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FEATURED PAPER

Quantifying the Monetary Value of Alaska National Forests to Commercial Pacific Salmon Fisheries

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Abstract
Forested landscapes support a diversity of ecological processes and organisms having direct value to society. Assessments placing monetary value on forest processes and organisms can help inform management actions affecting these ecosystem services. The temperate rain forest ecoregion along the west coast of North America is home to five species of Pacific salmon *Oncorhynchus* spp. that support subsistence, personal-use, sport, and commercial fisheries. This study aimed to quantify the number and monetary value of commercially caught Pacific salmon originating from Alaska's Tongass and Chugach national forests, two adjacent national forests containing some of the world's largest remaining tracts of intact temperate rain forest. The proportion of commercially harvested wild Pacific salmon originating from streams and lakes within national forest boundaries was estimated by subtracting hatchery salmon and salmon originating outside national forest areas from the total commercial catch. The Tongass and Chugach national forests were major contributors to the overall number and value of commercially caught Pacific salmon in southeastern and southcentral Alaska. From 2007 to 2016 these national forests contributed an average of 48 million Pacific salmon annually to commercial fisheries, with a dockside value averaging US$88 million (inflation adjusted to the base year 2017). These "forest fish" represented 25% of Alaska's commercial Pacific salmon catch for this time period and 16% of the total commercial value. These findings emphasize the importance of Alaska's forest rivers and lakes for sustaining Pacific salmon and can contribute to discussions about alternative land management strategies that might impact Pacific salmon populations and associated commercial salmon fisheries.

Forest lands support multiple ecological processes and diverse assemblages of organisms that have direct and indirect value to society (Godoy and Bawa 1993; de Groot et al. 2002; Penaluna et al. 2017). Clean water, clean air, carbon sequestration, animal viewing, hiking, hunting, and fishing are just a few of the services that forests provide (Brown et al. 2007). These goods and services are frequently considered to be "free" (de Groot et al. 2002). Indeed, services such as clean water and air can be provided at essentially no cost by functioning forests. However, degradation of forests may diminish the capacity of these ecosystems to provide desired services, which can result in negative impacts to society (Stanturf et al. 2014). For example, deforestation of the Amazon has been

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thought to contribute to reduced precipitation (Malhi et al. 2008; Zemp et al. 2017) and associated water shortages in Brazilian cities (Malhi et al. 2008). In our current society, where decisions are frequently driven by economic pressures, managing forest lands to support diverse values can be informed by quantifying the monetary value of these “free” goods and services (Norberg 1999; Knowler et al. 2003).

Pacific salmon *Oncorhynchus* spp. are a good example of organisms that provide direct services to humans in the form of food but that have also been adversely affected by forest management practices (Everest and Meehan 1981; Nehlsen et al. 1991; Lichatowich 2001). The Pacific Northwest of the United States once supported the largest Pacific salmon runs and associated fisheries in the world (National Research Council 1996; Gustafson et al. 2007). However, within a century of European colonization many of these runs were critically imperiled, due in part to logging activities that deteriorated freshwater spawning and rearing habitat (Lichatowich 2001; Lackey 2003). This legacy of forest management—combined with dam construction, overharvest, mining, and urbanization—has resulted in billions spent on hatcheries and other restoration actions aimed at maintaining recreational, commercial, and subsistence fisheries that were once provided by intact ecosystems (Levin et al. 2001; Lackey et al. 2006). Both the United States and Canada now have policies and laws in place to protect wild Pacific salmon, such as requirements for tree buffers along streams and water quality standards (Budd et al. 1987; Richardson et al. 2012). Nevertheless, strong economic pressures still exist that may be at odds with maintaining healthy Pacific salmon habitat, such as intensive timber harvest, mining, and urbanization. Weighing the economic costs and benefits of these activities requires accounting for the value of forest resources—such as Pacific salmon—that might be negatively impacted by development or resource extraction.

Perhaps the largest and most productive “salmon forests” in the world are in Alaska (Baker et al. 1996; Halupka et al. 2000). The Tongass and Chugach national forests in southeastern and southcentral Alaska (Figure 1) represent some of the largest tracts of intact rain forest in the world (Orians and Schoen 2017), and these forests support productive Pacific salmon fisheries. In southeastern Alaska, for instance, commercial fishing and seafood processing is the largest private-sector industry, accounting for 15% of regional employment (McDowell Group 2017). Many of the ocean-caught Pacific salmon that support the fishing industry likely began their lives in forest streams that drain the Tongass and Chugach national forests. Like other forests, these forests—particularly the Tongass—have historically been valued for timber production (Durbin 1999). However, given the importance of Pacific salmon fisheries to Alaska's economy and culture, understanding and quantifying the economic value of salmon that originate from the Tongass and Chugach national forests is also critical (Gillespie et al. 2018).

Our goal was to quantify the monetary value of commercially harvested Pacific salmon from Alaska's national forest lands. Specifically, this study addressed three questions:

1. How many commercially caught Pacific salmon in southeastern and southcentral Alaska originate from lakes, rivers, and streams in the Tongass and Chugach national forests?
2. What is the monetary value of these “forest fish” to commercial fisheries?
3. What proportion of Alaska's commercial Pacific salmon harvest originates from Alaska national forest lands?

This information can be used to weigh management decisions that may adversely impact Pacific salmon, as well as those management actions (e.g., habitat restoration) aimed at improving habitat and restoring functions critical to freshwater salmon productivity. While subsistence, sport, and personal-use fisheries are not included here, estimating the monetary value of commercial fisheries is an important first step towards a more comprehensive socioeconomic valuation of national forests for fisheries production.

METHODS

Study areas.— The Tongass and Chugach national forests are the first and second largest national forests in the United States, with a total area of approximately 97,000 km^2 (Figure 1). The Tongass National Forest covers most of southeastern Alaska and the Alexander Archipelago (69,000 km^2). The Chugach National Forest (28,000 km^2) covers the Copper River delta, Prince William Sound, and part of the Kenai Peninsula. Most of the Tongass and Chugach national forests lie within the temperate rain forest ecoregion and have high levels of precipitation (1,500–5,000 mm on the Tongass and 500–6,000 mm on the Chugach; University of Alaska Fairbanks 2015). This precipitation feeds into streams, rivers, and lakes, supporting five species of commercially important Pacific salmon: Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*, Sockeye Salmon *O. nerka*, Pink Salmon *O. gorbuscha*, and Chum Salmon *O. keta*.

The marine environments adjacent to the Tongass and Chugach national forests support lucrative commercial Pacific salmon fisheries. From 2007 to 2016, the total commercial Pacific salmon harvest from the Commercial Salmon Management Areas adjacent to the Tongass National Forest (Southeast Region) and Chugach National Forest (primarily Prince William Sound)

