229 fish/mile per year, or a growth of 6.24% to 11.6% per year.

Figure 4 shows the trend in observed salmonid abundance between 2000 and 2018. The significant variation in abundance over time is largely attributable to changes in ocean conditions, which is normal for anadromous fish (Beamish and Bouillon, 1993; Malick et al., 2015; Burke et al., 2013; Stout and Williams., 2012). The figure also shows simulated trends representing counterfactual scenarios without government and NGO expenditures. Abundance decreased from 1.58 to 0.88 fish per mile (-45%), but would have decreased further to 0.74 fish per mile (-53%) without NGO expenditures, 0.52 fish per mile (-67%) without government spending, and 0.38 fish per mile (-76%) without any expenditures. Our results therefore suggest that NGO and government spending helped prevent a steeper decline in salmonid abundance which, against a backdrop of negative ocean conditions, would have occurred in the absence of such spending.

6 Cost-Benefit Analysis

NGO and government expenditures reflect the costs of recovering species.[13] Our main model estimates the bio-physical impact of those investments on salmon abundance. In this section, we illustrate how these estimated impacts can be used to calculate the total cost of achieving given salmon recovery goals. Then, combining this estimated conservation cost with previously estimated benefits of recovering a specific threatened salmon species (Lewis et al., 2019), we can estimate the net benefits of salmon recovery efforts.

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[13]This does not include opportunity costs, such as the value of output forgone due to ESA-related restrictions.
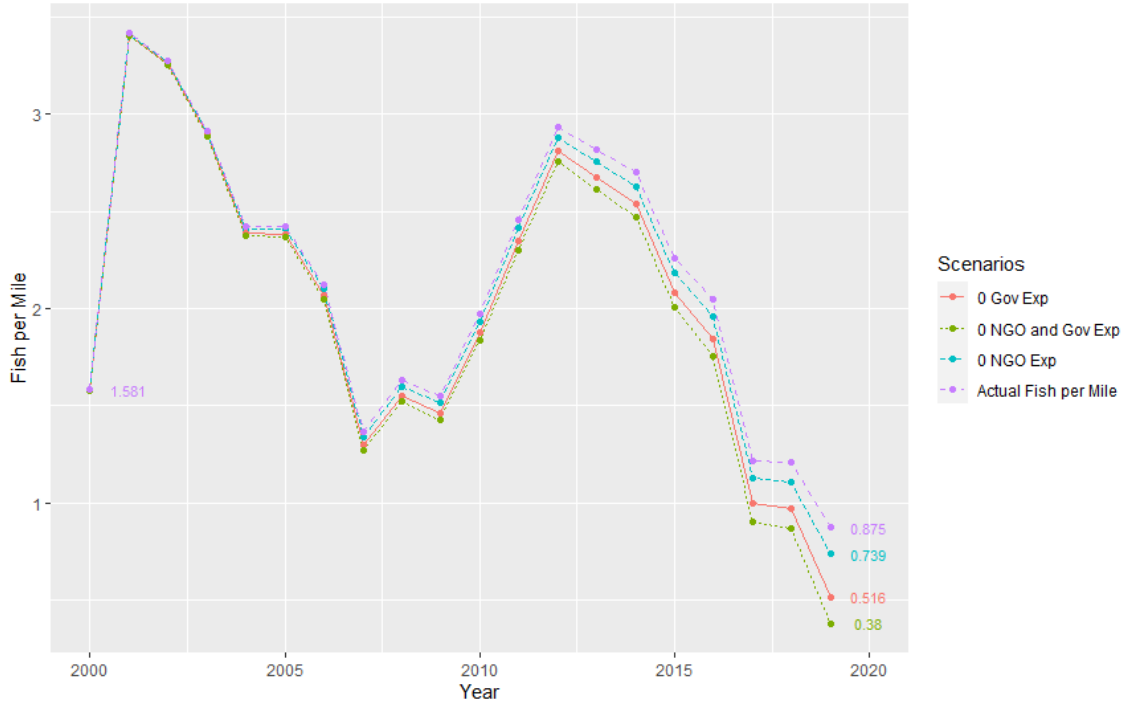
Figure 4. Actual Fish/Mile and Predicted Fish/Mile without Spending by Year
This figure shows average fish per mile across watersheds by year and predicted fish per mile when only NGOs invest (0 Gov Exp), when only the government invests (0 NGO Exp), and when neither NGOs nor the government invest (0 NGO and Gov Exp).

We use Oregon Coast (OC) Coho salmon as an example, leveraging Lewis et al.'s (2019) estimated non-market values of different recovery scenarios involving this ESU. Using a choice experiment survey sent to the general population of the greater Pacific Northwest, they estimate benefits under different scenarios based on alternative conservation goals involving the species status (threatened or recovered), increase in abundance relative to a baseline, and speed of abundance increase. For comparison purposes, we use the same baseline and conservation goals as Lewis et al. (2019). Our calculation proceeds as follows. First, we calculate the number of returning fish necessary to achieve a specific recovery goal. Next, we use our estimated coefficients to calculate the investment required to ensure this number of returning fish. Finally, we compare total costs of achieving a given population goal with the benefit estimates from Lewis et al. (2019).

