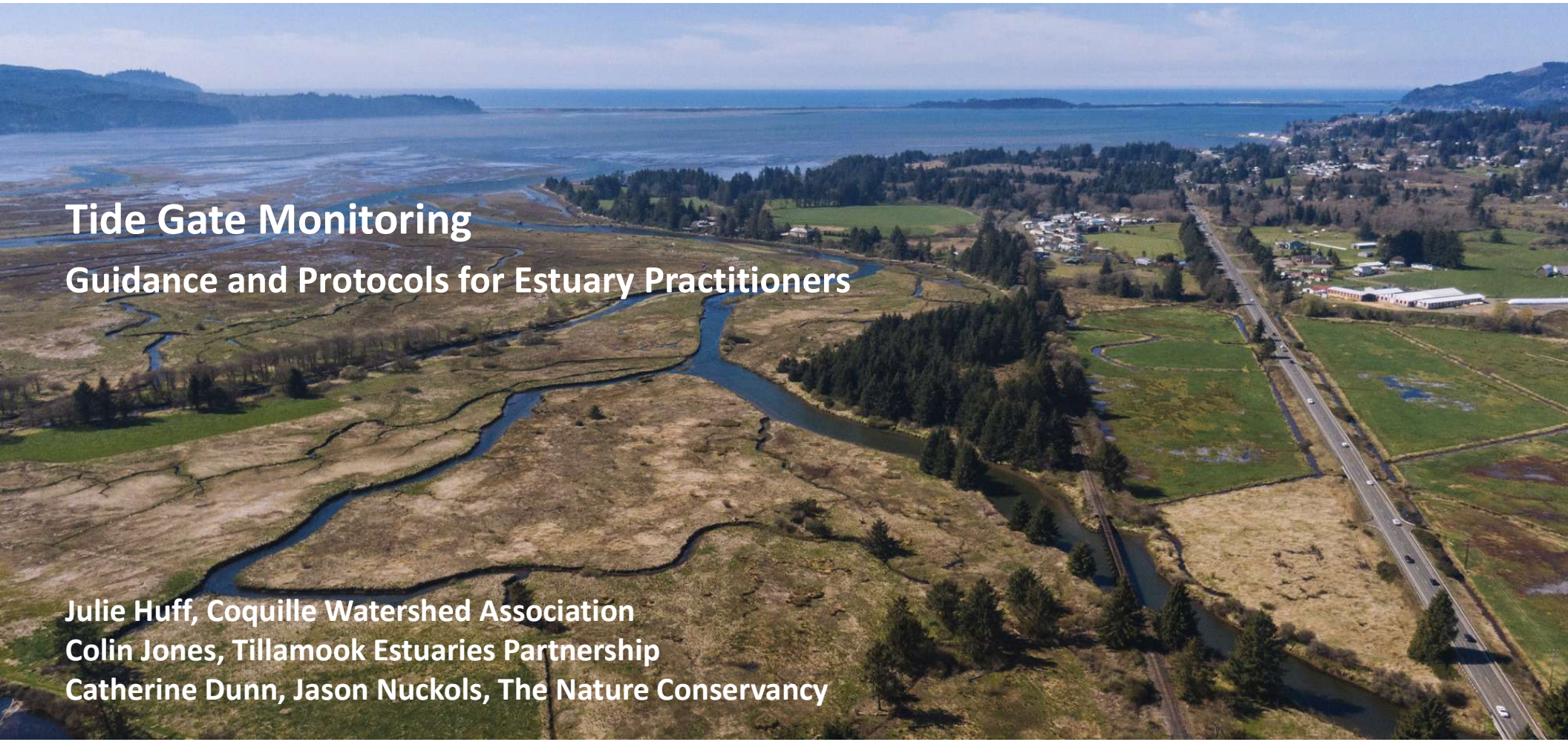

Tide Gate Monitoring

Guidance and Protocols for Estuary Practitioners

Julie Huff, Coquille Watershed Association
Colin Jones, Tillamook Estuaries Partnership
Catherine Dunn, Jason Nuckols, The Nature Conservancy

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Tide Gate & Tidal Wetland Monitoring

Guidance & Protocols for Estuary Practitioners

2024

Funded by the Oregon Watershed Enhancement Board (OWEB) in collaboration with the Coquille Watershed Association (CoqWA), The Nature Conservancy (TNC), and the Tillamook Estuaries Partnership (TEP).