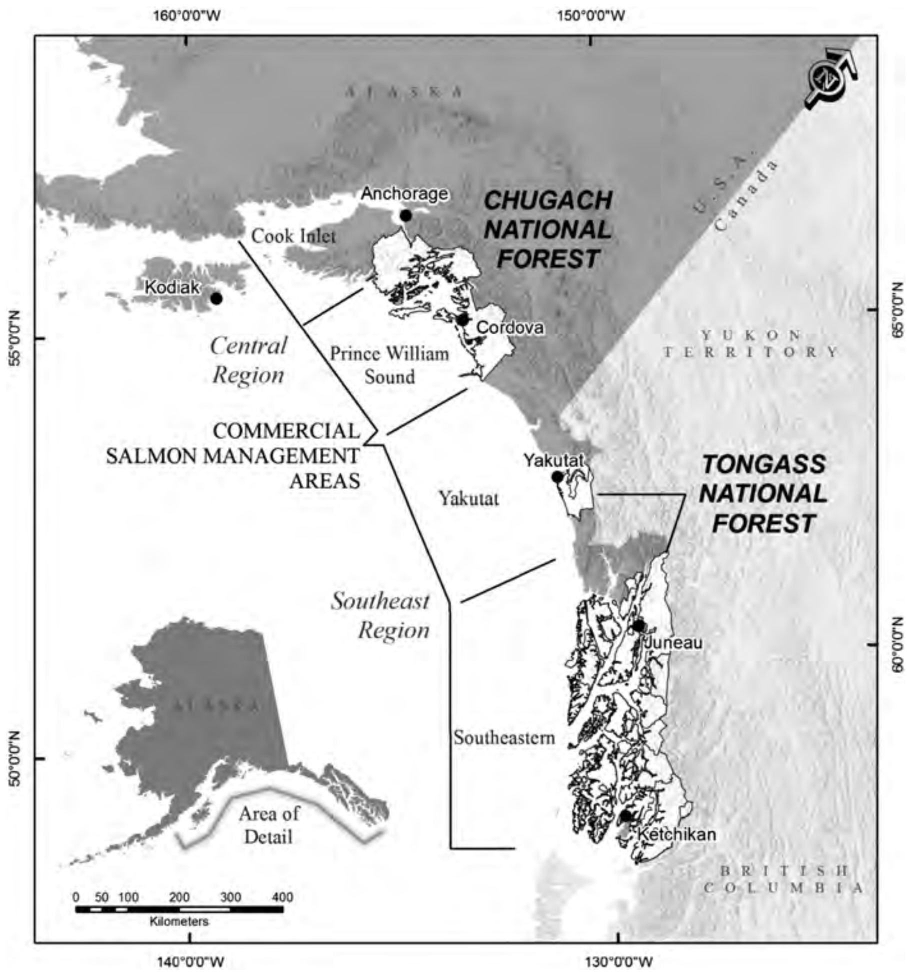

FIGURE 1. Map for the Tongass National Forest and Chugach National Forest (land area indicated in white with black border) and adjacent Alaska Department of Fish and Game Commercial Salmon Management Areas.

generally surpassed 100 million fish per year, with an annual value surpassing US$225 million (Conrad and Gray 2017; Russell et al. 2017). The Pacific salmon caught in these fisheries, however, do not all originate from national forest lands, and depending on the species and region, a large proportion of the fish may originate either from hatcheries or from lands outside Alaska's national forest boundaries. For instance, there are 21 hatchery facilities adjacent to the Tongass and Chugach national forests (Stopha 2017), which produce large numbers of Pacific salmon—primarily Chum Salmon and Pink Salmon—that are harvested in commercial fisheries.

Value assessment approach.— A simple set of calculations was made to estimate the number and monetary value of Pacific salmon originating from the Tongass and Chugach national forests that are harvested in commercial Pacific salmon fisheries. We define “originating from” as those Pacific salmon that emerged from stream gravels within Tongass or Chugach National Forest boundaries. Our approach began by obtaining estimates of the total annual commercial Pacific salmon harvest (*TotalHarvest*) from Commercial Fishing Management Areas adjacent to national forest lands (see Figures 1, 2). These values were then corrected to remove Pacific salmon not originating from either the Tongass or Chugach national forests, as follows:

$$ForestFish_i = TotalHarvest_i \times [1 - (PropHatchery_i + PropOutside_i)] \quad (1)$$

where $ForestFish_i$ represents the number of Pacific salmon of species i originating from national forest lands, $PropHatchery_i$ is the proportion of Alaska hatchery-produced Pacific salmon in the commercial harvest, and $PropOutside_i$ is the proportion of Pacific salmon that originate from streams, rivers, and hatcheries outside Alaska national forest lands. Once the number of Pacific salmon originating from Alaska's national forest lands

($ForestFish_i$) was estimated based on the geographic region, this value was converted to U.S. dollars by multiplying fish numbers by the average weight of each Pacific salmon species and the associated average ex-vessel price (i.e., dockside value) from Alaska Department of Fish and Game (ADFG) data (gross harvest number, weight, and value by species and harvest area; ADFG 2007–2016b). Average price per pound for fish was subsequently adjusted for inflation over time using the consumer price index averaged for U.S. cities (U.S. Department of Labor 2017) using January 2017 as the standard base.

Applying the approach.— We obtained commercial Pacific salmon harvest numbers for 2007–2016 for Commercial Salmon Management Areas adjacent to the Tongass and Chugach national forests from the ADFG statewide electronic fish ticket database (ADFG 2018a). For the Tongass National Forest, this comprised the Southeast Region, specifically the Yakutat Commercial Salmon Management Area and Southeastern Commercial Salmon Management Area (Figure 1). For the Chugach National Forest, this comprised the Central Region, specifically the Prince William Sound Commercial Salmon Management Area and a small portion (<10%) of the Cook Inlet Commercial Salmon Management Area, including the upper portion of Turnagain Arm west of Anchorage and a portion of the Kenai River draining into Cook Inlet (see Figure 1; Supplement A available in the online version of the article). In general, national forest boundaries and Commercial Salmon Management Areas closely overlapped (Figure 1). We then adjusted commercial Pacific salmon harvest numbers ($TotalCatch_i$) for these management areas using equation (1).

The proportion of the commercial Pacific salmon harvest that was of hatchery origin ($PropHatchery_i$) was determined from queries of ADFG databases with interpretation by ADFG fish biologists for 2006–2017 and other relevant references (Mark Stopha, Assistant Coordinator, Private Nonprofit Hatchery Program; Table 1; Supplement B available in the online version of the article). Most Alaska hatcheries thermally mark, chemically mark, or coded-wire-tag juvenile fish (ADFG 2007–2016a; see also Volk et al. 1999) as a means for ADFG to apportion hatchery harvest by origin. Estimates of commercially harvested, hatchery-origin fish were used in the calculation of nonforest fish for Chinook, Coho, Sockeye, Pink, and Chum salmons. Hatchery proportions included Pacific salmon harvested for hatchery brood stock and cost recovery (i.e., Pacific salmon harvested to pay for hatchery operations), as well as commercial common property fishery harvests.

The proportion of Pacific salmon that originated outside of national forest lands ($PropOutside_i$; Table 1) was estimated via two different approaches. In the Central Region (Prince William Sound and a portion of the Cook Inlet subregions), the proportion of Pacific salmon that did not originate from the Chugach National Forest was evaluated using the Alaska Anadromous Waters Catalog (AWC; Johnson and Blossom 2017; ADFG 2018b). We used the AWC to calculate the proportion of documented spawning habitat located outside Chugach National Forest boundaries. It was assumed that the proportion of spawning habitat outside of Chugach National Forest lands represented the fraction of Pacific salmon harvested from nearby fisheries that did not originate from neighboring national forest lands. It is important to note this approach assumes that all documented Pacific salmon streams produce the same number of salmon per unit distance of cataloged spawning habitat; we assumed this to be a reasonable assumption when averaging across the entire region. For the Southeast Region (Southeastern and Yakutat subregions), calculations using the AWC were not

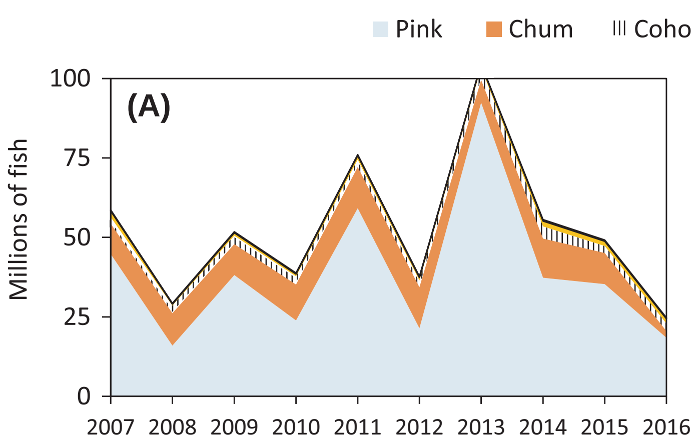

FIGURE 2. Total commercial harvest of Pacific salmon off shore from **(A)** the Tongass National Forest (Southeast Region Commercial Management Area, including Yakutat subregion) and **(B)** the Chugach National Forest (Prince William Sound subregion plus the Copper River and a portion of upper Cook Inlet).