The baseline is 150,000 fish, which is the average OC Coho abundance from 1994 to 2015. The State of Oregon's Oregon Coast Coho Salmon Conservation Plan (2007) specifies a conservation goal of 525,000 fish to be achieved in 50 years' time. The Lewis et al. (2019) study built their choice experiment around this official conservation goal,

but also included smaller returning fish goals of 250,000, 325,000, and 375,000 fish in the experimental design to estimate willingness-to-pay for abundance. We calculate the number of returning fish required each year to achieve these goals using a beta function (Yin et al., 2003), which was also used by Lewis et al. (2019) in their choice experiment:

$$RetFish(t) = RetFish(0) + (RetFish(T) - RetFish(0))(1 + \frac{T-t}{T-\tau})(\frac{t}{T})^{\frac{T}{T-\tau}} \quad (2)$$

Here $RetFish(t)$ is the number of returning adult fish in time t. The baseline fish abundance, $ReturnFish(0)$, at time 0 is 150,000 fish, T is 50 years and is based on the timeframe in the State of Oregon's Oregon Coast Coho conservation plan, and $RetFish(T)$ are the three different abundance scenarios (325,000, 375,000, or 525,000 fish). We divide the baseline fish abundance and conservation goals by total river miles of OC Coho habitat to calculate returning fish per mile. The parameter τ determines the path of salmon abundance growth. The value $\tau = 13.7$ defines the fast path, whereas $\tau = 38.7$ corresponds to the slow path. Figure 5 depicts the number of returning fish per mile for the two time path scenarios. A fast path has a relatively rapid increase in the number of returning fish at the beginning of the period, while a relatively stable increase in returning fish is shown in the slow path. Different salmon growth paths will result in different investment trajectories.
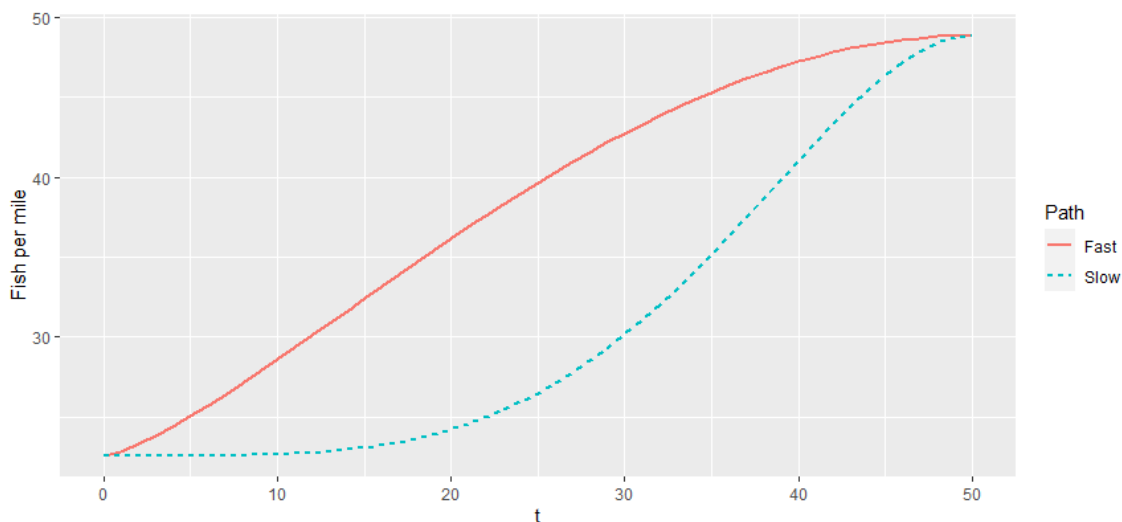

Figure 5. Salmon Population Growth Path with Different Growth Rates
This figure displays how τ determines the salmon population growth path.

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The beta function (Eq. 2) determines the required increase in number of fish each year to reach the overall recovery goal. The estimated coefficients for cumulative NGO and government spending from Table 2 allow us to estimate the increase in fish abundance in response to additional investments of \$1 million, for instance 0.00545 and 0.02 fish/mile. Since the estimated marginal effect of NGO spending is smaller than that of government spending, we define a lower bound of total costs to occur when both government and NGOs invest in species recovery, and we define an upper bound for costs to occur when only the government invests. Equation 3 shows how to calculate each year's lower bound investments $INVST_t^l$ and Equation 4 shows how to calculate each year's upper bound investments $INVST_t^u$. $\hat{\beta}_1$ is the estimated coefficient of NGOs expenditures and $\hat{\beta}_2$ is the estimated coefficient of government' expenditures from Equation 1. To be conservative, we use the smallest estimated coefficients to represent the impact of spending (0.00545 for NGO spending and 0.02 for government spending, from the main model with a 5-year lag), which will yield relatively high estimates of total costs.

$$INVST_t^u = \frac{RetFish(t+1) - RetFish(t)}{\hat{\beta}_2} \tag{3}$$

$$INVST_t^l = \frac{RetFish(t+1) - RetFish(t)}{\hat{\beta}_1 + \hat{\beta}_2} \tag{4}$$

Figure 5 illustrates the number of returning fish and the expenditures needed each year to achieve an abundance goal of 325,000 fish for the fast and slow growth paths. The figure also shows corresponding expenditures for two scenarios: when only the government invests (upper bound) and when both NGOs and government invest (lower bound). A fast recovery requires higher amounts of investment at the beginning of the 50-year period, while a larger investment is needed at the end of the period for a slower recovery.

Finally, the present value of lower bound total costs, $TotalINVST_t^l$, and upper bound total costs, $TotalINVST_t^u$, over the course of 50 years can be obtained by using Equation 5 and Equation 6. We use a 2.1% discount rate, δ, for future salmon, which is estimated by Lewis et al. (2022) for the same species.

$$TotalINVST_t^l = \sum_{t=1}^{50} \frac{1}{(1+\delta)^t} INVST_t^l \tag{5}$$

$$TotalINVST_t^u = \sum_{t=1}^{50} \frac{1}{(1+\delta)^t} INVST_t^u \tag{6}$$

Table 3 lists the present value of the total costs and total benefits for each recovery scenario. Table 3 shows that, even when using the smallest estimated impacts, costs are much lower than benefits for each recovery scenario, while the highest net present value occurs in the scenario with a fast rate of change to the terminal (50-year) abundance of 325,000 returning spawners. This suggests that, at least for this ESU, combined NGO and government recovery investments generate positive net social benefits. Further, the fast recovery trajectory requires larger investments in earlier periods when compared to the slow recovery trajectory. Therefore, the present value of total net benefits for fast recovery is higher than for slow recovery.