Improved Estuary Science set the Groundwork

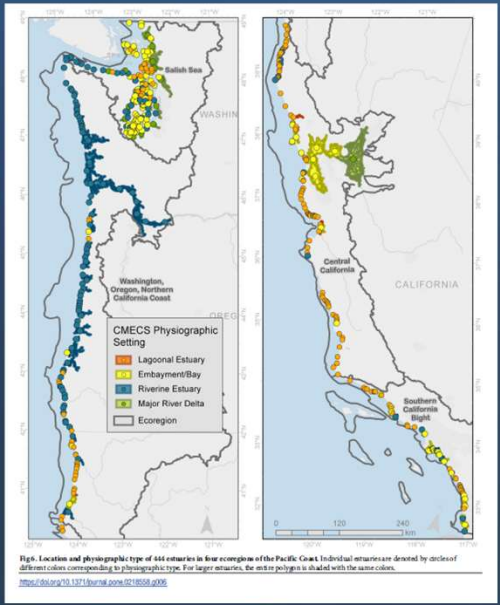
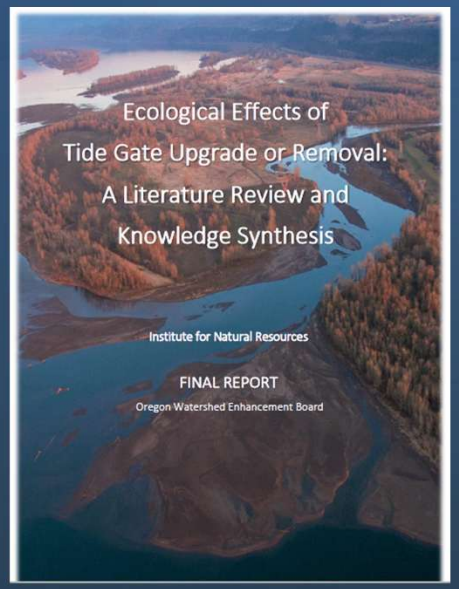
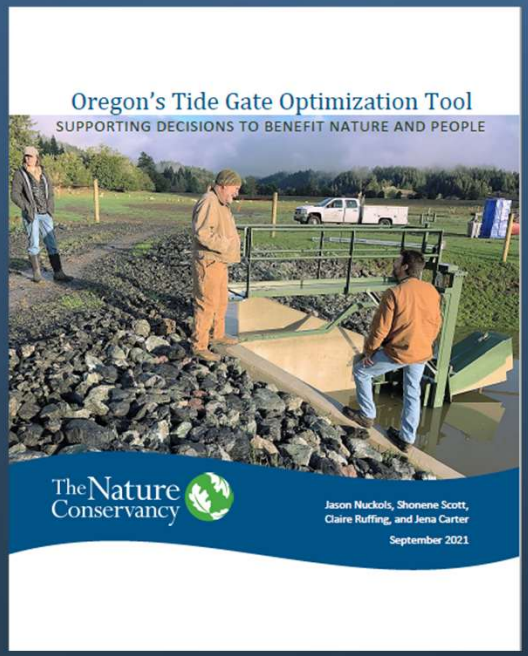


Fig 6. Location and physiographic type of 466 estuaries in four ecoregions of the Pacific Coast. Individual estuaries are denoted by circles of different colors corresponding to physiographic type. For larger estuaries, the entire polygon is shaded with the same colors.

https://doi.org/10.1371/journal.pone.0218558.g006





Estuaries and Coasts
https://doi.org/10.1007/s12237-023-01185-y

Estimating Juvenile Salmon Estuarine Carrying Capacities to Support Restoration Planning and Evaluation

Jason Hall[1] · Phil Roni[1] · Kai Ross[1] · Meghan J. Camp[1] · Jason Nuckols[2] · Claire Ruffing[2]

