SUPPLEMENTAL MATERIALS

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Accounting for Uncertainty in Regional Flow-Ecology Relationships

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Supplemental Materials

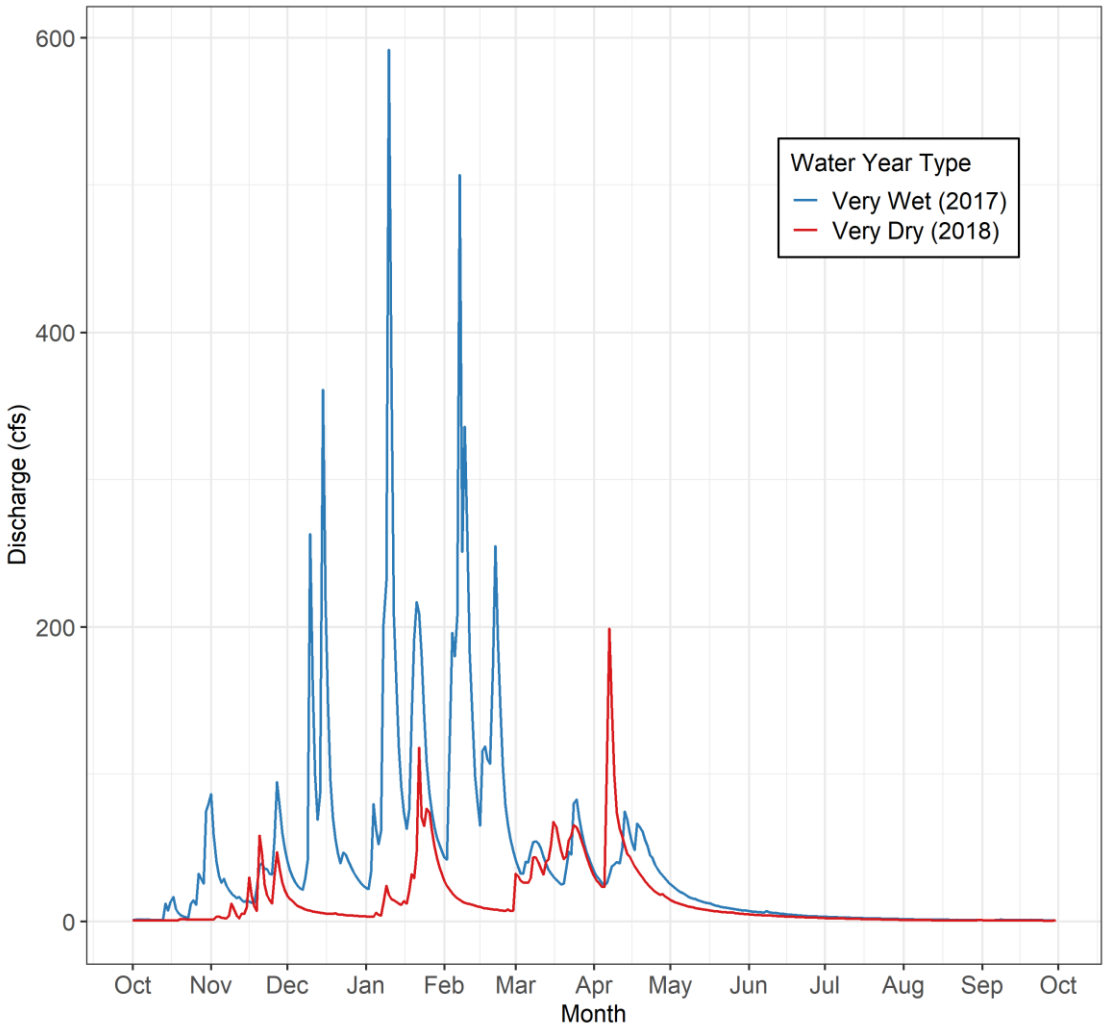

Figure S1. Mean daily flow (cfs) for Elder Creek (USGS 11475560) for a Very Wet and Very Dry Water Year Type