Table 3. The Costs and Benefits of Different Recovery Scenarios for OC Coho

Salmon Abundance in 50 Years	Present Value of Total Costs (Billion $)	Net Present Value of Total Costs (Billion $)	Present Value of Total Benefits (Billion $)*	Net Present Value (Billion $)
(*Baseline* = 150,000)		[NGO & Govt, Govt only]		[NGO & Govt, Govt only]
325,000	Slow	[0.52, 0.66]	10.59	[10.07, 9.97]
375,000		[0.67, 0.85]	11.13	[10.56, 10.28]
525,000		[1.11, 1.41]	12.80	[11.69, 11.39]
325,000		[0.70, 0.90]	12.77	[12.07, 11.87]
375,000	Fast	[0.90, 1.15]	12.96	[12.06, 11.81]
525,000		[1.51, 1.92]	13.32	[11.81, 11.4]

*Lewis et al.(2019) report annual benefits over a ten-year period. To facilitate comparison, we calculate the present value of the total benefits for the entire ten-year period.

7   Robustness Checks

In this section we further examine the mechanisms through which NGO spending can influence salmon recovery.

7.1   The Role of Short-Term vs. Lomng-Term NGO Spending

The scope of NGOs' activities suggests that their efforts mainly impact salmon abundance through the habitat restoration channel. Our main model shows that cumula-

tive expenditures have a statistically significant effect on salmon abundance, which suggests that spending impacts salmon over the long-term. In this section we further examine the hypothesis that NGO spending improves salmon recovery by increasing the stock of durable natural capital that enhances salmon habitat, and thereby the cumulative nature of NGO expenditures has a long-term impact on salmon.

First, we use lagged, non-cumulative NGO and government expenditures as independent variables. We use this model to test if NGOs' expenditures improve salmon abundance in the short term. Results are shown in Table A1.

Second, we separate cumulative expenditures into two parts: non-cumulative expenditure at year $t - m$, and expenditures that are accumulated until the preceding year, $t - m - 1$:

$$Salmon_{it} = \alpha_0 + \alpha_1 NGO_{i,t-m} + \alpha_2 GOV_{i,t-m} + \alpha_3 CMLT\ NGO_{i,t-m-1} +$$
$$\alpha_4 CMLT\ GOV_{i,t-m-1} + \alpha_5 Water_{i,t-m} + \alpha_5 Dam_{i,t-m} + \mu_i + \nu_t + \epsilon_{it}. \quad (7)$$

We separate the two variables to avoid double-counting of expenditures and to capture two different effects. Non-cumulative expenditure at year $t - m$ captures the short-term effect, such as protecting salmon from being harvested. The cumulative variable captures long-term effects, such as those from restoring durable habitat in places such as riparian zones. Results are in Table A2.

The results from the two models confirm our hypothesis and provide evidence that NGO spending affects salmon abundance primarily through increasing the amount of durable natural capital that enhances freshwater habitat. Through lags $m = 1, \ldots, 5$, the short-term effect is not statistically significant for NGOs, while the long-term effects are significant. Government's spending, which is more species-specific and larger, improves salmon in both the short term and long term.

7.2   Depreciation of Investments

Our cost-benefit analysis is based on the assumption that NGO spending will generate a long and durable effect on the salmon population because it improves the quality of habitat. For instance, activities such as planting trees will have long-lasting benefits for salmon. In this section, we furhter test whether the effect of NGOs' expenditures changes over time. To do so, we run two sets of models and compare their results. In the first set of models NGO expenditures are accumulated over 5 years, whereas in

the second set they are accumulated over 10 years. If the coefficient for the five-year accumulation of expenditures is the same as the coefficient for the ten-year accumulation of expenditures, it suggests the effect of NGO spending does not depreciate over time.

We run each set of models for lags $m = 1 - 5$. Results are shown in Table B1. For each lag, we test whether the coefficients for 5-year cumulative NGO spending and 10-year cumulative NGO spending are statistically different. We fail to reject the null hypothesis that the coefficients are equal at any reasonable significance level (Table B2). This suggests that NGO investments do not depreciate during the time period considered here. Along with the results from the preceding section (7.1), this provides evidence that habitat restoration achieved through NGOs' conservation efforts generates durable natural capital that provides a steady stream of long-run benefits for salmon.

7.3 Functional Form and Outliers in the Dependent Variable

Summary statistics of the dependent variable $Salmon_{it}$ show that a small number of watersheds are outliers with exceptionally large numbers of fish per mile. Figure 7 (left) displays this right-skewness of our data, by showing the value of the dependent variable by year. In this section, to mitigate this issue, we transform the dependent variable with the inverse hyperbolic sine (IHS). IHS generates similar interpretation as log transformation, but also allows the inclusion of zeros (Bellemare and Wichman, 2020). Figure 7 (right) shows the transformed data.

We estimate parameters in equation (1) using the IHS transformed dependent variable. The estimates, shown in Table A3, are broadly consistent with our main model. A \$1 million increase in NGO (government) spending raises annual salmon abundance by 0.13% to 0.18% (0.3% to 0.8%) depending on lag choice, and these estimates are significantly different from zero at any reasonable significance level.