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Abstract
Estimating juvenile salmon habitat carrying capacities is a critical need for restoration planning. We assimilated more than 4500 unique estimates of published juvenile densities (e.g., fish/m^2) in estuarine and floodplain habitats. These density data were categorized by species and life stage, habitat type, seasonal period, and geographic region to develop frequency statistics (e.g., 25th and 75th percentiles, or quartiles). These frequency statistics were then used in a habitat expansion approach to estimate carrying capacities based on habitat extent. We demonstrate the habitat expansion approach by applying the quantiles of observed juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) densities (fish/ha) to spatial data describing current, historical or potential, and predicted (based on seal level rise) habitat extents for 16 coastal Oregon estuaries to estimate carrying capacities. Current carrying capacities based on 75th percentile springtime (Apr–Jun) densities ranged from 2902 to 33,817 fish/delta for Chinook salmon and 2507 to 20,206 fish/delta for coho salmon. Historic carrying capacities during the peak rearing period (spring) ranged from 3869 to 71,844 fish/delta for Chinook salmon and 3201 to 38,337 fish/delta for coho salmon, representing a 3 to 72% loss in Chinook salmon capacity and 2 to 67% loss in coho salmon capacity. Estimated carrying capacities were predicted to decline by 2 to 54% with 1.4 m of sea level rise in systems that are projected to lose vegetated tidal wetland habitat, while a 1 to 320% increase in capacity was predicted for systems that are predicted to increase in area with sea level rise. Finally, we demonstrate how the carrying capacity estimates can be used to estimate changes in juvenile Chinook and coho salmon capacity following restoration, which can be used to both design and evaluate restoration projects.

Keywords Estuary · Salmon · Restoration · Capacity · Chinook · Coho

Introduction

Estuaries and floodplains are critical habitats for many marine and freshwaters fishes. These habitats are particularly important to Pacific salmon (*Oncorhynchus* spp.) populations because they support juvenile life stages and ecosystem processes that are critical to complex salmon life cycles (Simenstad et al. 1982; Beamer et al. 2005; Hall et al. 2018a). Unfortunately, these low-gradient habitats are often the most impacted by human development and losses or degradation of these habitats has been linked to population declines of Pacific salmon throughout the Pacific Northwestern USA (Simenstad et al. 1982; Simenstad and Cordell 2000; Beamer et al. 2005; Bottom et al. 2005; Lotze et al. 2006; Beechie et al. 2013; Greene et al. 2015; Hall et al. 2018a). Construction of levees and dikes; filling, drainage, and conversion of land for agricultural, industrial, and urban uses; and simplification of channel networks have disrupted lateral connectivity with estuarine floodplains and reduced accessible habitat for salmon (Pess et al. 2005; Morley et al. 2012; Finn et al. 2021). Levees and dikes, as well as other flood control infrastructures, may also constrain estuaries in the face of potential sea level rise (SLR) with climate change (Brophy et al. 2019). Because of the extensive loss of estuarine and floodplain habitats, they have been the focus of many restoration efforts for salmon recovery (Roni et al. 2019).

Communicated by Mark S. Peterson.

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Tide Gate & Tidal Wetland Monitoring

Guidance & Protocols for Estuary Practitioners

2024

Funded by the Oregon Watershed Enhancement Board (OWEB) in collaboration with the Coquille Watershed Association (CoqWA), The Nature Conservancy (TNC), and the Tillamook Estuaries Partnership (TEP).

Tiered approach based on project scale

Project Scale	Recommended Monitoring		
	Tier 1 Implementation	Tier 2 Compliance	Tier 3 Effectiveness
Scale I: Simple and small non-SRT upgrades or replacements with no formal monitoring required, minimal fish and wildlife habitat, and no WMP	Recommended	Optional	Optional
Scale II: Tide gate upgrades or replacements with SRTs, fish and wildlife habitat, WMPs, etc.	Recommended	Recommended	Optional
Scale III: Large, complex tide gate upgrade or replacement projects with extensive habitat and/or projects with an associated MAMP	Recommended	Recommended	Recommended

- **Implementation monitoring**: was the project built as designed
- **Compliance monitoring**: is the project functioning as designed and meeting permit requirements
- **Effectiveness monitoring**: evaluates a projects performance and restoration efficacy

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Implementation Monitoring

- Recommended for all projects
- Standardizes record keeping
- Simple 2-page datasheet
- Provides a means to quickly cross-reference similar information between projects

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ODFW Natural Resources Information Management Program

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Tide Gate Implementation Monitoring Datasheet

Please complete this sheet within six months of project completion.