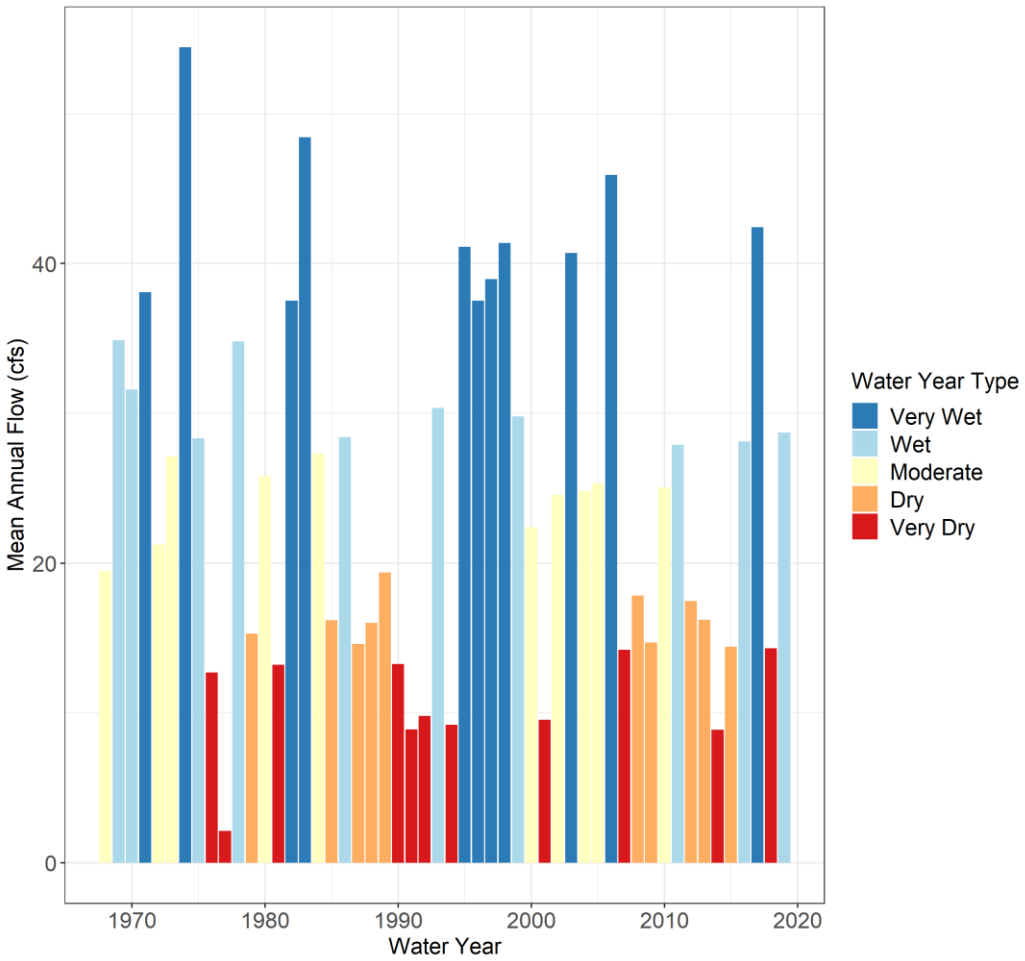

Figure S2. Mean annual flow (cfs) of water year types for Elder Creek (USGS 11475560)

LITERATURE REVIEW PROTOCOL AND CODE DEFINITIONS

Articles will be read in alphabetical order according to author last name. Refer to Table A1 as you are filling out the excel file for a complete list of attribute definitions.

1. **Fill in metadata attributes**
   1.1. Enter the *title, year, journal,* and *full citation* for the article.
   1.2. Enter the *Reference* as FirstAuthorLastNameEtAlYear or LastNameYear. Create a folder in documents>SF Eel>Eco_lit_review>GIS_files with the same reference label.
   1.3. Assign a *Study_ID*. This will remain consistent for each entry of the study.
   1.4. Assign a *Unique_ID* (e.g., 1, 2, 3) for different entries. Multiple entries may be required for an individual study if:
   - There are multiple relationships for a single location (e.g., a relationship between temperature-FYLF and temperature-Steelhead at a single location)
   - There are different relationships for different locations (e.g., a different relationship between temperature-breeding on the mainstem SFER and Elder Creek). **Note:** If a single relationship is developed from data at multiple locations (e.g., throughout the watershed), use a single entry.
   - There are different relationships for different years (e.g., a different relationship between temperature-breeding for 2008 versus 2010)

2. **Read/ skim the article**
   2.1. Skim the document to get a sense of spatial and temporal attributes, including study location, date range of data used in the study, and whether these attributes vary over the results presented in the study.
   2.2. Get a sense of the type of relationship(s) and variables described in the study: Are multiple entries needed?

