

# Evolution of tributary junctions and their capacity for rearing juvenile Chinook salmon (*Oncorhynchus tshawytscha*) on a regulated river

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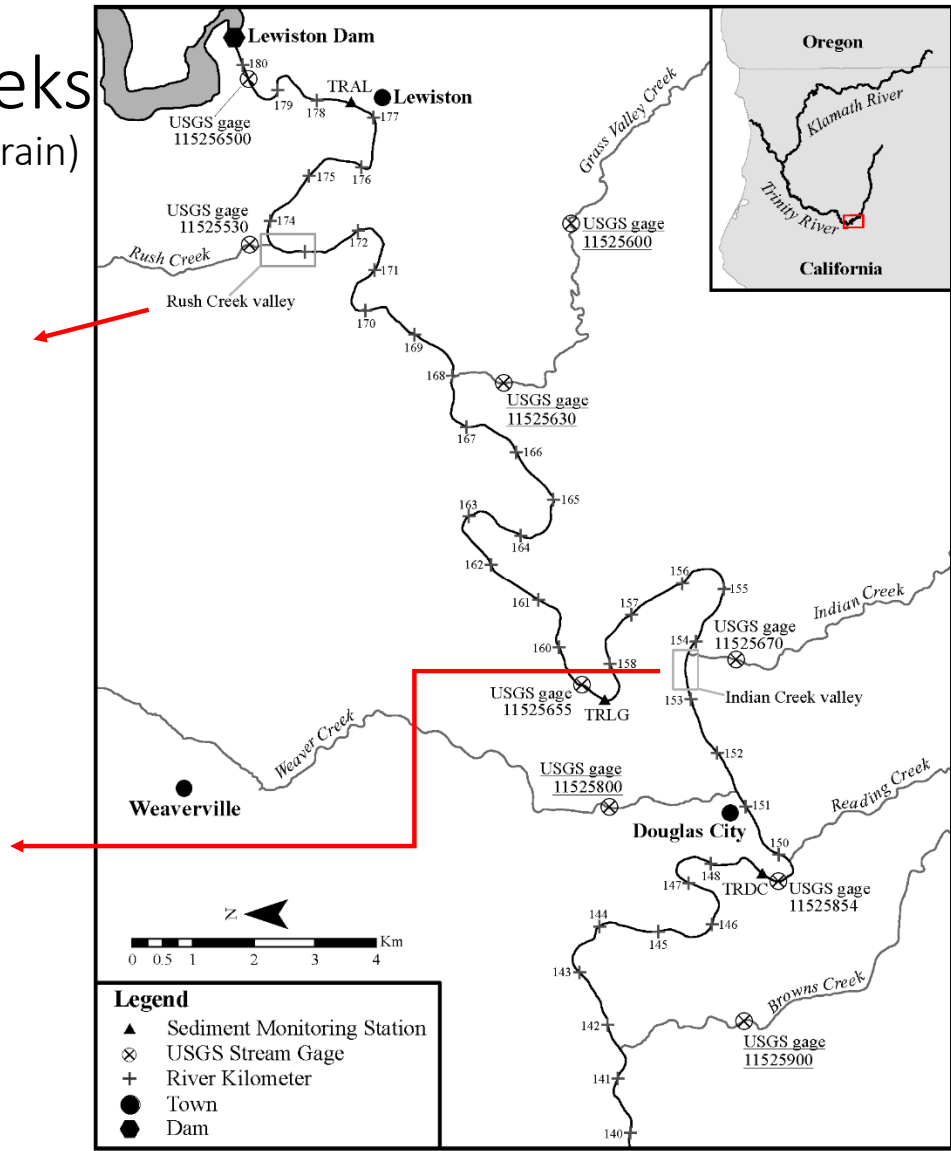
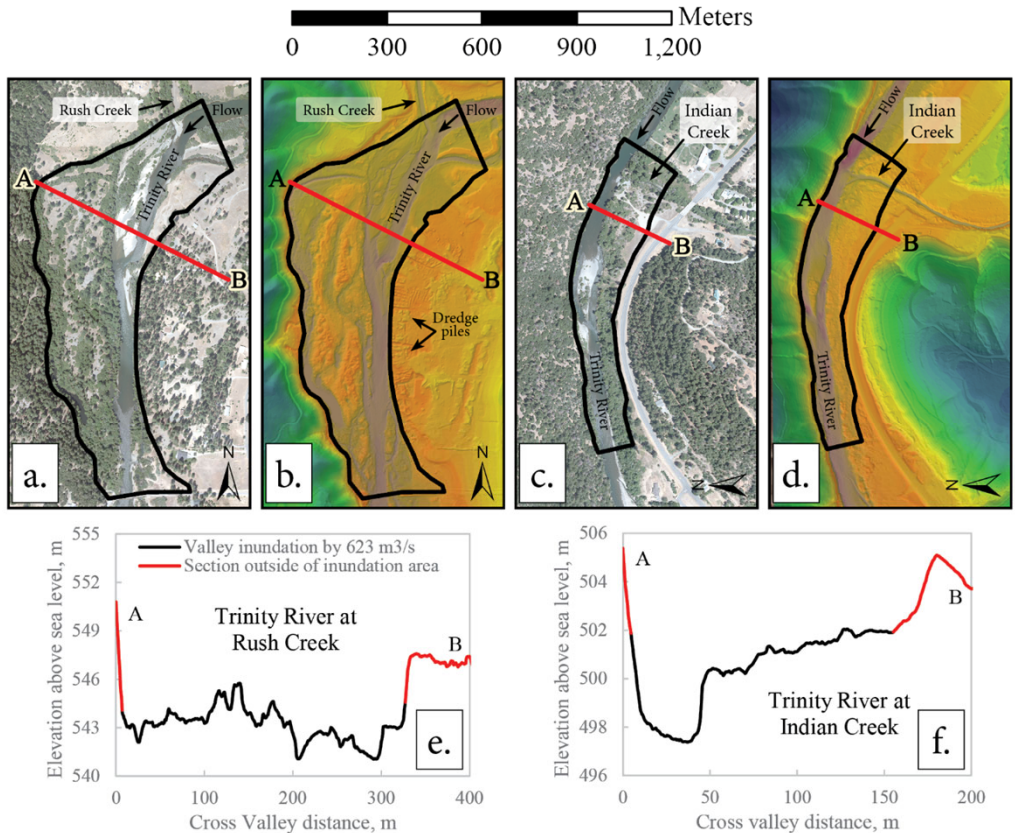
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Submitted to journal Ecohydrology (in review)

The study examines changes in the active channel, exposed bars, and delta areas in an unconfined and confined valley where Rush and Indian creeks respectively join the Trinity River. The examination is made with aerial imagery analyses starting from dam closure in 1960 through 2020. Within this period, regulated flows were successively increased from a low in 1961-1980, and indexes of sediment supply, surveys of riparian plant composition, and valley attributes are considered to explain the observed responses in the valleys. Chinook salmon rearing capacity is modeled under current conditions with estimates used to evaluate the suitability of the junction areas for the juvenile life stage of this species.