Site name:		Report date:	
Tide Gate Inventory ID #:			
Project manager/organization:			

Project Information

Project engineer firm and engineer name:			
Was the Pipe Sizing Tool* used for this project?			
Year of tide gate installation:			
Tide Gate Characteristics			
Style:	Model (if known):	# of gates:	
Implementation date of other project elements (riparian planting, channel formation, etc.):			
Is compliance and/or effectiveness monitoring being conducted?			

Site Characteristics

Primary watershed name:			
Watershed area (acres):			
Miles of channel habitat upstream of tide gate:			
Tide gate coordinates as latitude/longitude in decimal degrees: (example: 43.176514, -124.228959)			
Water surface elevation at MHHW** at tide gate outlet (NAVD88*** feet):			
Water surface elevation at MLLW**** at tide gate outlet (NAVD88 feet):			
Area of project inundation at MHHW (acres):			
Area of project inundation at MLLW (acres):			
Project area elevation (NAVD88 feet):	Mean:	Min:	Max:

Compliance Monitoring

- Ensure regulatory and legal requirements are met
- Provides an objective assessment of project progress and the degree to which projects goals are being met
- Fosters adaptive management through the early detection of potential issues, enabling prompt corrective actions to be taken

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Table 2 Compliance Monitoring Matrix. Note, color coding follows the Effectiveness Monitoring Matrix found below in **Table 3**.

Protocol ID[1]	Parameter	Monitoring Approach	Quantity	Frequency	Duration[2]	Performance Standard
1.2	Channel Water Level	Water level logger above and below tide gate	1 logger	15 min	Year 1/2	Maximum channel water level reached before tide gate door closes or tide gate operates in accordance with project's water management plan
1.3*	Gate Openness[3]	Water level logger above and below tide gate	2 loggers	15 min	Year 1/2	Tide gate is open 51% of time
1.4*		Direct gate location logger (gate angle)	Each tide gate	15 min	Year 1/2	
2.1*	Water Temperature	Temperature logger above tide gate	1 logger	15 min	Year 1/2	7-day average daily maximum temperature does not exceed 18 °C
4.6*	Velocity[4]	Float Measurement	1 location	2/yr	Year 1/2	Velocity does not exceed 2 ft/s
4.7*		Flowmeter	1 location	2/yr	Year 1/2	
5.2	Before/after photos	Photo monitoring	Inlet/outlet	1	Year B/1	Identify unforeseen tide gate infrastructure deterioration

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Effectiveness Monitoring

- Helps to answer monitoring questions for any scale project
- More likely used for larger scale or more complex projects
- Assists in developing Monitoring and Adaptive Management Plans
- Fosters adaptive management