3. **Update metadata attributes and categorical relationship attributes**
   3.1. Add however many *unique_ID*s are required for the study (e.g., if you found 3 unique relationships, there should be 3 unique_IDs).
   3.2. For each Unique_ID, update the following categorical attributes in excel and code in atlas. These should be the same (for example species in excel is algae, species in atlas is algae). Apply atlas codes to the titles of each document. More than one codes from individual code groups may be applied. A new set of codes should be applied for each Unique_ID, even if codes are similar.
   - Category of relationship: *Relationship_category*, *Relationship*
   - Species considered in study: *Species*, *Species*
   - Flow component considered in study: *Flow_regime*, *flow*
   - Physical condition considered in study: *Physical_condition*, *physical condition*
   - Lifestage considered in study: *Lifestage_interaction*, *Lifestage/interaction*

4. **Fill in temporal attributes for each unique_ID**
   4.1. Fill in the *start and end dates* of data collected for each relationship (month/day/year)
   4.2. Fill in the *start and end months* (numeric) of data collected for each relationship (month, e.g., 9 for September)

4.3. Enter the nearest, and most predominant (e.g., likely represents the majority of data), *USGS stream gage used in the study*.

5. Fill in the spatial attributes for each unique_ID

5.1. Denote the *Stream_reach* by listing the names of creeks, streams, and rivers used in the study (separated by commas).

5.2. After determining the study locations in ArcPro, go to the "Location" sheet and enter the COMID from the stream reaches where data collection occurred (under *GIS COMID* column) and the associated channel type (under *Channel Type* column). There should be a new line entry for each segment. Enter the Unique_ID and Study_ID (same as Attributes sheet) for all segment entries.

6. Denote the findings and methods of each relationship

6.1. Enter specific details about the study that are not disclosed in the spatial, temporal, or categorical attributes. These include:

- *Variables:* Specific variables within the above categories (e.g., if categorical attributes are peak flow and species, individual variables may be bankfull flow, cladophora, caddisfly)
- *Method description:* Provide a brief description of methods for each unique_ID

6.2. Provide a short *description of the findings*, including numeric values of importance. Only include the most important and easy to understand finding (e.g., can be easily understood and used by managers).

6.3. For each relationship, note whether it's *qualitative or quantitative* and provide the *units* of variables in the relationship. Note any *thresholds* derived from the relationship or referenced in the study (e.g., high flow > 500 cfs)

7. Update metadata

7.1. Make sure all metadata (e.g., title, citation, reference, etc.) are filled in for each unique_ID entry.

Table S1. Attribute descriptions for SFER literature review

Attribute	Description
Unique_ID	A unique number to denote different entries in excel. Each line in the excel database needs a unique_ID (e.g., multiple unique_IDs are needed if a study has multiple relationships).
Study_ID	A unique number to denote different studies in excel. Each study in the excel database needs a unique study_ID. A single study may have multiple unique_IDs, but will only have one study_ID.
GIS COMID	A unique GIS specifier to distinguish stream segments in ArcGIS pro
Channel Type	The channel type of stream segments where data collection occurred (found through the channel type shapefile).
Reference	Use a consistent in-text citation format as a reference shorthand: Multiple authors: FirstAuthorLastNameEtAlDate (e.g., SuttleEtAl2011), Single author: LastNameDate (e.g., Power2003)
Start_date	Start date of data used in study. Enter in the format: mo-d-yr.
End_date	End date of data used in study. Enter in the format: mo-d-yr.
Month_start	Use to denote seasonality if data collection occurs across multiple years. Enter month in shorthand: Jan, Feb, Mar, etc,
Month_end	Use to denote seasonality if data collection occurs across multiple years. Enter month in shorthand: Jan, Feb, Mar, etc,
Nearest_USGS	Enter the name (e.g., Elder) of the nearest USGS gage where data collection occurred
Stream_Reach	Enter the name(s) of the river or stream where data collection occurred.
Relationship_category	Categorize the relationship as: Flow – species, Flow – physical condition, Physical condition – physical condition, species – species, Physical condition – species, or Species-physical condition. **Code in Atlas.**
Flow_Regime	Categorize the flow regime according to "flow" codes in Atlas. **Code in Atlas.** Make a new code if needed.
Species	Categorize the species according to "species" codes in Atlas. **Code in Atlas.** Make a new code if needed.
Lifestage_interaction	Categorize lifestage according to "lifestage,interaction" codes in Atlas. Entries should be separated by a comma (e.g., juvenile, rearing). **Code in Atlas.** Make a new code if needed.
Physical_condition	Categorize the physical condition according to "physical condition" code in Atlas. **Code in Atlas.** Make a new code if needed.
Method_Description	Brief description of methods used (e.g., took water samples at 5 transects on Elder Creek, measured algae concentrations at 3 point locations, analyzed with ANOVA)
Variables	Provide additional specifics of flow regime, species, and physical condition categories (e.g., bankfull flow, cladophora)
Relationship_description	Brief summary (few sentences) of the relationship, including numeric descriptors.
Quant_Qual	Categorize as "Qualitative" or "Quantitative"
Type_of_Relationship	Brief overview of relationship (e.g., probabilistic outcome from field data)
Units	Provide the units used to measure variables (e.g., cfs, cm)