# River valleys at Rush and Indian creeks

(extent inundated by 623 m<sup>3</sup>/s (22k cfs) modeled with 2016 terrain)

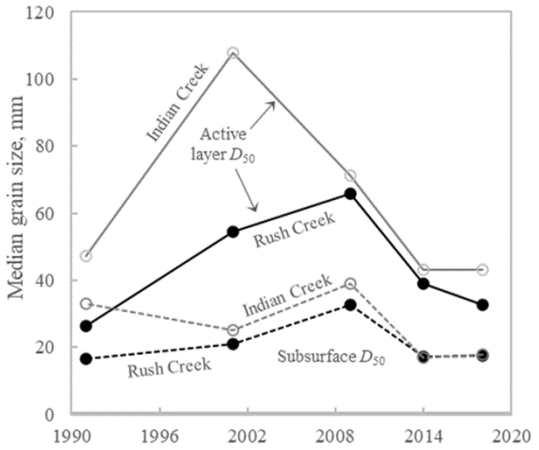


# River valleys at Rush and Indian creeks

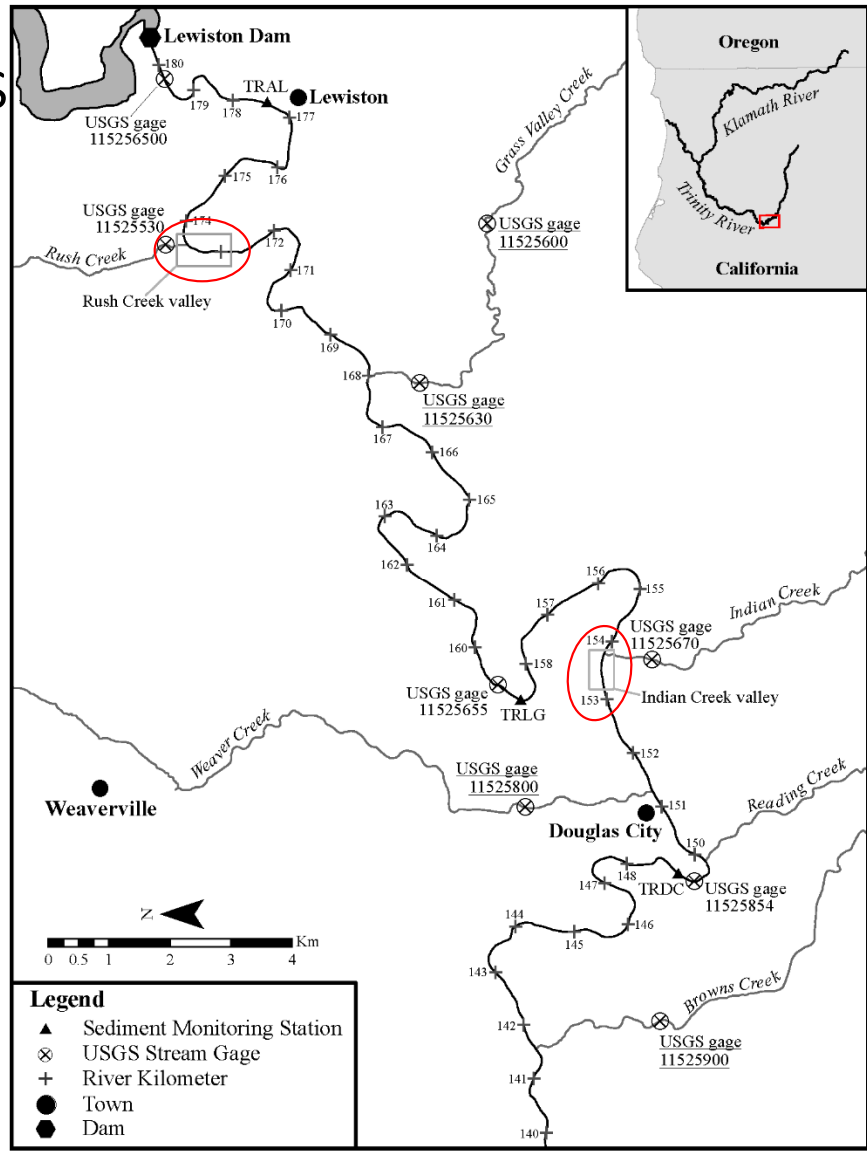
(extent inundated by 623 m<sup>3</sup>/s (22k cfs) modeled with 2016 terrain)

	Rush Creek confluence			Indian Creek confluence		
Maximum valley width (m)	320			147		
Valley length (m)	1,002			739		
Discharge (m <sup>3</sup> /s) <sup>1</sup>	311	453	623	311	453	623
Wetted area (Ha) <sup>2</sup>	20.8	21.4	22.0	6.0	6.8	8.4
Average wetted width (m) <sup>3</sup>	208	214	219	81	93	114
Energy slope (%) <sup>4</sup>	0.25	0.24	0.24	0.28	0.30	0.32

<sup>1</sup>Discharges in increasing order are 3.0, 4.2, and 7.4-year events in the annual flood record at Lewiston (water year 1912 to 2020). <sup>2</sup>Modeled by Bradley (2018) with SRH-2D (Lai, 2010) using topography surveyed in 2016 (Pryor, 2017). <sup>3</sup>Computed by dividing wetted area by valley length. <sup>4</sup>Energy slopes estimated by modeled water surface slopes.