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Goals	Monitoring Question Categories	Example Monitoring Questions	Protocol ID	Parameters	Monitoring Approach	Quantity	Frequency	Duration	Quantity	Frequency	Duration	Advanced Monitoring
Restore Hydrological Function	***Groundwater Connectivity***	*Is groundwater retained on site during summer?*	*[1.1]*	Shallow Groundwater Level & Duration	Water level logger in shallow well(s)	1 logger	15 min	Year 2	1+ logger	15 min	Year B/2/3/4/+	Paired well study, Offsite well monitoring
		Has groundwater salinity increased after restoration?	*[1.1]*	Salinity	Conductivity logger	-	-	-	1+ Wells	15 min	Year B/2/3/4/+	
	Tidal Connectivity	*Is the minimum water level behind the tide gate meeting the WMP?*	*1.2*	Water Level	Water level logger above and below tide gate	2 logger	15 min	Year 2	2+ loggers	15 min	Year B/2/+	
		How much of the tide cycle does the habitat experience during each phase of the WMP?	*1.3*	Gate Openness (Indirect)	Water level logger above and below tide gate	2 logger	15 min	Year 2	2 logger	15 min	Year 2/3/4/+	
		Is the tide gate open at least 51% of the time when species of interest are present?	*1.4*	Gate Openness (Direct)	Gate angle logger	-	-	-	Each TG	15 min	Year 2/3/4/+	Direct area of inundation measurements with temp loggers, Aerial mapping with drones
		Does the tide gate create a saline barrier for fish passage?	*[2.2]*	Salinity	Conductivity logger	-	-	-	2+ locations	15 min	Year B/2/3/+	
		How much land is inundated during mean water of each phase of the WMP?	*[1.5]*	Area of Inundation	GIS mapping through water level	-	-	-	1	Annually	Year B/2/3/+	
		How many stream miles are accessible during winter flows?	*[1.5]*	Floodplain Connectivity	GIS mapping through water level	-	-	-	1	Annually	Year B/2/3/+	
Improve Water Quality	***Water Quality***	*Does the tide gate create a thermal barrier for fish passage?*	*2.1*	Water Temperature	Continuous temperature logger	2 loggers	15 min	Year B/1/2	2+ loggers	15 min	Year B/1/2/3/+	
		How far above the tide gate does saline water (>0.5 psu) penetrate during rearing periods?		Salinity	Handheld conductivity meter	2+ locations	1/yr	Year B/1/2	-	-	-	TSS, DO, pH, bacteria, nutrients
		What are the maximum salinity levels observed in the project site compared to reference?	*2.3*	Salinity	Continuous conductivity logger	-	-	-	1+ logger	15 min	Year B/1/2/3/+	
Restore Wetland Vegetation	***Wetland Vegetation Development***	*Is plant community structure trending towards reference conditions?*	*3.1*	Vegetation Development	Photo Points	6+ points	annually	B/1/2/3	6+ points	1x/yr	B/1/2/3+	
		Is the overall cover of native species dominated plant communities increasing?	*3.2*	Vegetation Development	Mapping via aerial photo analysis	-	-	-	entire area	1x/yr	B/2/4/+	
		Is native woody plant density at least 300 trees & shrubs per acre?	*[3.3]*	Woody Plant Density	Stratified random sampling - Stem count	-	-	-		1x/yr	B/1/5/10/+	NPP, Aerial Monitoring (Drone)
		Does native plant cover exceed 50% within 5 years of restoration?	*[3.3]*	Herbaceous Plant Community Composition	Stratified random sampling - Species cover	-	-	-	25+plots/100m baseline	1x/yr	B/1/3/5/+	
		Is there a 60% or higher survival rate for native plantings?	*[3.3]*	Revegetation Success	Stratified random sampling - Survivorship	-	-	-	10 plots/ha	1x/yr	1/2/3/+	
	Invasive Species	*Are invasive species recolonizing this site?*	*3.4*	invasive species extent	Photo Points	1+/infestation	annually	B/1/2/3+	1+/infestation	annually	B/1/2/3+	-
		Are invasive species dominated plant communities decreasing in treatment areas?	*3.5*	Area of Infestation & Treatments	GIS mapping	-	annually	B/1/2/3+	-	annually	B/1/2/3+	
Improve Native Fish Populations	***Fish Presence/Absence***	*Are juvenile salmonids using the project site during rearing periods?*	*4.1*	Presence/Absence	Snorkel	1+ location(s)	1x + /yr	Year B/2	-	-	-	Density
		Are juvenile salmonids using the project site during rearing periods?	*4.2*	Presence/Absence	Seine netting	1+ location(s)	1x + /yr	Year B/2	1+ locations	3x + /yr	Year B/2/3/+	
	Fish Abundance	*Has the number of juvenile salmonids using the site increased?*	*4.3*	Catch Per Unit Effort	Seine netting	-	-	-	1+ locations	3x + /yr	Year B/2/3/+	Density
		What fish species (native/non native) are using the site?	*4.4*	Community Composition	Seine netting	-	-	-	1+ locations	3x + /yr	Year B/2/3/+	
	Fish Growth	*Are salmonids growing faster on site than a similar ODFW life cycle monitoing site?*	*[4.5]*	Fork Length	Seine netting	-	-	-	1+ locations	3x + /yr	Year B/2/3/+	Genetics
		What is fish growth after restoration?	*[4.5]*	Weight	Seine netting	-	-	-	1+ locations	3x + /yr	Year B/2/3/+	
	Fish Passage	*What range of water velocities do fish prefer during passage?*	*4.6/4.7*	Velocity	¥	-	-	-	-	-	-	Continuous velocity; PIT arrays; video arrays
	Fish Habitat	*Have the number and distribution of complex channel features increased over time?*	*4.8*	Channel Morphology	Side Channel Morphology	-	-	-	1+ locations	1/yr	B/2/5/+	Channel Morphology via main channel profile
		How have mussle populations responded to tide gate upgrades?	*4.9*	Presence/Absence	Freshwater Mussel Survey	1+ location(s)	1/yr	Year B/2	2+ locations	1/yr	Year B/2/3/5	Macroinvertebrates
Suppot Climate Mitigation	***Carbon Sequestration***	*tbd*	-	Soil Carbon Content	±	-	-	-	-	-	-	
		tbd	-	Above Ground Biomass	±	-	-	-	-	-	-	
	Sediment Processes	*Is the site gaining or losing elevation for the purpose of maintaining estuary habitat types?*	*5.1*	Accretion Rate	Sediment Accretion Plots	-	-	-	5+ plots	1/yr	B/5/+	geomorphology?; soil compaction;