7.4 Spillover Effect of NGO Spending

The positive impact of NGO spending in one watershed has the potential to spill over and affect salmon abundance in other watersheds through the river network. For example, if spending in an upstream watershed is successful in cooling river temperatures, then those same benefits should impact river temperatures in downstream adjacent watersheds. We leverage the hierarchy of the HUC system to test for this spillover effect. We use HUC8 watersheds as the unit of observation in the main
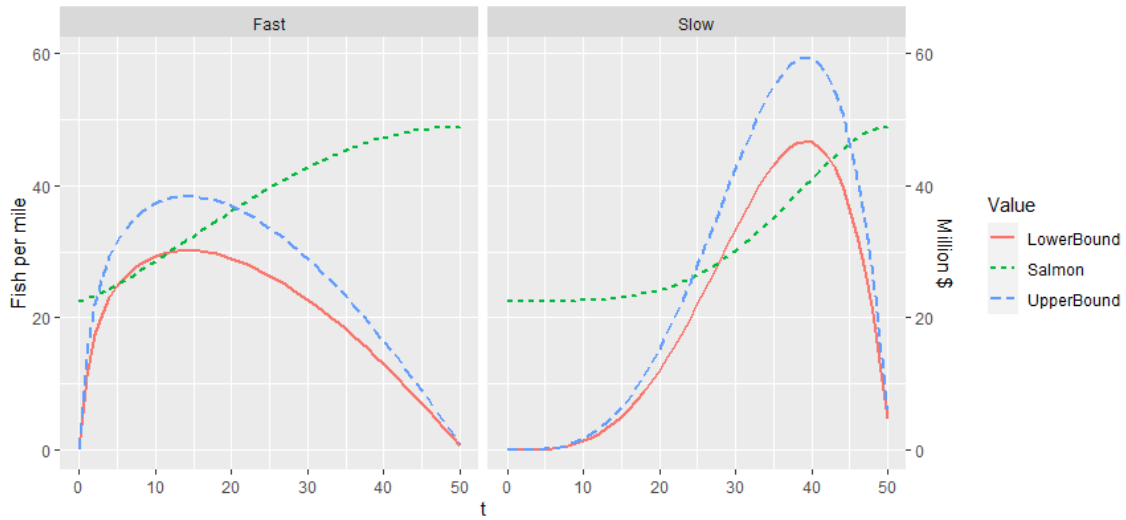
Figure 6. Slow Path and Fast Path of Investments to Recover OC Coho
This figure displays the trajectories of the upper-bound and lower-bound costs needed to achieve a population goal of 325,000 fish.
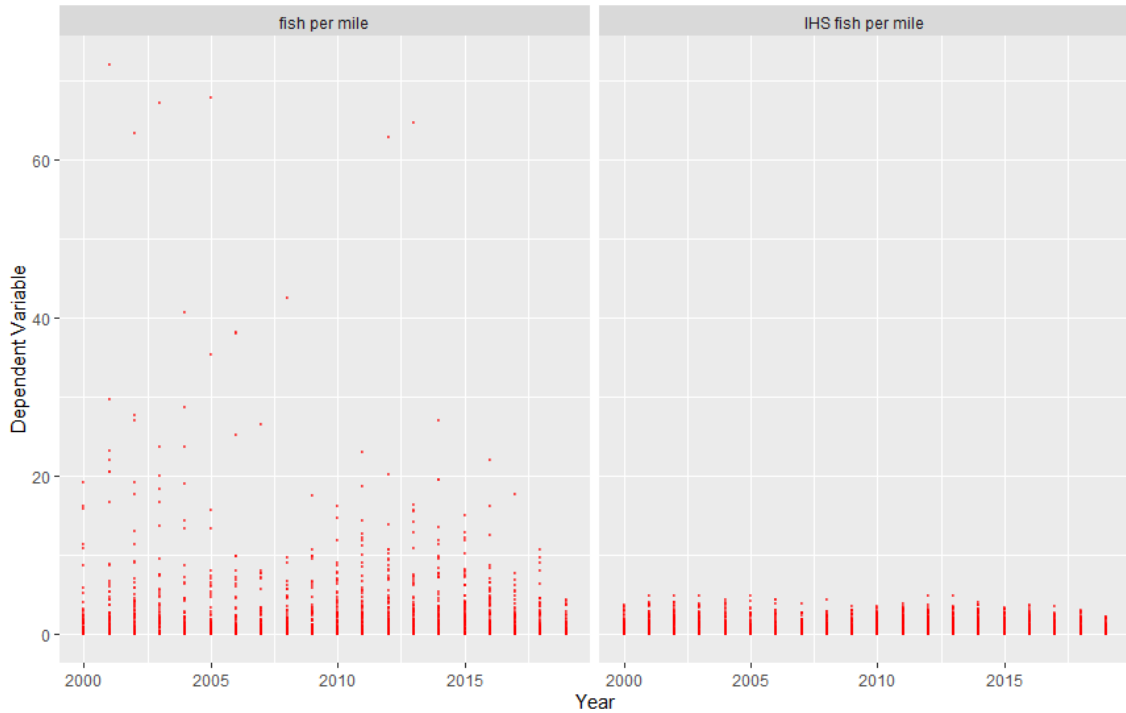

Figure 7. Fish per Mile and IHS Fish per Mile
This figure displays the values of *Fish per Mile* (left) and IHS of *Fish per Mile* (right) by year. *Fish per Mile* has some exceptionally large values; however, the IHS transformation mitigates this right-skewness.