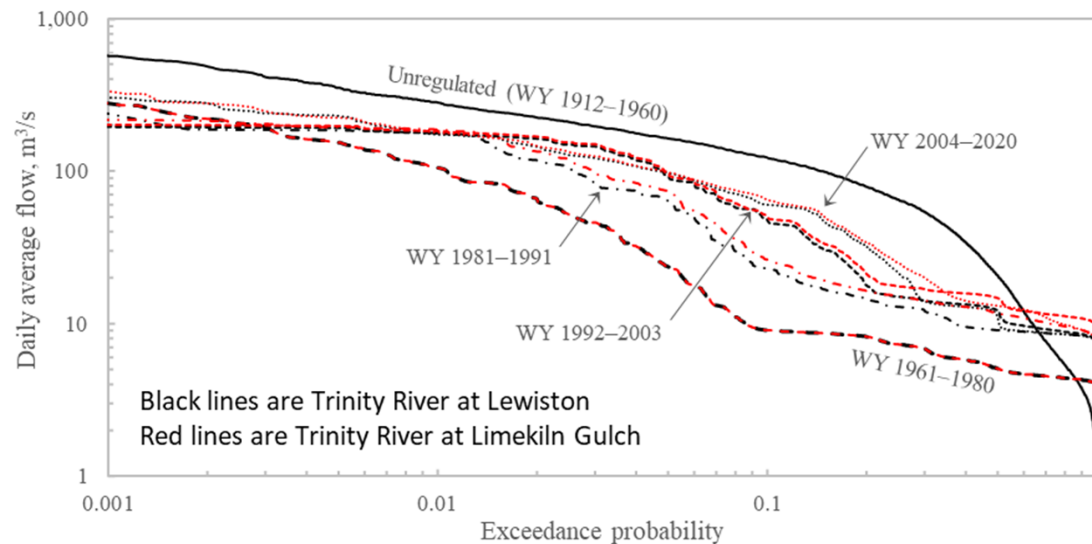
Median grain size ( $D_{50}$ ) on the bed and in the subsurface domain on the Trinity River near Rush and Indian creeks, 1991–2018



# Changes in river flow with dam closure and release authorizations

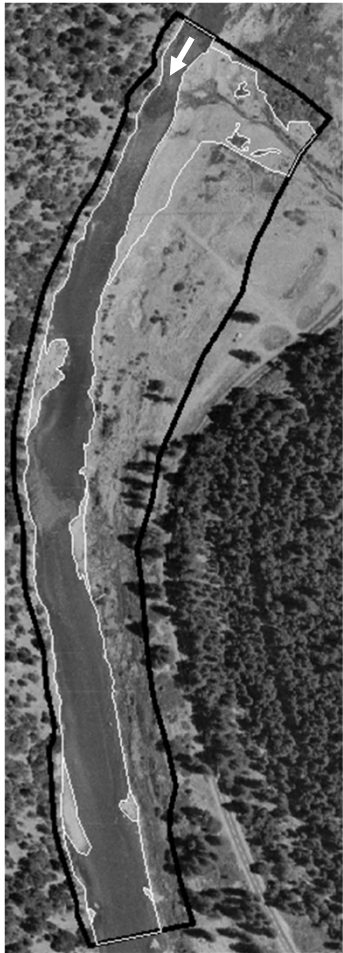
Water year	Average annual flood (m <sup>3</sup> /s) <sup>1</sup>	Minimum annual flood (m <sup>3</sup> /s) <sup>1</sup>	Maximum annual flood (m <sup>3</sup> /s) <sup>1</sup>	Authorized annual water volume (ha-m)	Observed average annual water volume (ha-m)	Authorizations
1912–1960	525	87	2,028	—	146,601	—
1961–1980	72	8	184	14,858	29,637	1955 Trinity Division Act
1981–1991	97	18	249	17,262 to 41,922	53,312	1981 Secretarial Decision
1992–2003	135	46	200	>41,922	71,441	1992 Central Valley Project Improvement Act
2004–2020	209	58	348	48,498 to 100,490 <sup>2</sup>	76,444	Record of Decision (ROD, 2000)

<sup>1</sup>Excludes releases for safety of dams. <sup>2</sup>Allocations apply to critically dry and wetter water years (USFWS and HVT, 1999).





Rush Creek alley



1960



1980



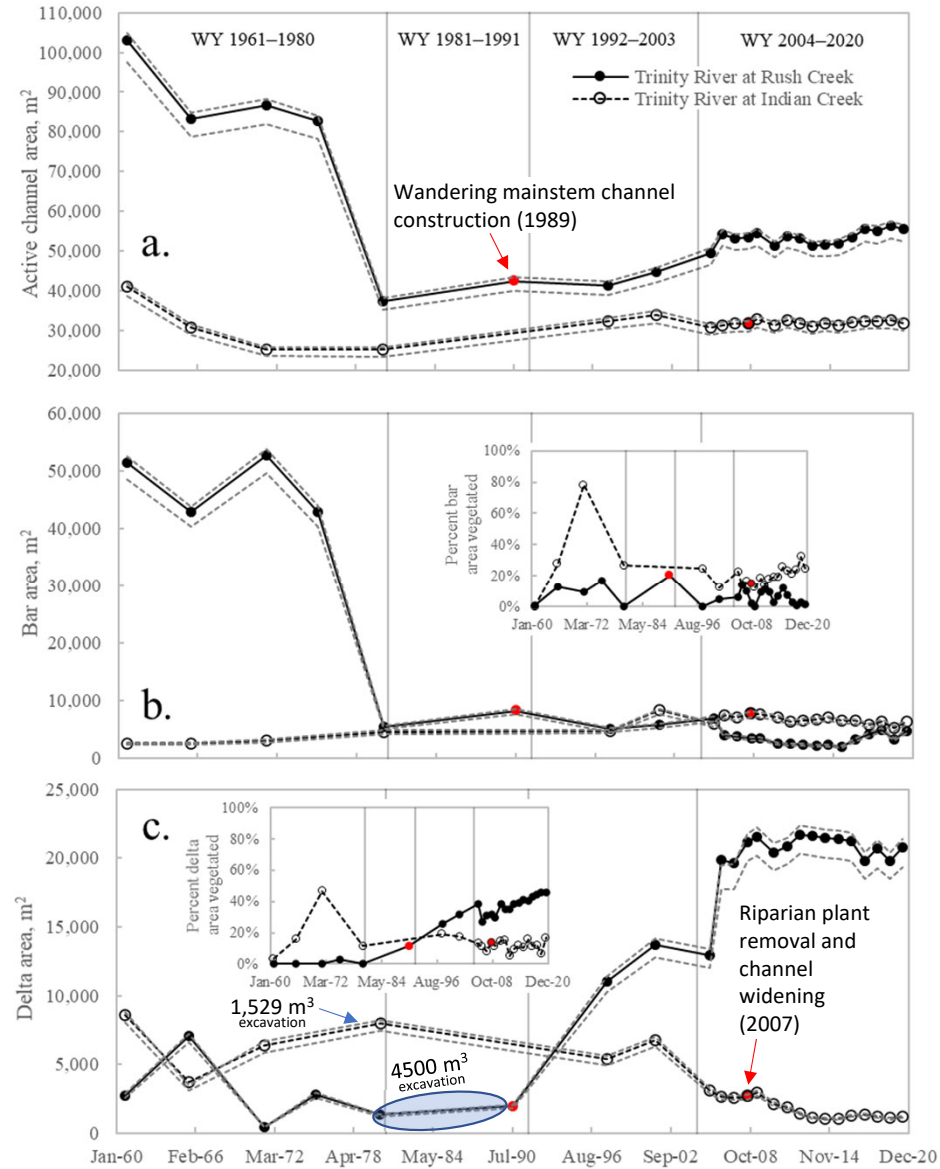
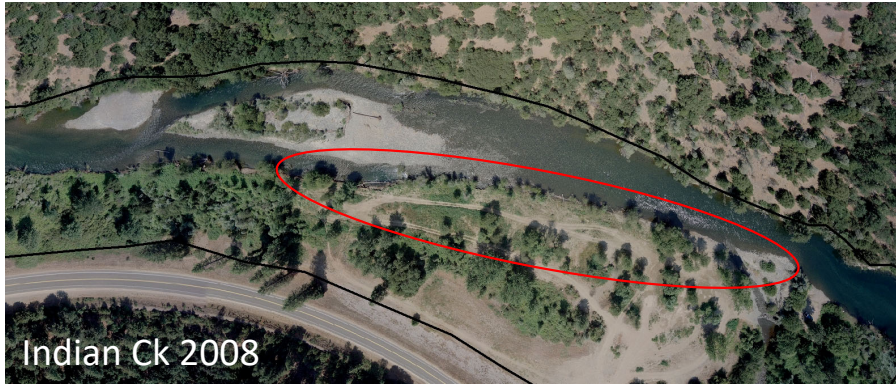
2001