4.5 Fish Growth

Fork Length & Wet Weight

Many tide gates are replaced to improve fish passage and increase access to habitat behind the gate. Juvenile salmonids grow at a faster rate in these off-channel wetland habitats. Measuring fork length and wetted weight of juvenile salmonids is a key metric to illustrate increased body condition of fish in these restored and accessible habitats.

Materials

- Waterproof gram scale
- Measuring board
- 5-gal buckets (2-4)
- Battery operated bubblers (2-4)
- Hand bait net
- Anesthetic (MS-222)
- Datasheet

Field Summary

- Sample fish captured by seining (Protocol 4.2) or other means
- Anesthetize fish before handling
- Allow fish to fully recover in a freshwater recovery bucket before release

Miscellaneous

- A measuring board can be purchased or made with 4"PVC pipe, a cloth measuring tape and fiberglass resin
- An ODFW permit is needed for handling non-ESA listed fish
- A NOAA permit is needed for handling ESA listed fish

Design

Field Tips:

State and federal permits are required to anesthetize and handle juvenile salmonids.

Wet weight and fork length of juvenile salmonids are essential biometrics of their growth and health.

Fish should be captured and measured upstream of the tide gate from a minimum of one location during baseline data collection. Refer to the seine netting protocol (4.2) in this handbook for fish capture methods. Since most tide gates are operated modestly immediately after installation to allow the land to recover, monitoring should start when the tide gate is operating according to a water management plan, typically after a year has passed, therefore, monitoring of fish biometrics post-restoration should start in year 2. For year-to-year comparison, sample at similar timing throughout the season so sampled fish are of similar age.

If funding and capacity allow for expanded monitoring design, consider seining and measuring fish at multiple locations behind the tide gate and one location in front of the tide gate.

Permitting: To capture, handle and anesthetize fish in the state of Oregon a scientific take permit is required, furthermore, if the expected fish are ESA listed a 4(d) permit is needed through NOAA.

Methods

Procedure: Keep all captured fish in holding tanks of freshwater (5 gallon bucket or similar) equipped with a battery powered bubbler to ensure adequate dissolved oxygen. Set up the scale on a flat surface, use a small wetted plastic tray with the scale. Tare the scale to account for tray weight. Set up the measuring board on the ground, table or on top of a 5 gallon bucket and place a small amount of water on the measuring board so the fish stay wet. When setup is complete, mix 5 mL of a 60 mg/L MS-222 solution into 2.5 gallons of water in a 5 gallon bucket outfitted with a bubbler. When all personnel are ready, place 10 fish in the anesthetizing bucket. Once the first anesthetized fish has stopped swimming remove it from the bucket with a hand net. Place the fish onto the scale, record the weight to the nearest 0.1 g. Move the fish to the measuring board and measure from the tip of the snout to the fork in the tail (the V-shaped indentation where the caudal fin splits into two lobes). Record the length in millimeters. Move the fish to the freshwater recovery bucket. Repeat with all remaining fish in the anesthetic bucket, and continue processing all of the fish in batches of 10. Fish are ready to release back to the capture location once they are active and the anesthetic has worn off, roughly 20 minutes.