model. A HUC6 watershed is a larger geographical unit that can be subdivided into multiple smaller HUC8s. Additionally, a HUC6 can be nested within or be equivalent to a larger unit, the HUC4. HUC8s that fall under the same HUC6 or HUC4 share the same river system. Based on this hierarchy, we aggregate spending in HUC8 watersheds to the higher watershed level, HUC6 or HUC4.[14] If spillover effects from other HUC8s in the same river network exist, then variables representing spending from other HUC8s within the same HUC4 or HUC6 should be included in our main model from Equation (1). We test for spillover effects of NGO spending by estimating the following equations:

$$Salmon_{it} = \alpha_0 + \alpha_1 NGO\_HUC8_{i,t-m} + \alpha_2 NGO\_HUC4_{i,t-m} +$$
$$\alpha_3 GOV_{i,t-m} + \alpha_4 Water_{i,t-m} + \alpha_5 Dam_{i,t-m} + \mu_i + \nu_t + \epsilon_{it}, \quad (8)$$

$$Salmon_{it} = \alpha_0 + \alpha_1 NGO\_HUC8_{i,t-m} + \alpha_2 NGO\_HUC6_{i,t-m}$$
$$+ \alpha_3 GOV_{i,t-m} + \alpha_4 Water_{i,t-m} + \alpha_5 Dam_{i,t-m} + \mu_i + \nu_t + \epsilon_{it}, \quad (9)$$

where $NGO\_HUC8_{i,t-m}$ is the NGO spending in HUC8 i at $t-m$, $NGO\_HUC4_{i,t-m}$ is the aggregation of all the NGOs' spending within the same HUC4 minus $NGO\_HUC8_{i,t-m}$, and $NGO\_HUC6_{i,t-m}$ is the aggregation of all the NGOs' spending within the same HUC6 minus $NGO\_HUC8_{i,t-m}$.[15] As shown in Table A4, we do not find statistically significant spillover effects within the same HUC4 or HUC6.

8 Conclusion

This paper examines the effectiveness of NGOs' conservation efforts in recovering endangered and threatened species, using the case of Pacific salmon and steelhead along the Pacific coast of the United States. By exploiting salmon and steelhead's biological features, we estimate the impacts of cumulative NGO investments up to the time that salmon are juveniles in freshwater on the abundance of returning adult

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[14]https://water.usgs.gov/GIS/huc.html

[15]The government investments are made at the ESU/DPS level, which is equivalent to either the HUC4 or HUC6 level. Due to this, we cannot examine the spillover effect of government spending using the same approach. Therefore, we solely focus on testing the spillover effect of NGO spending.

salmon. Our estimates yield several key findings.

First, we find strong evidence that NGO conservation efforts have a positive impact on salmon abundance, though the magnitude of the impact of NGOs' spending is smaller than that of government spending. However, the effect of NGO expenditure is meaningful in terms of the underlying annual rate of change of salmon abundance. Our results also suggest that NGO and government spending between 2000 and 2018 helped prevent a decline in salmonid abundance that would have occurred in the absence of such spending.

Second, our results provide a framework for calculating the costs of recovering Pacific salmon and, in combination with previously estimated non-market benefits (Lewis et al., 2019), for estimating the net present value of species recovery efforts. We illustrate the ability of our model to contribute to such a full cost-benefit analysis using the case of Oregon Coast Coho salmon. For this ESU, we estimate a positive net present value of all recovery scenarios considered. Even if we assume that only NGOs invest in OC Coho, the net present value of recovery efforts remains positive.

Third, our analysis reveals the mechanism by which NGO conservation efforts help promote salmon recovery. Based on the characteristics of these organizations and anecdotal evidence, we hypothesize that their expenditures mainly increase salmon abundance by improving their habitat. Multiple robustness checks support our hypothesis. This revealed mechanism highlights the importance of restoring habitat for the recovery of endangered and threatened species. Additionally, Pacific salmon and steelhead share habitat with many other species. Improving salmon habitat can also be beneficial to other species.

Further research on this topic would benefit from more detailed expenditure data. We use total annual NGO expenditures. A better understanding of the mechanism could be possible if expenditure data could be further categorized by species or usage. Government expenditure data is species-specific, but its usage is only categorized by land acquisition and other costs. With more specific expenditure data, a similar analysis could potentially provide guidance for targeting the most efficient expenditures, and thereby for better planning of species recovery.

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A   Appendix Tables and Figures

Results of robustness checks are displayed below.

Appendix Table A1. Non-Cumulative Expenditures Only

Fish Per Mile	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.0779	0.0498	0.0696	0.0723	0.0637**	0.0643	0.0473	0.0615	0.0832*	0.0693**
	(0.0814)	(0.0430)	(0.0545)	(0.0524)	(0.0315)	(0.0732)	(0.0346)	(0.0386)	(0.0422)	(0.0315)
$GOV_{i,t-m}$	0.188*	0.259**	0.201**	0.0923	0.0152	0.222*	0.246*	0.108	0.0398	0.0321
	(0.110)	(0.125)	(0.0822)	(0.0759)	(0.0691)	(0.125)	(0.133)	(0.0973)	(0.0970)	(0.0990)
$Dam_{i,t-m}$	-0.123	-0.187	-0.183	-0.700*	-0.168	-0.221	-0.273	-0.0856	-0.333	0.147
	(0.394)	(0.408)	(0.357)	(0.379)	(0.448)	(0.284)	(0.337)	(0.335)	(0.467)	(0.418)
$Water_{i,t-m}$	-0.0913*	-0.0705	-0.0322	0.0317	-0.00917	-	-	-	-	-
	(0.0487)	(0.0442)	(0.0342)	(0.0348)	(0.0180)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1278	1335	1398	1421	1615	1721	1828	1938	2000

[1] In this model, the NGO and government spending are not accumulated. This non-cumulative spending approach allows us to capture the short-term impact of the spending. However, we did not find a statistically significant impact of non-cumulative expenditures across different time lags.