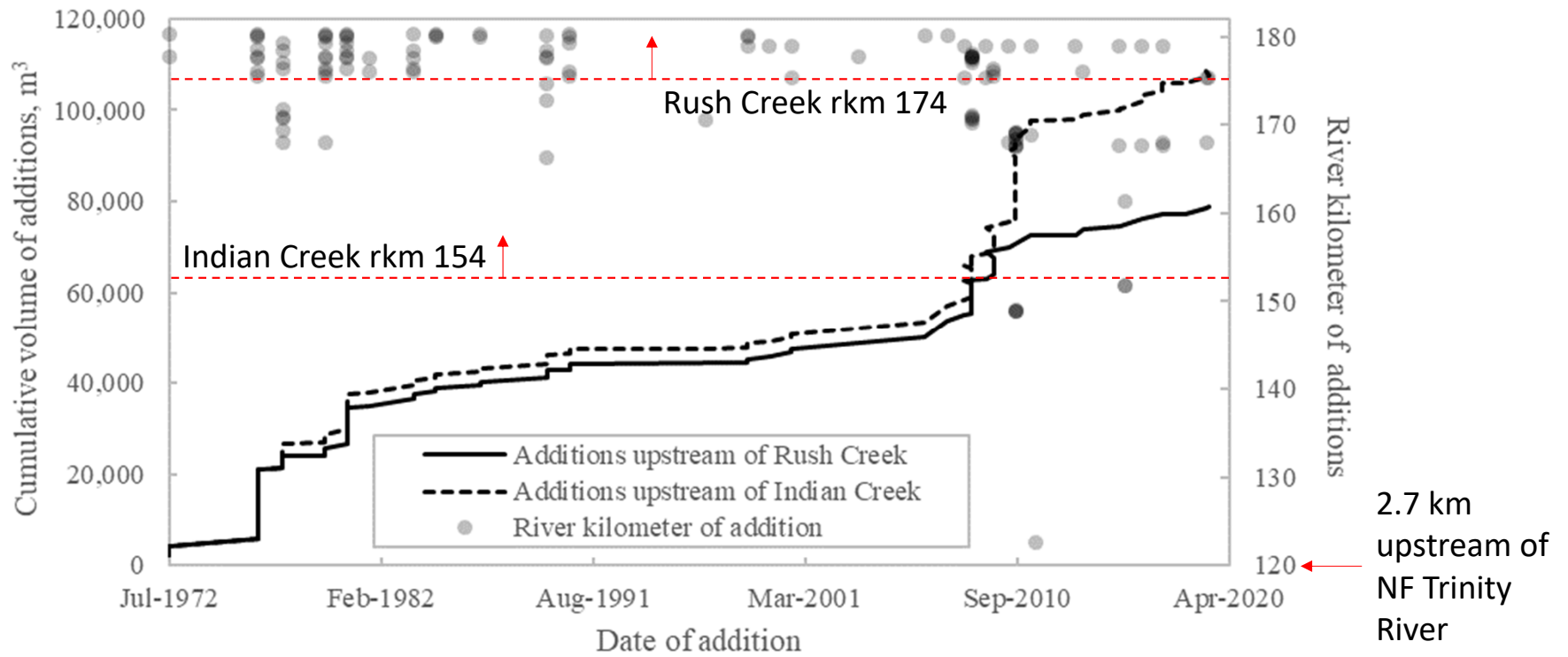
2020

Indian  
Creek  
Valley

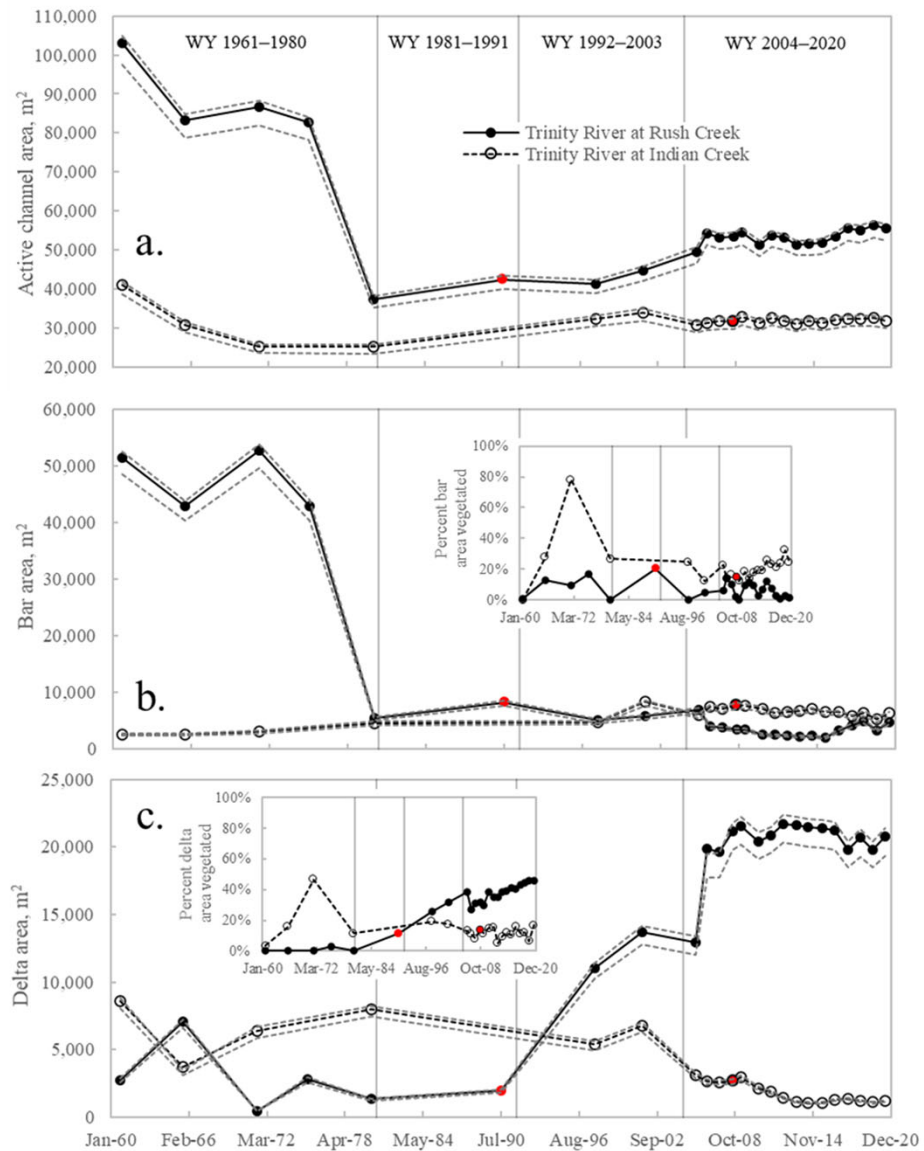