Field Tips:

To improve fish recovery, intermittently swirl the water of the recovery bucket to get freshwater passing through the gills of the recovering fish.

Data Analysis: To compare multiple years of data use various statistical tests and techniques. For example, a one-way ANOVA (Analysis of Variance) test is a simple approach to determine if fork length or weight are significantly different from year to year. Organize the data by year and sampling period (so similar aged fish are compared). Run a one-way ANOVA test in excel or R for each sampling period. The ANOVA test produces an F-Statistic and a p-value. If the p-value is less than 0.05 this indicates there are statistically significant differences in the weight and lengths from year to year.

References

Feldhaus, J.W., & Wilson, W.H.. 2021. ODFW Hatchery Monitoring and Evaluation: Juvenile fork length and weight. Monitoring Methods http://www.monitoringmethods.org/Method/Details/458

PTSC (PIT Tag Steering Committee). PIT tag marking procedures manual, version 3.0. 2014.

Field Tips:

Windy conditions make scale readings inaccurate. Temporary wind breaks can be created out of sampling gear or the scale can be placed in an extra bucket lying down on it's side.

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Summary

- Establish consistent and comparable monitoring methods
- Promote distribution of knowledge across geographies
- Standardize monitoring practices and protocols
- Products can be used in any tide gate project, regardless of scale, location, or funding
- Results inform future project design and ongoing adaptive management

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- Team: Julie Huff and Chris Gabrielli (Coquille Watershed Association) Colin Jones (Tillamook Estuaries Partnership), Catherine Dunn and Jason Nuckols (The Nature Conservancy)

- We would like to thank the Columbia River Estuary Study Taskforce (CREST), The Confederated Tribes of Siletz Indians and the many practitioners, funders, regulatory agencies and landowners who provided valuable feedback and guidance through developing this document. This project was inspired by Giannico, et al. 2018, who recognized the need for a standardized set of tide gate monitoring protocols.

- Financial Support: OWEB , TNC and private donors

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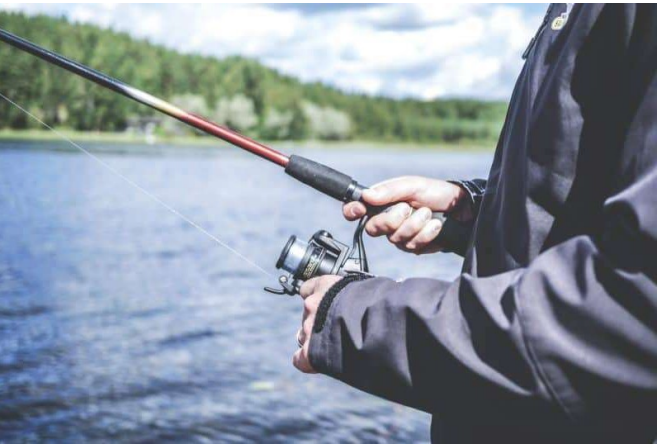

Thank you

Jason Nuckols, jnuckols@tnc.org

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A two-year project to standardize tide gate monitoring practices along the Oregon Coast. The result will be a monitoring document that has buy-in from practitioners, funders and regulators. We are partnering with TNC, Tillamook Estuaries Partnership and Columbia River Estuary Study Taskforce.

a. A Southern Coast tour was held on February 11th in Coos Bay and we handed out the remaining TGMP Handbooks to a group of 20 practitioners from 6 different agencies/organizations.

b. The grant ended December 31st and the final report was submitted in February.

a. A Northern and Central Oregon Coastal tour to meet with practitioners, agency and funders happened in early November. We gave out over 60 TGMP handbooks and they were well received.

b. A data repository was set up with the ODFW Natural Resources Information Management Program (NRIMP) for the implementation monitoring datasheet. I will be the contact person for the data clearinghouse record.

c. The handbook has been uploaded to OWEB's website.

d. The handbook was presented at the joint WA-BC-Idaho AFS Annual Meeting by project Partner Jason Nuckols (TNC)

e. The Handbook was presented at the OR Chapter American Fisheries Society Annual Meeting in late February and was well received.

f. Next Steps: Continue with outreach throughout the PNW

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