TABLE 1. Estimates of the average percent and range of Pacific salmon caught in commercial fisheries from 2007 to 2016 that did not originate from the Tongass National Forest (within Southeast Region) or Chugach National Forest (within Central Region). Estimates include Pacific salmon from hatcheries and Pacific salmon originating from lands outside Tongass and Chugach National Forest boundaries. Ranges represent the minimum and maximum estimates for the 10-year period. Data is summarized from Alaska Department of Fish and Game reports and personal communication (see Methods for details).

Species and Commercial Salmon Management Area	Average percent fish from Alaska hatcheries (range)	Average percent fish from Washington, Oregon, Canada, or outside national forest lands (range)	References and personal contacts for sources of Alaska Department of Fish and Game data
Chinook Salmon			
Southeast Region	29 (16–42)	67 (55–80)	Hatchery data (Mark Stopha); Southeast Region forest fish (Peterson et al. 2017); Yakutat area (Nicole Zeiser); transboundary river information (Pacific Salmon Commission 2017); Glacier Bay (Dave Harris); Chilkat River (Richard Chapell)
Central Region	0 (no range)	93 (86–97)	Prince William Sound Region and Copper River contribution (Stormy Haught); Cook Inlet contribution (Mark Willette)
Sockeye Salmon			
Southeast Region	17 (10–28)	60 (47–66)	Hatchery data (Mark Stopha); Yakutat area (Nicole Zeiser); transboundary river information (Pacific Salmon Commission 2017, Steve Heinl, Troy Thynes, Julie Bednarski); Glacier Bay (Dave Harris); Taku, Chilkoot, Chilkat (Steve Heinl)
Central Region	44 (35–65)	25 (12–33)	Prince William Sound and Copper River contribution (Stormy Haught); Cook Inlet contribution (Mark Willette)
Coho Salmon			
Southeast Region	31 (24–39)	2 (1–5)	Hatchery data (Mark Stopha); Yakutat area (Nicole Zeiser); transboundary river information (Pacific Salmon Commission 2017); Glacier Bay (Dave Harris)
Central Region	23 (3–39)	16 (13–18)	Prince William Sound and Copper River contribution (Stormy Haught); Cook Inlet contribution (Mark Willette)
Pink Salmon			
Southeast Region	3 (1–6)	2 (0–6)	Hatchery data (Mark Stopha); Yakutat area (Nicole Zeiser); transboundary river information (Pacific Salmon Commission 2017); Glacier Bay (Dave Harris); Taku, Chilkoot, Chilkat (Steve Heinl)
Central Region	87 (74–97)	1 (0–3)	Prince William Sound and Copper River contribution (Stormy Haught); Cook Inlet contribution (Mark Willette)
Chum Salmon			
Southeast Region	84 (78–91)	1 (0–1)	Hatchery data (Mark Stopha); Yakutat area (Nicole Zeiser); transboundary river information (Pacific Salmon Commission 2017); Glacier Bay (Dave Harris); Taku, Chilkoot, Chilkat (Steve Heinl)
Central Region	94 (83–97)	1 (0–1)	Prince William Sound and Copper River contribution (Stormy Haught); Cook Inlet contribution (Mark Willette)

feasible for two reasons. First, much of the spawning habitat lies in large transboundary rivers in Canada and, thus, is not included in the AWC (Alsek, Stikine, and Taku rivers). Second, significant proportions (>50%) of Chinook Salmon harvested in the Southeast Region originate from Oregon, Washington, or southern British Columbia (Peterson et al. 2017). Rather than using the AWC, in the Southeast Region $PropOutside_i$ was based on expert opinion from local ADFG fisheries biologists. Making these estimates required combining harvest information and expert opinion from numerous fishing districts and subdistricts across southeastern Alaska. These $PropOutside_i$ estimates accounted for Pacific salmon originating from a variety of non-national-forest lands, including the following: (1) Glacier Bay and Wrangell–St. Elias national parks, (2) transboundary rivers that originate in Canada (Alsek, Stikine, and Taku rivers), and (3) Pacific salmon from outside the region (Oregon, Washington, and southern British Columbia) that may have returned to natal streams had they not been intercepted by Alaskan fisheries. All $PropOutside_i$ and $PropHatchery_i$ values for 2007–2016 are reported in Supplement B, and the assumptions underlying these proportions are detailed in Supplement A.

To understand how uncertainty in $PropOutside_i$ and $PropHatchery_i$ might influence our estimates, we conducted an uncertainty analysis (Manly 2007). To do this we assumed that the true value for each proportion was plus or minus 10% of the estimated value. For example, in 2016 we estimated that 64% of Sockeye Salmon caught in southeastern Alaska were progeny of fish that spawned outside of national forest lands, with an associated uncertainty range of 54–74%. When proportions were less than 10% or greater than 90%, the uncertainty range was capped at 0% and 100%, respectively. These ranges represent the general magnitude of uncertainty we expected in our proportions (which in some cases were coarse) and, thus, provided a reasonable assessment of how this uncertainty affects our estimates. We used these ranges to calculate 1,000 separate estimates of the total number and monetary value of Pacific salmon from national forest lands, whereby we randomly selected values of $PropOutside_i$ and $PropHatchery_i$ within the specified range assuming a uniform distribution. We used these 1,000 separate estimates to create uncertainty ranges for the total number and monetary value of Pacific salmon from the Tongass and Chugach national forests. Reported uncertainty values represent the 2.5 and 97.5 percentile values of the 1,000 estimates (i.e., 95% of the 1,000 estimates of fish number and value lie within between these values).

RESULTS

Total Pacific salmon harvests from Commercial Salmon Management Areas adjacent to the national forest lands totaled nearly 110 million fish annually, from 2007 to 2016 (Figure 2). During the 10-year study period, >70% of the harvest was Pink Salmon in both regions. Of the remaining Pacific salmon, on average, <20% was Chum Salmon (19% from Southeast Region, 5% from Prince William Sound subregion), <5% was Coho Salmon, <5% was Sockeye Salmon, and <1% was Chinook Salmon.