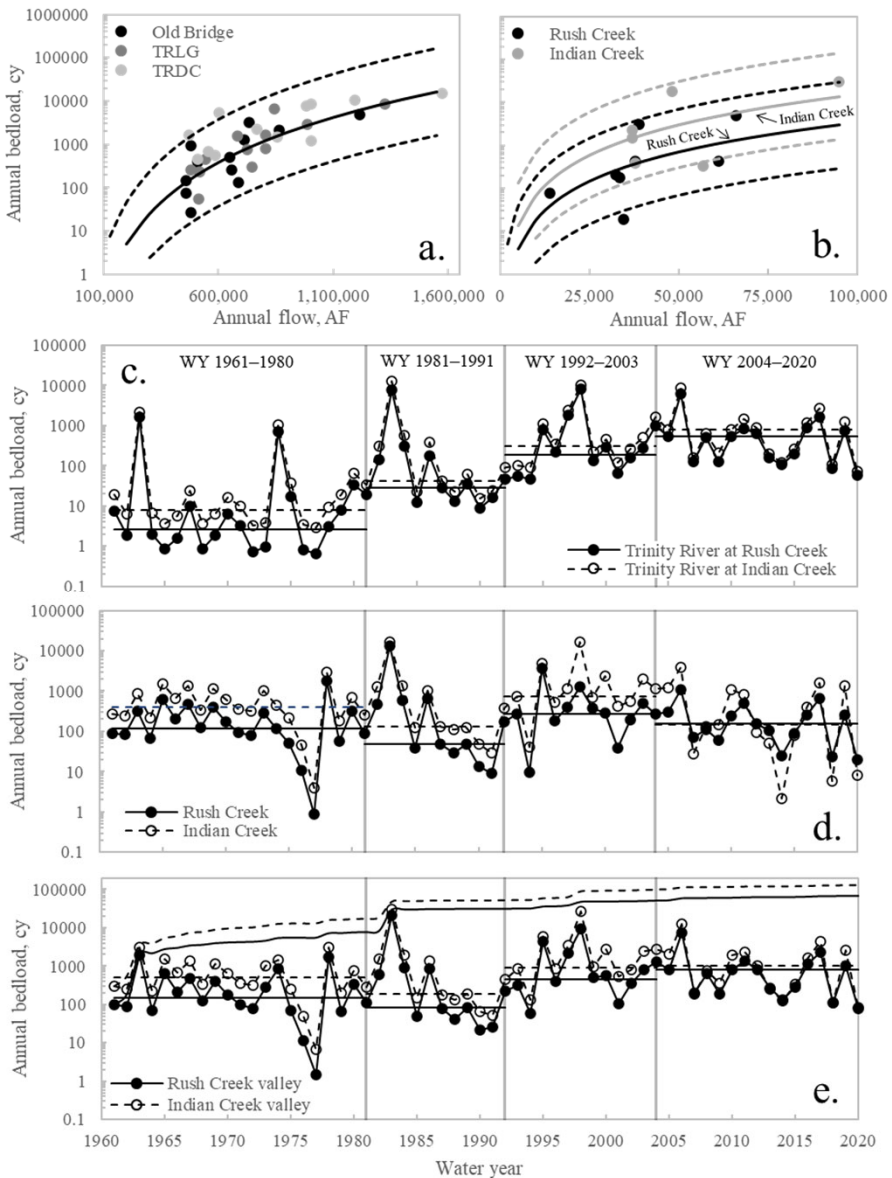
# Changes in active channel, bar, and delta areas, 1960-2020