Appendix Table A2. Non-Cumulative Expenditures and Cumulative Expenditures

Fish Per Mile	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.0432	0.00422	0.0130	0.0365	0.0287	0.0356	0.0119	0.0243	0.0565	0.0348
	(0.0878)	(0.0326)	(0.0437)	(0.0512)	(0.0324)	(0.0804)	(0.0291)	(0.0373)	(0.0408)	(0.0283)
$GOV_{i,t-m}$	-0.0492	0.0702	-0.0171	-0.0867	-0.125**	-0.0180	0.0619	-0.0926	-0.140	-0.117
	(0.0932)	(0.101)	(0.0717)	(0.0682)	(0.0564)	(0.107)	(0.116)	(0.0981)	(0.0930)	(0.0894)
$NGO^{CMLT}_{i,t-m-1}$	0.00755**	0.00918***	0.0107**	0.00736**	0.00716**	0.00727*	0.00823**	0.00823**	0.00670**	0.00795**
	(0.00336)	(0.00349)	(0.00426)	(0.00299)	(0.00314)	(0.00371)	(0.0035)	(0.0035)	(0.0030)	(0.0033)
$GOV^{CMLT}_{i,t-m-1}$	0.0421***	0.0360***	0.0406**	0.0343**	0.0287***	0.0404***	0.0339***	0.0358***	0.0336***	0.0301***
	(0.0127)	(0.0108)	(0.0177)	(0.0148)	(0.0107)	(0.0106)	(0.0092)	(0.012)	(0.011)	(0.010)
$Dam_{i,t-m}$	-0.0327	-0.113	-0.0756	-0.591	-0.0763	-0.0453	-0.104	0.112	-0.133	0.385
	(0.459)	(0.467)	(0.449)	(0.417)	(0.489)	(0.361)	(0.419)	(0.473)	(0.569)	(0.570)
$Water_{i,t-m}$	-0.102**	-0.0797*	-0.0400	0.0245	-0.0167					
	(0.0500)	(0.0452)	(0.0357)	(0.0330)	(0.0190)					
HUC8 FE	Y	Y	Y	Y	Y	-	-	-	-	-
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1278	1335	1398	1421	1615	1721	1828	1938	2000

[1] In this model, we decompose cumulative spending at year $t - m$ to non-cumulative spending at year $t - m$ and cumulative spending up till year $t - m - 1$. The goal of this regression is to analyze the long-term and short-term impacts of spending on the salmon population separately.

[2] We do not find statistically significant short-term impact in either NGOs or government spending. However, the long-term impact is strong, even across different time lags. Taken together with Table A1, these results show that expenditures have an impact on the salmon population through their long-term effects.

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Appendix Table A3. Using IHS Fish Per Mile as Dependent Variable

IHS Fish Per Mile	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.0013***	0.0015***	0.0016***	0.0017***	0.0018***	0.0012***	0.0013***	0.0015***	0.0015***	0.0016***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0004)
$GOV_{i,t-m}$	0.0080***	0.0078***	0.0063***	0.0043**	0.0030*	0.0083***	0.0079***	0.0057***	0.0041***	0.0032**
	(0.0018)	(0.0018)	(0.0018)	(0.0017)	(0.0016)	(0.0018)	(0.0018)	(0.0017)	(0.0016)	(0.0016)
$Dam_{i,t-m}$	-0.012**	-0.0047	-0.0029	0.0015	-0.0035	-0.184**	-0.114	-0.0346	-0.166	0.0896
	(0.0049)	(0.0051)	(0.0055)	(0.0053)	(0.0048)	(0.0868)	(0.0790)	(0.114)	(0.169)	(0.113)
$Water_{i,t-m}$	-0.177	-0.106	-0.0657	-0.253*	0.0127	-	-	-	-	-
	(0.108)	(0.0848)	(0.123)	(0.143)	(0.0760)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1278	1335	1398	1421	1615	1721	1828	1938	2000

[1] In this robustness check, we transformed the original dependent variable, *Fish per Mile*, to its inverse hyperbolic sine (IHS). The IHS transformation is similar to the logarithm transformation, but it allows for 0s in the data. Using the IHS of *Fish per Mile* as the dependent variable, we found that both NGO and government spending still have a statistically significant positive impact on the salmon population.

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Appendix Table A4. The Spillover Effect of NGO Spending

Fish Per Mile	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO\_HUC8_{i,t-m}$	0.00650 (0.00413)	0.00658 (0.00449)	0.00815 (0.00575)	0.00696 (0.00501)	0.00676 (0.00406)	0.00617** (0.00282)	0.00630** (0.00283)	0.00774** (0.00385)	0.00660** (0.00323)	0.00643** (0.00258)
$NGO\_HUC4_{i,t-m}$	0.00339 (0.00385)	0.00348 (0.00420)	0.00536 (0.00551)	0.00486 (0.00528)	0.00476 (0.00429)	-	-	-	-	-
$NGO\_HUC6_{i,t-m}$	-	-	-	-	-	0.00290 (0.00215)	0.00319 (0.00235)	0.00500 (0.00332)	0.00461 (0.00315)	0.00431* (0.00251)
$GOV_{i,t-m}$	0.0429* (0.0240)	0.0443 (0.0255)	0.0474 (0.0310)	0.0374 (0.0287)	0.0302 (0.0232)	0.0417*** (0.0152)	0.0437** (0.0157)	0.0466** (0.0203)	0.0368** (0.0183)	0.0292** (0.0142)
$Dam_{i,t-m}$	-0.0900 (0.0588)	-0.0709 (0.0577)	-0.0228 (0.0325)	0.0417 (0.0485)	0.00226 (0.0145)	-0.0899* (0.0474)	-0.0703* (0.0421)	-0.0219 (0.0305)	0.0428 (0.0410)	0.00169 (0.0164)
$Water_{i,t-m}$	-0.217 (0.545)	-0.388** (0.173)	-0.233 (0.317)	-0.781* (0.427)	-0.281 (0.603)	-0.189 (0.447)	-0.164 (0.475)	-0.210 (0.409)	-0.762** (0.357)	-0.259 (0.445)
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1278	1335	1398	1421	1213	1278	1335	1398	1421

[1] In this model, we test for the spillover effect of NGO spending through the river network. To do so, we estimate the cumulative NGO spending in HUC8 i and the cumulative NGO spending aggregated from all other HUC8s within the same HUC6/HUC4. We do not use this approach to test government expenditures because they are too geographically broad, as an ESU is equivalent to a HUC4. Our results do not show a statistically significant spillover effect.