For the 10-year study period, the Tongass and Chugach national forests contributed, on average, approximately 44% of the Pacific salmon harvested from these Commercial Salmon Management Areas. From 2007 to 2016, an average of 48 million Pacific salmon originating (i.e., emerged as fry) from the Tongass and Chugach national forests were caught annually in Alaskan commercial Pacific salmon fisheries (Figure 3A; see Supplement B). In our uncertainty analysis, average forest contributions to commercial fisheries ranged between 35 to 53 million Pacific salmon annually for the 10-year study period, or approximately ±25% of our reported value (assuming 10% uncertainty in value of the proportions used to calculate our estimate; see Supplement C available in the online version

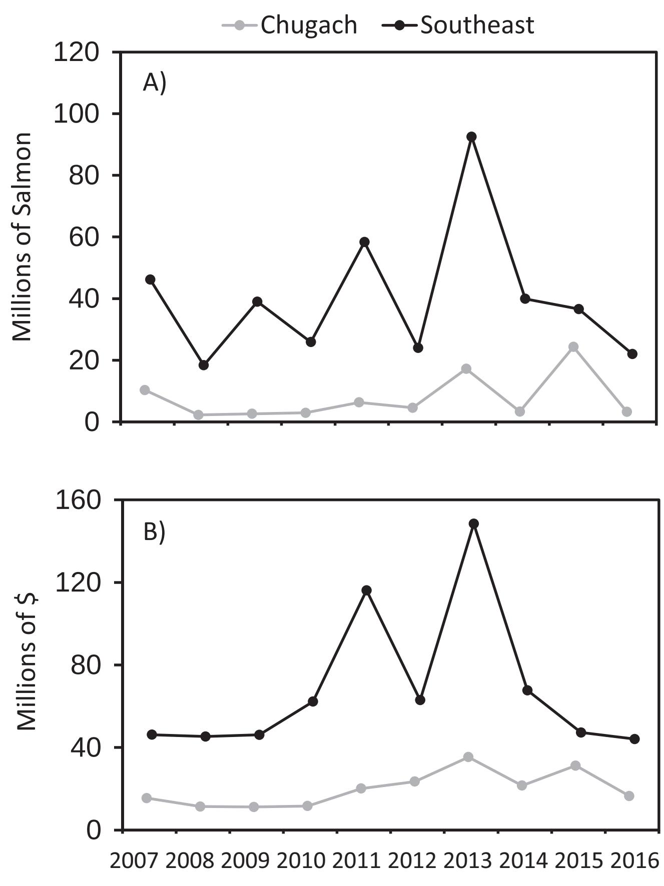

FIGURE 3. Estimates of the **(A)** total number and **(B)** value of Pacific salmon harvested in Alaska's commercial fisheries from 2007 to 2016 that originated from either the Chugach National Forest or the Tongass National Forest (Southeast Region).

of the article for annual values of uncertainty for 2007–2016). On average, these Pacific salmon had a dockside value of $88 million (Figure 3B), with an average annual uncertainty range of $63 to $98 million for the 10-year study period (Supplement C). Compared to the statewide commercial Pacific salmon harvest for 2007 to 2016, these "forest fish" represented, on average, approximately 25% of Alaska's total commercial Pacific salmon harvest number and 16% of the total value.

There were significant differences in the commercial harvest and value of Pacific salmon originating from the Tongass and Chugach national forests (Figure 3). Although the total commercial harvest in marine environments adjacent to the Tongass and Chugach national forests was similar (Figure 2), a much greater proportion of regional commercial Pacific salmon harvests originated from the Tongass National Forest than from the Chugach National Forest (75% average versus 13% average, respectively; Figure 4). This discrepancy was largely due to differences in the percentage of hatchery fish in the commercial harvests (Figure 4). On average for the 10-year study period, hatchery fish represented 21% of the commercial harvest in the Southeast Region (adjacent to the Tongass National Forest) but 84% of the commercial Pacific salmon harvest in the Prince William Sound subregion adjacent to the Chugach National Forest.

Although there was substantial year-to-year variation in the amount of Pacific salmon originating from the Tongass and Chugach national forests (Figure 3A), Pink Salmon were—by far—the most numerically dominant "forest fish" comprising the commercial Pacific salmon harvest (Figure 5). On average, Pink Salmon represented approximately 91% (37 million) and 83% (6.4 million) of the total commercial harvests from the Tongass and Chugach national forests, respectively. For the Tongass National Forest, Chum Salmon averaged 3% (1.6 million),

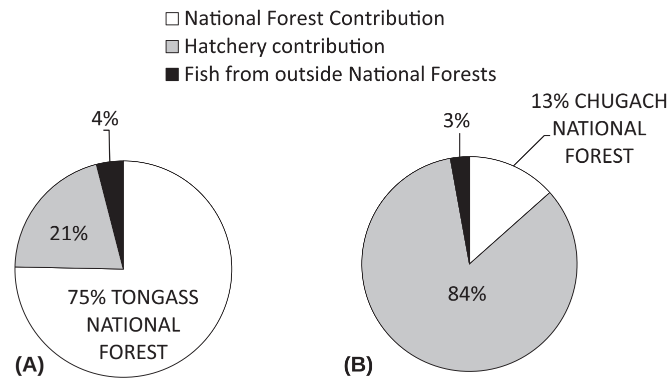

FIGURE 4. Pie charts showing the origin of Pacific salmon caught off shore from **(A)** the Tongass National Forest (Southeast Region) and **(B)** the Chugach National Forest (Prince William Sound subregion).

Coho Salmon averaged 4% (1.8 million) [Correction added on December 12, 2019, after first online publication: This number has been corrected.], Sockeye Salmon averaged <1% (276,000), and Chinook Salmon represented <0.1% (13,000) of commercial harvests. On the Chugach National Forest, Sockeye Salmon represented nearly 15% (922,000) of the commercial harvest, Coho Salmon averaged 4% (245,000), Chum Salmon averaged 2% (157,000), and Chinook Salmon averaged 0.01% (1,000).

From 2007 to 2016, the average Pacific salmon commercial value (in U.S. dollars) ranged from a low of $0.31 per pound for Tongass National Forest Pink Salmon to a high of $5.50 per pound for Chugach National Forest Chinook Salmon (Figure 6). Average price per pound of both Chum Salmon and Coho Salmon was higher for fish from the Tongass National Forest than for those from the Chugach National Forest ($0.65 versus $0.60 and $1.23 versus $1.07, respectively). Average price per pound of Pink, Sockeye, and Chinook salmons was higher for fish

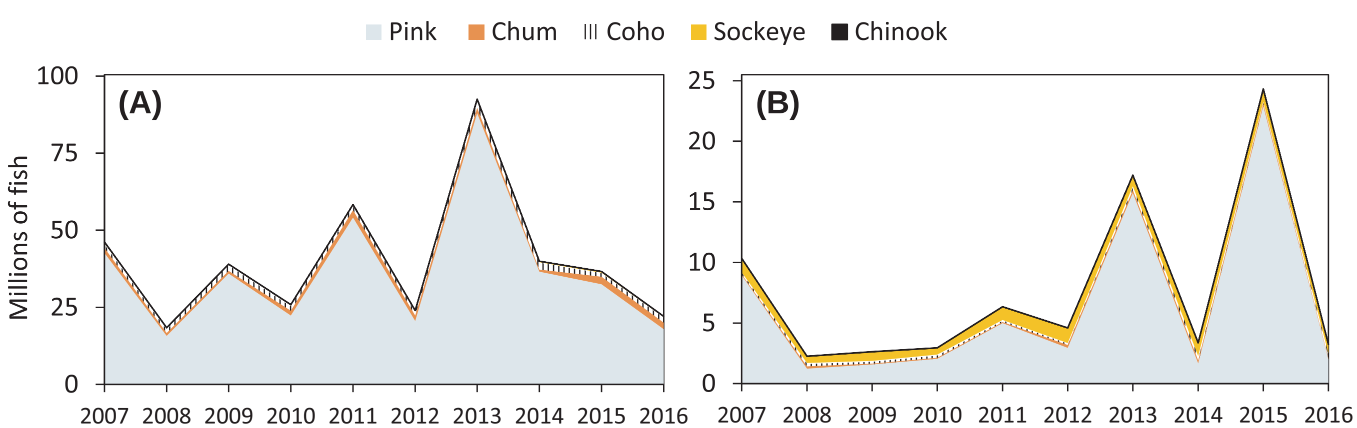

FIGURE 5. Estimated number of each Pacific salmon species originating from the **(A)** Tongass National Forest and **(B)** Chugach National Forest that are commercially harvested.