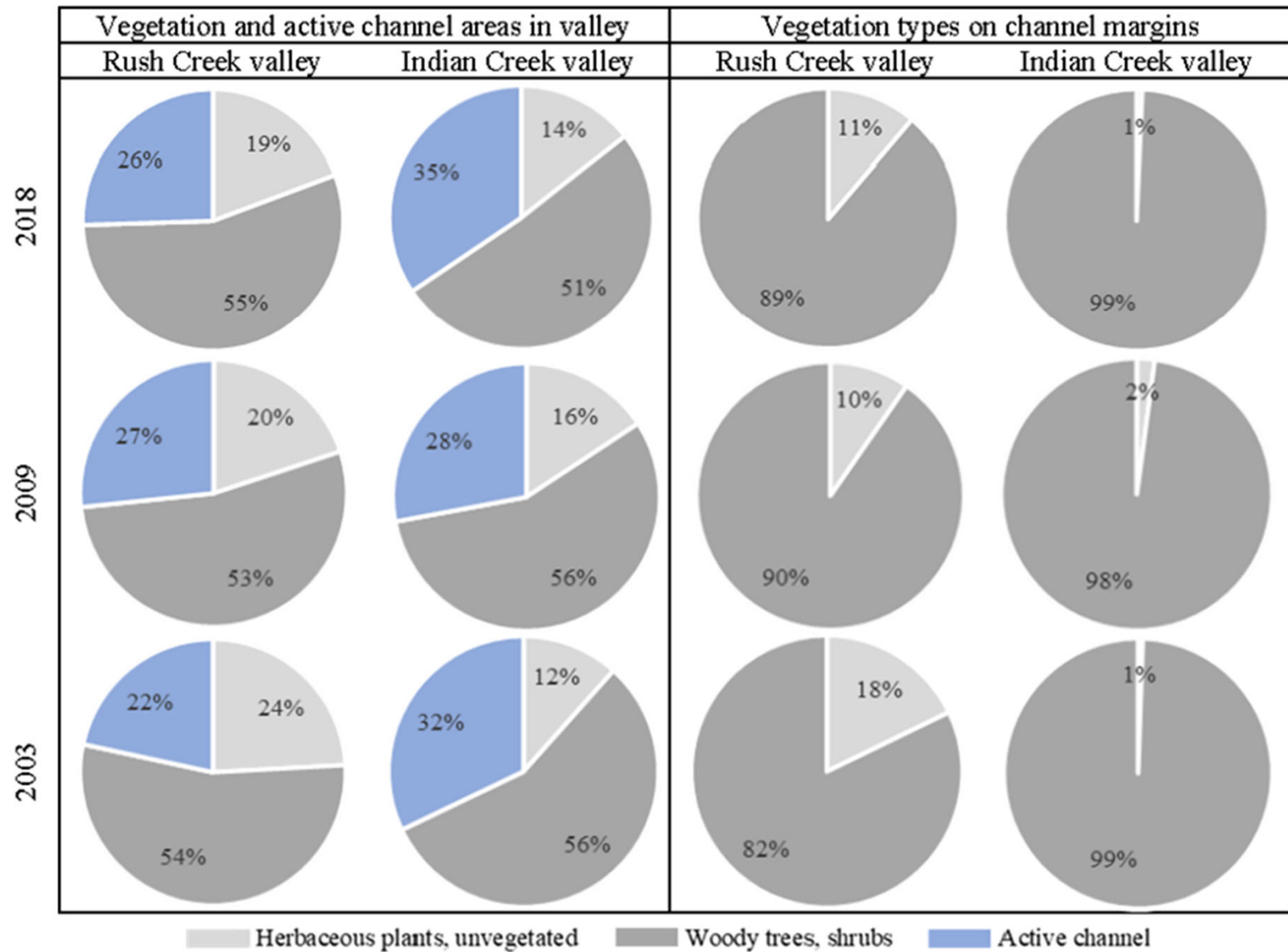
# Gravel additions made to the Trinity River

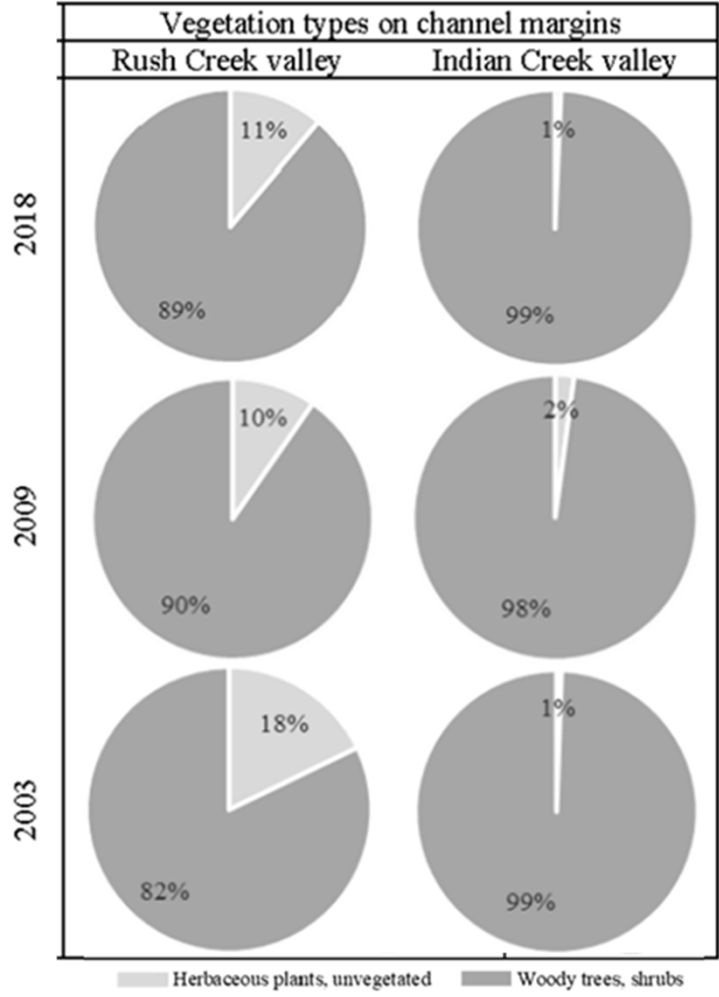


# Index of bedload supply to valley areas



# Riparian plant composition at tributary junctions





# Chinook salmon rearing capacity on the Trinity River at the junction of Rush and Indian creeks



ARTICLE

## N-mix for fish: estimating riverine salmonid habitat selection via N-mixture models

Nicholas A. Som, Russell W. Perry, Edward C. Jones, Kyle De Julio, Paul Petros, William D. Pinnix, and Derek L. Rupert

**Abstract:** Models that formulate mathematical linkages between fish use and habitat characteristics are applied for many purposes. For riverine fish, these linkages are often cast as resource selection functions with variables including depth and velocity of water and distance to nearest cover. Ecologists are now recognizing the role that detection plays in observing organisms, and failure to account for imperfect detection can lead to spurious inference. Herein, we present a flexible N-mixture model to associate habitat characteristics with the abundance of riverine salmonids that simultaneously estimates detection probability. Our formulation has the added benefits of accounting for demographic variation and can generate probabilistic statements regarding intensity of habitat use. In addition to the conceptual benefits, model application to data from the Trinity River, California, yields interesting results. Detection was estimated to vary among surveys, but there was little spatial or temporal variation. Additionally, a weaker effect of water depth on resource selection is estimated than that reported by previous studies not accounting for detection probability. N-mixture models show great promise for applications to riverine resource selection.