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B Appendix One: Tables of Depreciation of Investments

In section 7.2, we run following equation:

$$Salmon_{it} = \alpha_0 + \alpha_1 NGO^j_{i,t-m} + \alpha_2 GOV_{i,t-m}$$
$$+ \alpha_3 Water_{i,t-m} + \alpha_4 Dam_{i,t-m} + \mu_i + \nu_t + \epsilon_{it}, \quad (1)$$

in which $NGO^j_{i,t-m}$ is the NGOs' expenditures accumulated until year j. In our test, we estimate the model when $j = 5$ and $j = 10$ and test the estimated coefficients of $NGO^j_{i,t-m}$ are statistically different from each other.

The regression results are shown in Table B2.

For each model $(m = 1, 2, \ldots, 5)$, we test:

$$H0 : \alpha_1^{\hat{j}=5} \neq \alpha_1^{\hat{j}=10} \ vs. \ H1 : \alpha_1^{\hat{j}=5} = \alpha_1^{\hat{j}=10}$$

The results of the tests are shown in Table B1.

Appendix Table B1. Tests Results of Depreciation of Investments

m	$m=1$	$m=2$	$m=3$	$m=4$	$m=5$
$Prob > chi2$	0.4521	0.1635	0.9370	0.6118	0.2170

[1] The results across all lag lengths indicate that we reject the null hypothesis, $H1 : \alpha_1^{\hat{j}=5} = \alpha_1^{\hat{j}=10}$, that the coefficients are equal, at any reasonable significance level.

Appendix Table B2. Regression Results of Testing the Depreciation of Spending

Fish Per Mile	m=1		m=2		m=3		m=4		m=5	
	j=10	j=5	j=10	j=5	j=10	j=5	j=10	j=5	j=10	j=5
$NGO_{i,t-m}^{j}$	1.59e-08	1.13e-08	1.56e-08	8.40e-09	1.99e-08**	2.04e-08	1.82e-08	1.56e-08*	2.13e-08	1.50e-08**
	(1.17e-08)	(1.70e-08)	(1.07e-08)	(1.67e-08)	(9.81e-09)	(1.77e-08)	(1.61e-08)	(8.32e-09)	(1.39e-08)	(7.08e-09)
$GOV_{i,t-m}$	0.0353***	0.0350***	0.0368***	0.0361***	0.0387***	0.0374***	0.0263***	0.0271***	0.0215***	0.0226***
	(0.00901)	(0.00902)	(0.00835)	(0.00834)	(0.00853)	(0.00851)	(0.00721)	(0.00723)	(0.00722)	(0.00725)
$Dam_{i,t-m}$	-0.0792	-0.0617	-0.114	-0.107	-0.124	-0.117	-0.677	-0.679	-0.170	-0.169
	(1.428)	(1.429)	(1.507)	(1.508)	(1.517)	(1.519)	(1.429)	(1.428)	(1.368)	(1.366)
$Water_{i,t-m}$	-0.0981**	-0.0999**	-0.0791*	-0.0808**	-0.0398	-0.0405	0.0279	0.0282	-0.0109	-0.0122
	(0.0426)	(0.0427)	(0.0404)	(0.0404)	(0.0398)	(0.0398)	(0.0368)	(0.0368)	(0.0346)	(0.0346)
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1213	1213	1278	1278	1335	1335	1398	1398	1421	1421

[1] j is the time length for which we accumulate the NGO spending. We choose $j = 5$ and $j = 10$ and test whether the coefficients of $NGO_{i,t-,m}^{j=5}$ and $NGO_{i,t-,m}^{j=10}$ are statistically the same. If we reject the null hypothesis that the coefficients are different, then the coefficients are statistically the same, indicating that the impact of spending does not change over time.

C   Appendix Two: Total Number of Salmon as the Dependent Variable

In our main model, we use fish per mile at watershed i at year t as our dependent variable. Table C1 shows the results of using total number of fish as the dependent variable. NGOs' and government's expenditures still have statistically significant, positive impacts on total number of salmon.

Appendix Table C1. Total Number of Salmon as Dependent Variable

Total Number of Salmon	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	1.883**	2.442**	2.759**	2.940**	3.132**	2.078**	2.485**	2.591**	2.718**	2.820**
	(0.909)	(1.150)	(1.265)	(1.308)	(1.323)	(0.960)	(1.128)	(1.122)	(1.241)	(1.237)
$GOV_{i,t-m}$	15.92***	18.20***	19.41***	21.63***	23.92***	9.858**	11.69**	10.67**	7.918*	6.510
	(5.185)	(5.852)	(5.952)	(6.217)	(6.273)	(4.416)	(4.509)	(4.376)	(4.334)	(4.379)
$Dam_{i,t-m}$	-238.1	-186.7	164.4	-691.1***	183.1	-238.7*	-228.8*	-49.12	-305.6	143.0
	(172.2)	(189.2)	(222.8)	(187.9)	(258.6)	(127.2)	(132.9)	(265.3)	(383.6)	(217.2)
$Water_{i,t-m}$	-20.35	-10.11	-9.515	-9.556	-9.521	-	-	-	-	-
	(14.80)	(16.98)	(16.88)	(16.79)	(16.68)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1150	1223	1229	1235	1247	1570	1677	1785	1890	2000

[1] Instead of using *Fish per mile* as a dependent variable, we use total number of fish at watershed i at year t. The results still show statistically significant positive impact of both NGOs' and government's expenditures through out all time lags, which is consistent with our main model.