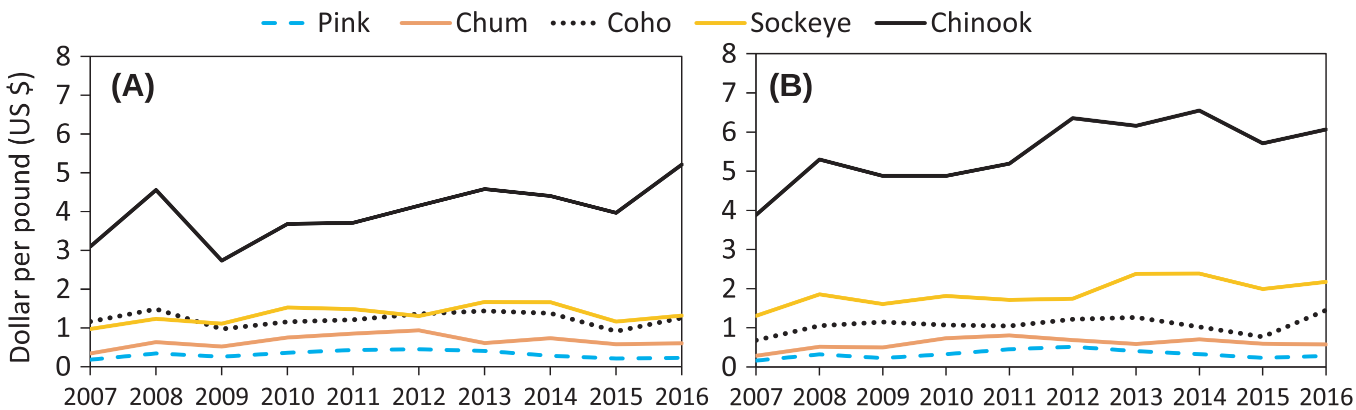

FIGURE 6. Average dockside price per pound paid for different Pacific salmon species harvested off shore from **(A)** the Tongass National Forest (Southeast Region) and **(B)** the Chugach National Forest (Prince William Sound subregion). Note that the price per pound for fish was adjusted for inflation.

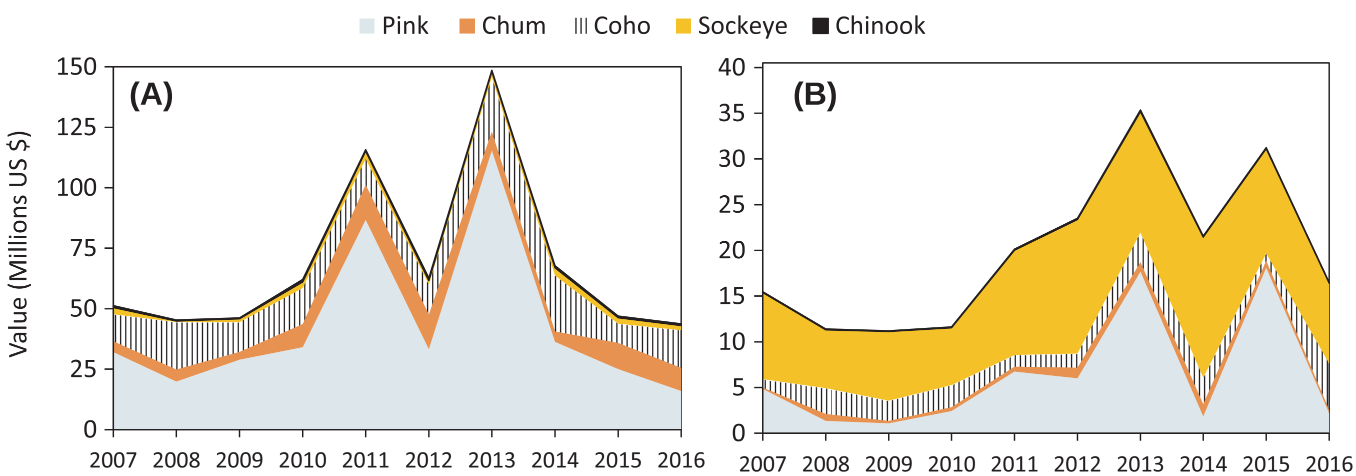

FIGURE 7. Estimated dockside value of each Pacific salmon species from the **(A)** Tongass National Forest and **(B)** Chugach National Forest that are commercially harvested.

from the Chugach National Forest than for those from the Tongass National Forest ($0.33 versus $0.31, $1.90 versus $1.34, $5.50 versus $4.00, respectively).

Pink Salmon originating from the Tongass National Forest, averaging $42 million annually for the study period, had the greatest overall value. Sockeye Salmon, averaging $10.5 million annually, had the highest total value on the Chugach National Forest (Figure 7). On the Tongass National Forest, the value of Chum, Coho, Sockeye, and Chinook salmons averaged $8.8 million, $14.8 million, $2.2 million, and $676,000, respectively, during the 10-year study period. On the Chugach National Forest, the value of Pink, Chum, Coho, and Chinook salmons averaged $6.2 million, $694,000, $2.3 million, and $107,000, respectively.

DISCUSSION

Using 2007 to 2016 existing fisheries data, we estimated the monetary value of Alaska's national forest lands to commercial Pacific salmon fisheries. We found that the Tongass and Chugach national forests—the largest national forests in the United States—were major contributors to the overall number and value of commercially caught Pacific salmon in southeastern and southcentral Alaska. In turn, these commercial fisheries are significant contributors to community well-being and the regional economy (e.g., Smith and Clay 2010; TCW Economics 2010; ASMI 2011; Gillespie et al. 2018). Alaska typically accounts for 12–15% of the global supply of Pacific salmon (ASMI 2011), and the Tongass and Chugach national forests, with a land area less than 100,000 km^2, contributed an estimated 25% of the state's commercial Pacific salmon harvest. These findings further emphasize the importance of forest rivers and lakes for sustaining healthy fisheries (Goulding 1980; Naiman et al. 2000; Tanentzap et al. 2014).

Our estimates of the value of Pacific salmon from the Tongass and Chugach national forests can contribute to discussions about alternative land management strategies that might adversely impact salmon populations and associated commercial fisheries (e.g., road building, mining, and logging), as well as those management strategies aimed at improving forest conditions for Pacific salmon (e.g., habitat restoration). Moreover, our estimates provide the basis for a more inclusive evaluation of the socioeconomic value of Pacific salmon from forests that include sport, personal-use, and subsistence fisheries, as well as the indirect value of these fish to local communities.