**Résumé:** Les modèles qui forment des liens mathématiques entre l'utilisation d'habitats par les poissons et les caractéristiques des habitats sont utilisés à différentes fins. Pour les poissons de rivière, ces liens sont souvent présentés sous forme de fonctions de sélection de ressources avec des variables comme la profondeur et la vitesse de l'eau et la distance du couvert le plus proche. Les écologistes reconnaissent maintenant le rôle que joue la détection dans l'observation d'organismes, et le défaut de tenir compte d'une détection imparfaite peut mener à des inférences erronées. Nous présentons un modèle de mélange de N simple pour associer des caractéristiques de l'habitat à l'abondance de salmonides de rivière qui estime simultanément la probabilité de détection. Notre formulation a aussi l'avantage de tenir compte des variations démographiques et peut générer des énoncés probabilistes concernant l'intensité de l'utilisation de l'habitat. En plus des avantages conceptuels, l'application du modèle à des données de la rivière Trinity (Californie), entraîne deux résultats intéressants. S'il est estimé que la détection varie selon la personne qui réalise le relevé, il y a peu de variation spatiale ou temporelle. En outre, l'effet estimé de la profondeur de l'eau sur la sélection de ressources est plus faible que ce dont font état des études antérieures qui ne tiennent pas compte de la probabilité de détection. Les modèles de mélange de N sont très prometteurs pour des applications touchant à la sélection de ressources dans les cours d'eau. [Traduit par la Rédaction]

### Introduction

Coupled physical and biological models often focus on interactions of target species with their environment for the purposes of exploring emergent properties (Jarvis and Kallibet 2009), evaluating management scenarios (Sandoval-Solis et al. 2012; Gurd 2014), or predicting effects of future climate change (Holsinger et al. 2016). Key inputs to these models are information on the association of species with habitat characteristics, and quantifying these relationships allows dynamic models to simulate individual or population response to physical habitat change. As such, an essential component of model construction is mathematically linking habitat quality to the model's spatial domain as a function of physical variables (Scheurell et al. 2006).

Habitat models are commonly labeled as species distribution, resource selection, or habitat suitability models, and the last several decades have seen tremendous contributions regarding meth-

ods for modeling habitat quality and use as a function of physical variables. Initial methods relied on professional judgement (Bovee 1986), which has been modernized via improvements that include fuzzy inference methods and rule sets (Akmal-Neftcihan et al. 2008; Conallin et al. 2010). Quantitative methods have become prevalent, with fisheries applications beginning with univariate frequency analysis (i.e., habitat suitability curves; HSC) (Hart and Jowett 1994; Som et al. 2015). The suite of quantitative methods has continued to grow and includes applications of generalized linear models (Allridge and Desprez 2002; Labropoulou et al. 2003), pattern recognition methods such as neural networks (Brosse et al. 1999), and more complex Bayesian, Microbial models (Boone et al. 2012). Methods have even been proposed for data containing presence-only observations (Phillips et al. 2006; Royle et al. 2012), which can be common in species distribution studies (Hickey and Hooten 2016), though some controversy remains re-

Received 20 January 2017; Accepted 21 August 2017.