D   Appendix Three: Density Dependence Model

The biological literature have studied how previous periods' spawner abundance impacts current salmon abundance, known as recruits (Scheuerell et al., 2021). The model used to study this impact is Ricker population model with density dependence. In this section, we estimate Ricker population model with density dependence including NGOs and government spending.

We estimate following model:

$$
\begin{aligned}
log(fish\ per\ mile)_{it} = {} & \alpha_0 + \alpha_1 NGO_{i,t-m} + \alpha_2 GOV_{i,t-m} \\
& + \alpha_3 fish\ per\ mile_{i,t-m} + \alpha_4 Dam_{i,t-m} + \alpha_5 Water_{i,t-m} + \mu_i + \nu_t + \epsilon_{it}, \quad (1)
\end{aligned}
$$

Because the variable *fish per mile* contains many zeroes, taking the logarithm transformation would result in the loss of numerous observations. Therefore, we also estimated the model using the inverse hyperbolic sine (IHS) transformation of *fish per mile* as the dependent variable.

Our results are shown in Table D1 and Table D2.

Appendix Table D1. Density Dependence Model with Log ($Fish\ per\ Mile$) as the Dependent Variable

$log(\frac{Fish}{per\ Mile})$	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.0027***	0.0034***	0.0037***	0.0040***	0.0043***	0.0023***	0.0025***	0.0031***	0.0035***	0.0039***
	(4.61)	(5.59)	(5.84)	(6.33)	(7.28)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
$GOV_{i,t-m}$	0.0154***	0.0164***	0.0151***	0.0128**	0.0101*	0.0151***	0.0146***	0.0125***	0.0110***	0.0097**
	(3.94)	(4.14)	(3.75)	(3.21)	(2.49)	(0.0046)	(0.0046)	(0.0043)	(0.0041)	(0.0043)
$Fish\ per\ Mile_{i,t-m}$	0.0267**	0.0011	0.0051	0.0036	0.0001	0.0343***	0.0093	0.0108*	0.0075**	-0.0003
	(3.04)	(0.15)	(1.27)	(1.19)	(0.03)	(0.0122)	(0.0102)	(0.0058)	(0.0037)	(0.0039)
$Dam_{i,t-m}$	-0.0268*	-0.0120	-0.0203	-0.0006	-0.0032	-0.175**	-0.194	-0.230	-0.399	0.0652
	(-2.20)	(-0.75)	(-1.29)	(-0.04)	(-0.29)	(0.0791)	(0.162)	(0.424)	(0.243)	(0.0660)
$Water_{i,t-m}$	-0.0730	-0.122	-0.171	-0.384	0.0497	-	-	-	-	-
	(-0.56)	(-0.63)	(-0.36)	(-1.80)	(0.39)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	800	837	864	892	899	1078	1135	1192	1251	1280

[1] We use a density-dependence model in this table. The results indicate that even with this model specification, both NGOs' and government's expenditures have a statistically significant and positive impact on salmon population.

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Appendix Table D2. Density Dependence Model with IHS ($Fish\ per\ Mile$) as the Dependent Variable

$\overset{LHS}{Fish\ per\ Mile}$	m=1	m=2	m=3	m=4	m=5	m=1	m=2	m=3	m=4	m=5
$NGO_{i,t-m}$	0.0011***	0.0015***	0.0016***	0.0017***	0.0018***	0.0010***	0.0011***	0.0013***	0.0015***	0.0016***
	(4.36)	(4.72)	(5.11)	(5.25)	(5.93)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0004)
$GOV_{i,t-m}$	0.0071***	0.0077***	0.0061***	0.0043*	0.0030	0.0073***	0.0077***	0.0056***	0.0041**	0.0034**
	(4.14)	(4.22)	(3.49)	(2.48)	(1.84)	(0.0017)	(0.0018)	(0.0017)	(0.0016)	(0.0017)
$Fish\ per\ Mile_{i,t-m}$	0.0303**	0.0025	0.0052	0.0026	-0.0044	0.037***	0.0087	0.0080**	0.0023	-0.0077**
	(2.97)	(0.30)	(1.76)	(1.06)	(-0.84)	(0.0125)	(0.0105)	(0.0038)	(0.0023)	(0.0037)
$Dam_{i,t-m}$	-0.0108*	-0.0047	-0.0016	0.0012	-0.0032	-0.198**	-0.119	-0.0398	-0.174	0.0786
	(-2.30)	(-0.90)	(-0.29)	(0.21)	(-0.63)	(0.0872)	(0.0798)	(0.117)	(0.169)	(0.114)
$Water_{i,t-m}$	-0.188	-0.107	-0.0697	-0.262	0.0068	-	-	-	-	-
	(-1.76)	(-1.26)	(-0.55)	(-1.84)	(0.09)					
HUC8 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1200	1257	1302	1349	1359	1592	1681	1766	1849	1887

[1] Different from Table D1, we employ the inverse hyperbolic sine (IHS) transformation of the $Fish\ per\ Mile$ variable in this model. The IHS transformation allows for observations with a value of 0. Consequently, the number of observations in this model has improved significantly. We observe a statistically significant positive impact of both NGOs' and government's expenditures in this model.