Our analysis showed that Pink Salmon and Sockeye Salmon were the highest-commercial-value Pacific salmon species originating from forest lands on the Tongass National Forest and Chugach National Forest, respectively. The high value of Pink Salmon from the Tongass National Forest resulted from their numerical abundance. Despite their small size and lower price per pound, Pink Salmon were over an order of magnitude more abundant in the commercial catch than any other Pacific salmon species. Relative to Chinook Salmon, for instance, Pink Salmon were one-quarter the size, one-third the value, but 100 times more numerous. Pink Salmon also dominated commercial Pacific salmon harvests from the Chugach National Forest during the 10-year study period; however, Sockeye Salmon had a higher overall value due to the greater weight and higher price per pound of Sockeye Salmon relative to Pink Salmon (10-year average of \$0.33 versus \$1.90 per pound). Nevertheless, Pink Salmon were still the highest-value Pacific salmon derived from both national forests combined because of the total weight of the catch. That said, it is important to acknowledge that Chinook, Sockeye, and Coho salmons are more important for sport, subsistence, and personal-use fisheries (e.g., Jennings et al. 2007; Conitz 2008) because they are preferred and targeted by these user groups.

This study helped to clarify the magnitude of hatchery Pacific salmon harvests adjacent to national forest lands, particularly in the commercial fishing region adjacent to the Chugach National Forest, where hatchery fish comprised, on average, over 84% of the commercial harvest (versus 21% adjacent to the Tongass National Forest) for the study period. Hatcheries were established in the 1970s to rehabilitate depleted Pacific salmon fisheries. That said, concerns about hatchery effects on wild Pacific salmon populations are rising, warranting further review of multiple ecological and genetic interactions associated with hatcheries (Evenson et al. 2018). The concerns include the impacts of hatchery strays on wild stock population structure and productivity (Gorman et al. 2018), competition between hatchery- and wild-origin juvenile Pacific salmon and resulting density-dependent effects (Holt et al. 2008; Ruggerone et al. 2012; Lewis et al. 2015; Sergeant et al. 2017), and complications for wild-stock fisheries management (Evenson et al. 2018). Despite concerns about the potential effects of hatchery fish on wild fish, from a commercial fishery perspective, hatchery and wild fish are generally indistinguishable and thus have the same monetary value.

Despite their value, Pacific salmon are susceptible to the economic pressures of resource extraction (e.g., logging, mining; Beschta et al. 1987; Baker and McLelland 2003; Crone 2005; Scannell 2012) and development (e.g., dam construction, urbanization; Taylor 2002). These activities have contributed to the loss of populations of Atlantic Salmon *Salmo salar* across most of their historic range, as well as dramatic declines in Pacific salmon—particularly in the contiguous USA (California, Oregon, and Washington) (Nehlsen et al. 1991; Lichatowich 2001; Montgomery 2003). Although Alaskan Pacific salmon populations remain relatively healthy, these populations are susceptible to the same set of factors that have led to declines in other regions (Schoen et al. 2017). Moreover, these populations will have to contend with rapid environmental changes associated with climate change, which may negatively impact the capacity for forest streams to sustain Pacific salmon via a variety of mechanisms (Bryant 2009; Shanley and Albert 2014; Sergeant et al. 2017; Sloat et al. 2017). Our findings illustrate that reductions in the capacity of forest streams to produce Pacific salmon could have consequences for commercial fisheries, as well as the regional economy.

We acknowledge that assessing the number and value of Pacific salmon from national forests to commercial salmon fisheries required making numerous assumptions about the proportion of hatchery-origin fish, as well as fish that emerged from streams outside national forest boundaries. Our analysis would no doubt benefit from a more robust examination of these assumptions. In particular, better evaluation of the proportion of Pacific salmon harvests that did not originate from national forest lands ($PropOutside_i$) would improve our estimates. Nevertheless, our uncertainty analysis suggested that even relatively substantial changes to these proportions (±10%) do not dramatically modify our overall findings. Moreover, because our analysis was restricted to Pacific salmon that originated—i.e., emerged from the gravel as fry—on national forest lands, our estimates of Pacific salmon number and value from national forests to the commercial fishery could be considered conservative. Our estimates do not account for the numerous pathways by which forests support Pacific salmon. For instance, Pacific salmon fry that emerge upstream of national forest lands (e.g., in transboundary rivers and large watersheds like the Copper River) will migrate downstream and may utilize rivers, lakes, and estuaries within national forest boundaries for rearing (e.g., Murphy et al. 1997). Streams and rivers in southeastern and southcentral Alaska also contribute massive fluxes of nutrients, organic matter, and organisms to the marine environment that may support ocean Pacific salmon productivity via numerous energetic pathways (Tanentzap et al. 2014; O'Neel et al. 2015; Whitney et al. 2018). Finally, and perhaps most importantly, our study does not account for subsistence, personal-use, and sport fisheries, which are extremely valuable to local communities, the regional economy, and the Alaskan way of life (TWC Economics 2010).

Management Implications and Conclusions

These analyses can be updated into the future to track changes in the number and value of forest salmon caught in the commercial fishery. In turn, this information can be used to communicate the value of Alaska's national forests for fish production and can contribute to discussions about management decisions that might influence the capacity of these forests to sustain Pacific salmon in the future. Furthermore, this study provides a starting point for more extensive analyses of salmon production from Alaska's national forest lands. Next steps could include further assessment of the value of sport, personal-use, and subsistence fisheries as well as the nonmonetary value of Pacific salmon to communities and culture. Additional research is needed to understand the mechanistic pathways by which forests support Pacific salmon production. In particular, food web studies are needed that illuminate the flows of energy and nutrients from forests to fish (e.g., Wipfli and Baxter 2010; Tanentzap et al. 2014; Rine et al. 2016). For example, in an Amazonian river, Correa and Winemiller (2014) found that both forest plant material and insects from the forest canopy were major contributors to fish diets. By understanding how forest streams support fish production, a value can be placed on the intermediate ecosystem goods and services (Boyd and Banzhaf 2007), such as aquatic macroinvertebrate diversity (Daniels et al. 2019), that are important for sustaining forest fishes.

We illustrate that Pacific salmon that originate from Alaska's national forests represent a substantial proportion of the number and value of Pacific salmon harvested in regional commercial fisheries. The Alaska salmon industry harvests enough Pacific salmon to feed every human on the globe at least one salmon meal per year (McDowell Group 2017), and our analysis suggests that for the 2007–2016 study period the Tongass and Chugach national forests contributed to at least 25% of this harvest. Although Pacific salmon populations are currently relatively healthy in Alaska, the forests that contribute to Pacific salmon production encounter the same threats that have led to the decline of Pacific salmon populations in other regions (e.g., habitat destruction and damming, mining, hatchery interactions, overharvest; Schoen et al. 2017). Moreover, ongoing climate change has the potential to significantly affect freshwater and saltwater habitats and associated Pacific salmon populations (Mueter et al. 2002; Bryant 2009; Brander 2010; Johnson et al. 2019). Maintaining the capacity for these and other forests to support healthy Pacific salmon will require adaptive learning and preserving the processes that create habitat complexity, including natural disturbances such as floods and landslides (Reeves et al. 1995; Johnson et al. 2000; Benda et al. 2003, 2004; Miller and Burnett 2008), factors promoting a diversity of Pacific salmon species and life histories that may be necessary to maintain productive and adaptive Pacific salmon populations in a changing world (Schindler et al. 2003; Moore et al. 2010; Schoen et al. 2017).

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REFERENCES

ADFG (Alaska Department of Fish and Game). 2007–2016a. Mark, tag, and age laboratory. Available: https://mtalab.adfg.alaska.gov/default.aspx. (July 2017).

ADFG (Alaska Department of Fish and Game). 2007–2016b. Commercial salmon harvest information. Available: http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmon_grossearnings_byarea. (June 2017).

ADFG (Alaska Department of Fish and Game) 2018a. Statewide electronic fish ticket database 1985 to present. ADFG, Division of Commercial Fisheries, Juneau.