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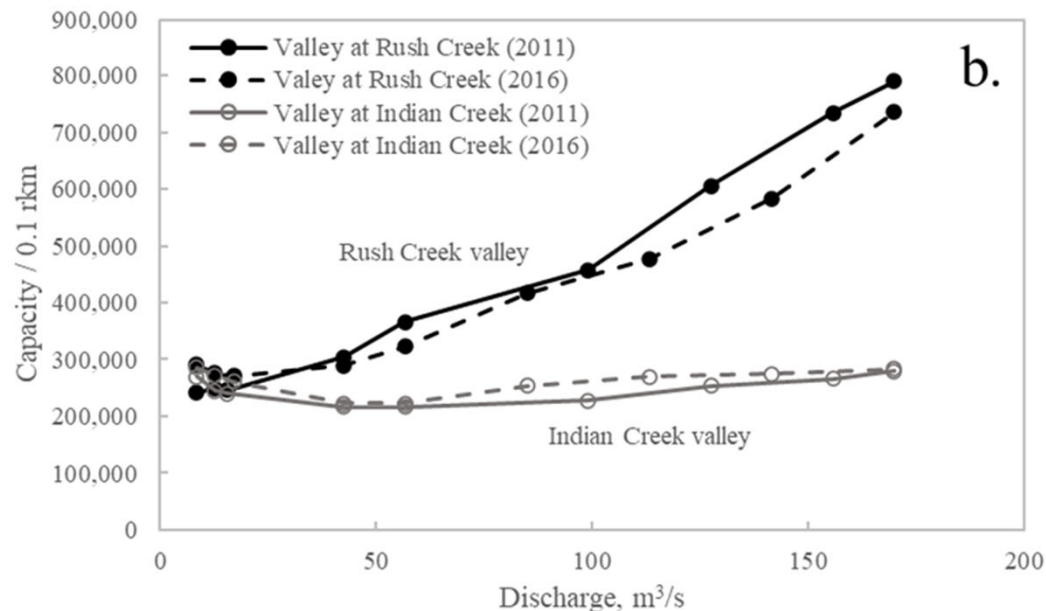
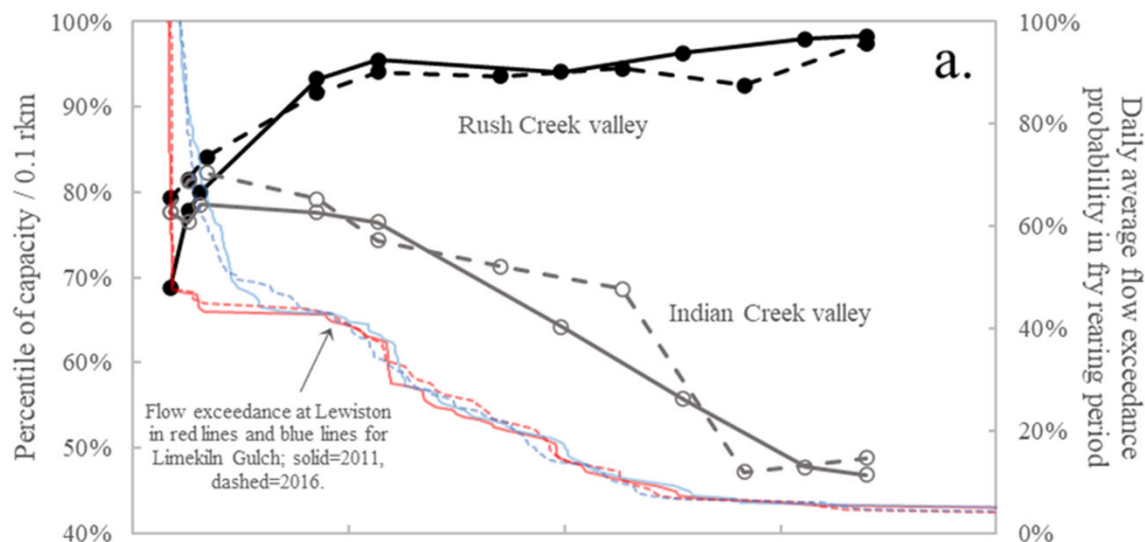
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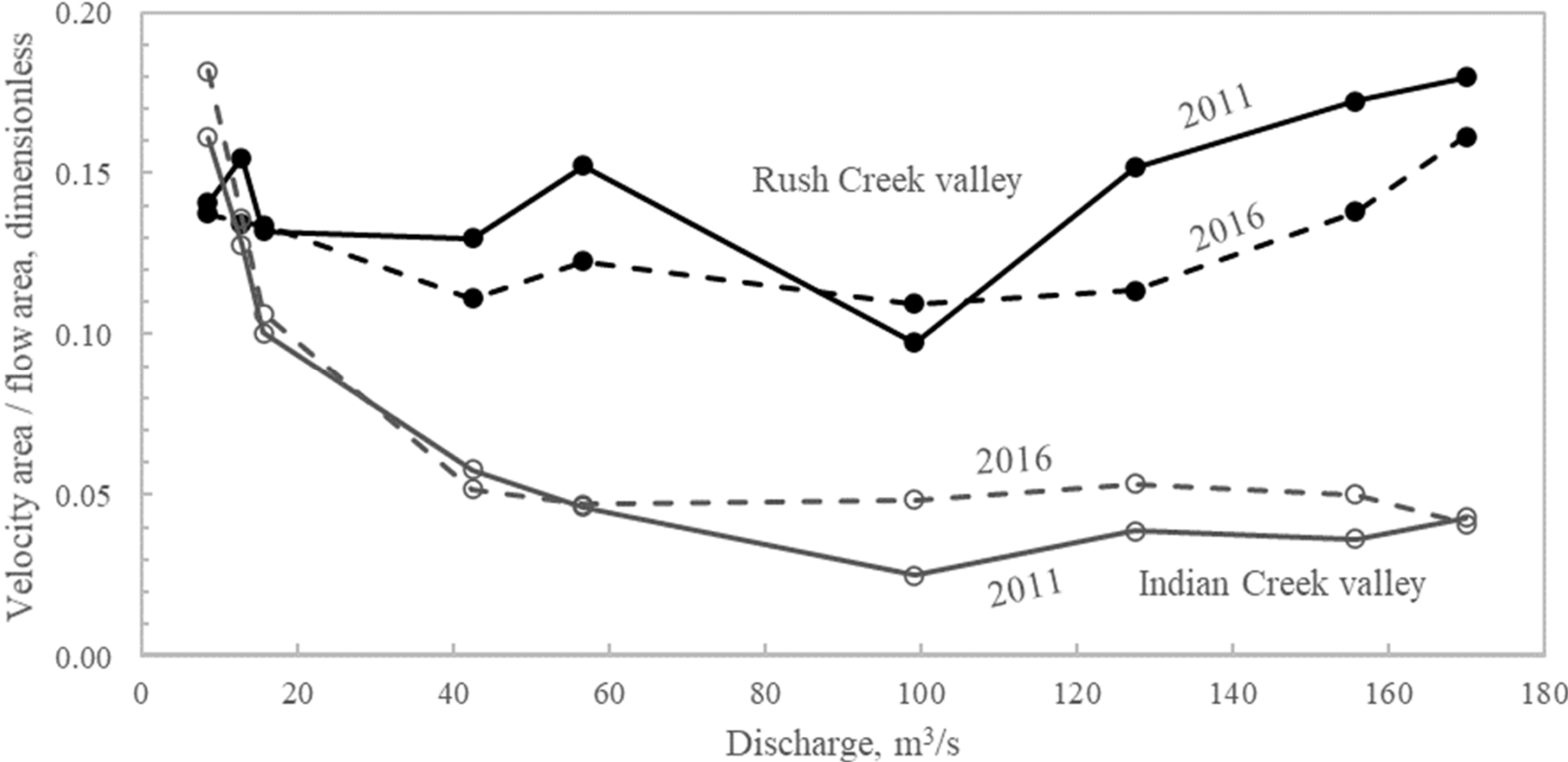
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Can. J. Fish. Aquat. Sci. 75: 1048–1058 (2018). doi:10.1139/cjfas-2017-0027

Published at www.nrcresearchpress.com/cjfas on 7 September 2017.



The primary cause of lower capacity at higher flows at Indian Creek is flow velocity increases with discharge faster than at Rush Creek.



# Conclusions

- The wide valley at Rush Creek exhibited larger impacts from damming than the narrow valley at Indian Creek yet recovered to a more functional state for juvenile Chinook as regulated flows and sediment supplies increased through the regulatory periods. This suggests that while unconfined reaches may be particularly susceptible to change when a river is dammed, they may also provide the greatest opportunity for restoration of salmon populations.
- Channel forcing by alluvial deposits appears had a larger influence on bank deformation than riparian plant composition. Absent a forcing element sized to the channel, bank retreat did not occur even where vegetation was absent.
- Removal of 4,500 m<sup>3</sup> of sediment from Rush Creek delta in 1979-1989 had no discernible effect on its size in this period. However, construction of a meandering mainstem channel at Rush Creek in 1989 may have reduced competence of the river and aided delta expansion in subsequent years. The delta continued to enlarge through 2020 and may be capturing bedload and suppressing local downstream bar development.
- A riparian plant removal and top-bank widening project at Indian Creek in 2007 to promote river channel widening had little influence on the active channel, bar, or delta areas. This may have resulted from channel restriction and higher slope in this relatively narrow valley.
- The Trinity River has evolved at Rush Creek to a state that generates significantly higher capacity for rearing Chinook fry than at Indian Creek and most the rest of the restoration reach. The function most responsible for this is active channel expansion from delta growth.
- Expansion of Rush Creek delta may not restrict bedload routing through the backwater pool upstream of the delta, as suggested by differencing the 2003 and 2016 bathymetric surveys of the pool, which showed little change in pool volume. The relatively low density of elevations surveyed in 2003 requires this problem be revisited after channel surveys are redone in 2022 (hopefully).