ADFG (Alaska Department of Fish and Game) 2018b. 2018 Regulatory mapping data files—statewide AWC shapefiles. Available: https://

www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=maps.dataFiles. (October 2018).

ASMI (Alaska Seafood Marketing Institute). 2011. May 2011 seafood market bulletin. Available: http://www.alaskaseafood.org/fishingprocessing/seafoodweb_may11/index.html. (March 2016).

Baker, D. C., and J. N. McLelland. 2003. Evaluating the effectiveness of British Columbia's environmental assessment process for First Nations' participation in mining development. Environmental Impact Assessment Review 23:581–603.

Baker, T. T., A. C. Wertheimer, R. D. Burkett, R. Dunlap, D. M. Eggers, E. I. Fritts, A. J. Gharrett, R. A. Holmes, and R. L. Wilmot. 1996. Status of Pacific salmon and steelhead escapements in southeastern Alaska. Fisheries 21(10):6–18.

Benda, L. E., D. Miller, R. Sias, D. Martin, R. Bilby, C. Veldhuisen, and T. Dunne. 2003. Wood recruitment processes and wood budgeting. Pages 49–73 *in* S. V. Gregory, K. L. Boyer, and A. M. Gurnell, editors. The ecology and management of wood in world rivers. American Fisheries Society, Symposium 37, Bethesda, Maryland.

Benda, L. E., N. L. Poff, D. Miller, T. Dunne, G. Reeves, G. Pess, and M. Pollock. 2004. The network dynamics hypothesis: how channel networks structure riverine habitats. AIBS Bulletin 54:413–427.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. University of Washington Institute of Forest Resources Contribution 57:191–236.

Boyd, J., and S. Banzhaf. 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63:616–626.

Brander, K. 2010. Impacts of climate change on fisheries. Journal of Marine Systems 79:389–402.

Brown, T. C., J. C. Bergstrp, and J. B. Loomis. 2007. Defining, valuing, and providing ecosystem goods and services. Natural Resources Journal 47:329.

Bryant, M. D. 2009. Global climate change and potential effects on Pacific salmonids in freshwater ecosystems of Southeast Alaska. Climatic Change 95:169–193.

Budd, W. W., P. L. Cohen, P. R. Saunders, and F. R. Steiner. 1987. Stream corridor management in the Pacific Northwest. I. Determination of stream-corridor widths. Environmental Management 11:587–597.

Conitz, J. M. 2008. Klawock Lake subsistence Sockeye Salmon project, 2006 Annual Report and 2004–2006 summary. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, Juneau.

Conrad, S., and D. Gray. 2017. Overview of the 2016 Southeast Alaska and Yakutat commercial, personal use, and subsistence salmon fisheries. Alaska Department of Fish and Game, Fishery Management Report 17-25, Anchorage.

Correa, S. B., and K. O. Winemiller. 2014. Niche partitioning among frugivorous fishes in response to fluctuating resources in the Amazonian floodplain forest. Ecology 95:10–224.

Crone, L. K. 2005. Southeast Alaska economics: a resource-abundant region competing in a global marketplace. Landscape and Urban Planning 72:215–233.

Daniels, S., J. R. Bellmore, J. R. Benjamin, N. Witters, J. Vangronsveld, and S. V. Passel. 2019. Quantification of the indirect use value of functional group diversity based on the ecological role of species in the ecosystem. Ecological Economics 153:181–194.

de Groot, R. S., M. A. Wilson, and R. M. J. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393–408.

Durbin, K. 1999. Tongass: pulp politics and the fight for the Alaska rain forest. Oregon State University Press, Corvallis.

Evenson, D. F., C. Habicht, M. Stopha, A. R. Munro, T. R. Meyers, and W. D. Templin. 2018. Salmon hatcheries in Alaska – a review of the implementation of plans, permits, and policies designed to provide protection for wild stocks. Alaska Department of Fish and Game, Special Publication 18-12, Anchorage.

Everest, F. H., and W. R. Meehan. 1981. Forest management and anadromous fish habitat productivity. Transactions of the North American Wildlife and Natural Resources Conference 46:521–530.

Gillespie, N., J. Epstein, S. Alexander, J. M. Bowker, R. Medel, M. Leonard, and A. Thoms. 2018. Socioeconomic benefits of recreational, commercial, and subsistence fishing associated with national forests. Fisheries 43:432–439.

Godoy, R., and K. Bawa. 1993. The economic value and sustainable harvest of plants and animals from the tropical forest: assumptions, hypotheses, and methods. Economic Botany 47:215–219.

Gorman, K., J. McMahon, P. Rand, E. Knudsen, and D. R. Bernard. 2018. Interactions of wild and hatchery Pink Salmon in Prince William Sound. Alaska Department of Fish and Game, Contract CT 160001756, Final Report for 2017. Available: http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.findings_updates. (October 2019).

Goulding, M. 1980. The fishes and the forest: explorations in Amazonian natural history. University of California Press, Berkeley.

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.

Halupka, K. C., M. D. Bryant, M. F. Willson, and F. H. Everest. 2000. Biological characteristics and population status of anadromous salmon in Southeast Alaska. U.S. Forest Service General Technical Report PNW-GTR-468

Holt, C. A., M. B. Rutherford, and R. M. Peterman. 2008. International cooperation among nation-states of the North Pacific Ocean on the problem of competition among salmon for a common pool of prey resources. Marine Policy 32:607–617.

Jennings, G., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, Juneau.

Johnson, A. C., J. Noel, D. P. Gregovich, L. E. Kruger, and B. Buma. 2019. Impacts of submerging and emerging shorelines on various biota and indigenous Alaskan harvesting patterns. Journal of Coastal Research 35:765–775.

Johnson, A. C., D. N. Swanston, and K. E. McGee. 2000. Landslide initiation, runout, and deposition within clearcuts and old-growth forests of Alaska. JAWRA Journal of the American Water Resources Association 36:17–30.

Johnson, J., and B. Blossom. 2017. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, effective June 1, 2017. Alaska Department of Fish and Game, Special Publication 17-03, Anchorage.

Knowler, D. J., B. W. MacGregor, M. J. Bradford, and R. M. Peterman. 2003. Valuing freshwater salmon habitat on the west coast of Canada. Journal of Environmental Management 69:261–273.

Lackey, R. T. 2003. Pacific Northwest salmon: forecasting their status in 2100. Reviews in Fisheries Science 11:35–88.

Lackey, R. T., D. H. Lach, and S. L. Duncan. 2006. Wild salmon in western North America: forecasting the most likely status in 2100. Pages 57–70 *in* R. T. Lackey, D. H. Lach, and S. L. Duncan, editors. Salmon 2100: the future of wild Pacific salmon. American Fisheries Society, Bethesda, Maryland.

Levin, P. S., R. W. Zabel, and J. G. Williams. 2001. The road to extinction is paved with good intentions: negative association of fish hatcheries with threatened salmon. Proceedings: Biological Sciences 268:1153–1158.

Lewis, B., W. S. Grant, R. E. Brenner, and T. Hamazaki. 2015. Changes in size and age of Chinook Salmon *Oncorhynchus tshawytscha* returning to Alaska. PLoS ONE [online serial] 10(6):e0130184.

Lichatowich, J. 2001. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Malhi, Y., J. T. Roberts, R. A. Betts, T. J. Killeen, L. Wenhong, and C. A. Nobre. 2008. Climate change, deforestation, and the fate of the Amazon. Science 319:169–172.

Manly, B. F. 2007. Randomization, bootstrap and Monte Carlo methods in biology. Chapman and Hall/CRC, Boca Raton, Florida.

McDowell Group. 2017. The economic value of Alaska's seafood industry. McDowell Group, Juneau, Alaska.

Miller, D. J., and K. M. Burnett. 2008. A probabilistic model of debris-flow delivery to stream channels, demonstrated for the Coast Range of Oregon, USA. Geomorphology 94:184–205.

Montgomery, D. R. 2003. King of fish: the thousand-year run of salmon. Westview Press, Boulder, Colorado.

Moore, J. W., M. McClure, L. A. Rogers, and D. E. Schindler. 2010. Synchronization and portfolio performance of threatened salmon. Conservation Letters 3:340–348.

Mueter, F. J., R. M. Peterman, and B. J. Pyper. 2002. Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (*Oncorhynchus* spp.) in northern and southern areas. Canadian Journal of Fisheries and Aquatic Sciences 59:456–463.

Murphy, M. L., K. V. Koski, J. M. Lorenz, and J. F. Thedinga. 1997. Downstream migrations of juvenile Pacific salmon (*Oncorhynchus* spp.) in a glacial transboundary river. Canadian Journal of Fisheries and Aquatic Sciences 54:2837–2846.

Naiman, R. J., R. E. Bilby, and P. A. Bisson. 2000. Riparian ecology and management in the Pacific coastal rain forest. AIBS Bulletin 50:996–1011.

National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. National Academies Press, Washington, D.C.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–21.

Norberg, J. 1999. Linking nature's services to ecosystems: some general ecological concepts. Ecological Economics 29:183–202.

O'Neel, S., E. Hood, A. L. Bidlack, S. W. Fleming, M. L. Arimitsu, A. Arendt, E. Burgess, C. J. Sergeant, A. H. Beaudreau, K. Timm, and G. D. Hayward. 2015. Icefield-to-ocean linkages across the northern Pacific coastal temperate rainforest ecosystem. BioScience 65:499–512.

Orians, G., and J. Schoen, editors. 2017. North Pacific temperate rainforests: ecology and conservation. University of Washington Press, Seattle.

Pacific Salmon Commission. 2017. Joint Transboundary Technical Committee final estimates of transboundary river salmon production, harvest and escapement and a review of joint enhancement activities in 2015. Pacific Salmon Commission, Report TCTR (17)-2, Vancouver.

Penaluna, B. E., D. H. Olson, R. L. Flitcroft, M. A. Weber, J. R. Bellmore, S. M. Wondzell, J. B. Dunham, S. L. Johnson, and G. H. Reeves. 2017. Aquatic biodiversity in forests: a weak link in ecosystem services resilience. Biodiversity and Conservation 26:3125–3155.

Peterson, R., D. Evenson, S. Gilk-Baumer, K. Shedd, E. Jones, and J. Nichols. 2017. Harvest of Southeast Alaska wild-origin Chinook Salmon in the Southeast Alaska troll and sport fisheries, 2005–2017. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Memorandum, Juneau.

Reeves, G. H., L. E. Benda, K. M. Burnett, P. A. Bisson, and J. R. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. Pages 334–349 *in* J. L. Nielsen and D. A. Powers, editors. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium 17, Bethesda, Maryland.

Richardson, J. S., R. J. Naiman, and P. A. Bisson. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? Freshwater Science 31:232–238.

Rine, K. M., M. S. Wipfli, E. R. Schoen, T. L. Nightengale, and C. A. Stricker 2016. Trophic pathways supporting juvenile Chinook and Coho salmon in the glacial Susitna River, Alaska: patterns of freshwater, marine, and terrestrial food resource use across a seasonally dynamic habitat mosaic. Canadian Journal of Fisheries and Aquatic Sciences 73:1626–1641.

Ruggerone, G. T., B. A. Agler, and J. L. Nielsen. 2012. Evidence for competition at sea between Norton Sound Chum Salmon and Asian hatchery Chum Salmon. Environmental Biology of Fishes 94:149–163.

Russell, C. W., J. Botz, S. Haught, and S. Moffitt. 2017. 2016 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report 17-37, Anchorage.

Scannell, W. P. 2012. Taku-Tulsequah River mining activity, background environmental monitoring and potential mining effects. Alaska Department of Fish and Game, Technical Report 12-01, Douglas.

Schindler, D. E., M. D. Scheuerell, J. W. Moore, S. M. Gende, T. B. Francis, and W. I. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. Frontiers in Ecology and the Environment 1:31–37.

Schoen, E. R., M. S. Wipfli, E. J. Trammell, D. J. Rinella, A. L. Floyd, J. Grunblatt, M. D. McCarthy, B. E. Meyer, J. M. Morton, J. E. Powell, and A. Prakash. 2017. Future of Pacific salmon in the face of environmental change: lessons from one of the world's remaining productive salmon regions. Fisheries 42:538–553.

Sergeant, C. J., J. R. Bellmore, C. McConnell, and J. W. Moore. 2017. High salmon density and low discharge create periodic hypoxia in coastal rivers. Ecosphere [online serial] 8:e01846.

Shanley, C. S., and D. M. Albert. 2014. Climate change sensitivity index for Pacific salmon habitat in Southeast Alaska. PLoS ONE [online serial] 9(8):e104799.

Sloat, M. R., G. H. Reeves, and K. R. Christiansen. 2017. Stream network geomorphology mediates predicted vulnerability of anadromous fish habitat to hydrologic change in Southeast Alaska. Global Change Biology 23:604–620.

Smith, C., and P. Clay. 2010. Measuring subjective and objective well-being: analyses from five marine commercial fisheries. Human Organization 69:158–168.

Stanturf, J. A., B. J. Palik, and R. K. Dumroese. 2014. Contemporary forest restoration: a review emphasizing function. Forest Ecology and Management 331:292–323.

Stopha, M. 2017. Alaska fisheries enhancement annual report 2016. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J17-04, Anchorage.

Tanentzap, A. J., E. J. Szkokan-Emilson, B. W. Kielstra, M. T. Arts, N. D. Yan, and J. M. Gunn. 2014. Forests fuel fish growth in freshwater deltas. Nature Communications 5:4077.

Taylor, J. E. III. 2002. Making salmon: an environmental history of the Northwest fisheries crisis. University of Washington Press, Seattle.

TCW Economics. 2010. Economic contributions and impacts of salmonid resources in Southeast Alaska. Final Report to Trout Unlimited Alaska Program, Anchorage.

University of Alaska Fairbanks. 2015. Scenarios Network for Alaska and Arctic Planning (SNAP). Available: https://www.snap.uaf.edu. (July 2017).

U.S. Department of Labor. 2017. Databases, tables & calculators by subject: CPI inflation calculator. Available: https://www.bls.gov/data/inflation_calculator.htm. (July 2017).

Volk, E. C., S. L. Schroder, and J. J. Grimm. 1999. Otolith thermal marking. Fisheries Research 43:205–219.

Whitney, E. J., A. H. Beaudreau, and E. R. Howe. 2018. Using stable isotopes to assess the contribution of terrestrial and riverine organic matter to diets of nearshore marine consumers in a glacially influenced estuary. Estuaries and Coasts 41:193–205.

Wipfli, M. S., and C. V. Baxter. 2010. Linking ecosystems, food webs, and fish production: subsidies in salmonid watersheds. Fisheries 35:373–387.

Zemp, D. C., C. F. Schleussner, H. M. Barbosa, M. Hirota, V. Montade, G. Sampaio, A. Staal, L. Wang-Erlandsson, and A. Rammig. 2017. Self-amplified Amazon forest loss due to vegetation-atmosphere feedbacks. Nature Communications 8:14681.

SUPPORTING INFORMATION

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