Threshold/States	Provide thresholds and associated values if provided within study (e.g., high temperature > 24C)
Uncertainty	Rate as 1, 2, 3, or 4 (low to high)
Title	Full title of the study
Journal	Title of Journal where article is published
Year	Year published
Citation	Full citation (APA)
Notes	Miscellaneous notes

Atlas Code Definitions

Table S2. Definition for categorical attribute codes applied in Atlas

Code Group	Code	Definition
Flow	Dry-season baseflow	Relationship related to summer baseflow (e.g., summer low flow, dry-season baseflow) or any reference to flow during the months of June–October. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Flow	Duration	Flow specifier related to the duration (e.g., 4 weeks, 4 months) of individual flow events or seasonal functional flows within a flow relationship. Must be used with a flow code (e.g., dry-season baseflow).
Flow	Frequency	Flow specifier related to the frequency (e.g., every 5 years, at least once a year) of individual flow events or seasonal functional flows within a flow relationship. Must be used with a flow code (e.g., dry-season baseflow).
Flow	Magnitude	Flow specifier related to the magnitude (e.g., 50 cfs) of individual flow events or seasonal functional flows within a flow relationship. Must be used with a flow code (e.g., dry-season baseflow).
Flow	Peak flow	Relationship related to peak flows (e.g., high winter flows, winter storms, bankfull) or any reference to flow during the months of Nov–March. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Flow	Rate of change	Flow specifier related to the rate of change (e.g., 200 cfs over 5 days) of individual flow events or seasonal functional flows within a flow relationship. Must be used with a flow code (e.g., dry-season baseflow).

Flow	Spring recession	Relationship related to spring recession flows (e.g., spring spates, receding flows, spring flows) or any reference to flow during the months of April–June. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Flow	Timing	Flow specifier related to the timing (e.g., early January–Feb) of individual flow events or seasonal functional flows within a flow relationship. Must be used with a flow code (e.g., dry-season baseflow).
Flow	Wet-season initiation	Relationship related to wet-season initiation flows (e.g., fall flush, first high flows) or any reference to flow during the months of Nov–Dec. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Flow	Winter-baseflow	Relationship related to winter baseflows or any reference to non-storm flows during Dec–Mar. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Flow	WYT	Relationship related to the water year type of the entire flow regime. This code must be used with a flow relationship code (flow – physical condition, flow – species). If possible, use this code with a flow specifier (timing, magnitude, duration, rate of change, frequency).
Identity	Keep	Use as a sorting code to designate article for the SFER flow-ecology literature review
Identity	Reject	Use for articles that are not relevant for the SFER flow-ecology literature review. Non-relevant articles include those that do not relate to instream processes including aquatic species, physical conditions, or flow. Articles may also be rejected if they do not collect any original data within the SFER watershed (but reference studies that do) or reference processes beyond the basic understanding of flow-ecology relationships (e.g., carbon flow in food webs).
Identity	uncertain	To be used for articles that may be relevant for the literature review, but the coder is uncertain.
Life stage/ interaction	Adult	To be used as an adult life stage specifier for aquatic species. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with an interaction specifier (e.g., Breeding, predation).

Life stage/ interaction	Breeding	To be used as an interaction specifier for breeding or reproduction of aquatic species. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with a life stage specifier (e.g., adult, juvenile).
Life stage/ interaction	Feeding	To be used as an interaction specifier for feeding interactions between aquatic species. Use with any mention of dietary preferences, feeding patterns, or general food web ecology. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with a life stage specifier (e.g., adult, juvenile).
Life stage/ interaction	Invasive predation	To be used as an interaction specifier for predation between non-native and native aquatic species. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with a life stage specifier (e.g., adult, juvenile).
Life stage/ interaction	Juvenile	To be used as a juvenile life stage specifier for aquatic species. Applies to any reference of juvenile aquatic species, such as a tadpole, fry, etc. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with an interaction specifier (e.g., Breeding, predation).
Life stage/ interaction	Migration	To be used as an interaction specifier for migrating aquatic species. Always use with a species code (e.g., steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with a life stage specifier (e.g., adult, juvenile).
Life stage/ interaction	Rearing	To be used as an interaction specifier for rearing aquatic species. Always use with a species code (e.g., Steelhead) and a species relationship code (species – species, flow – species, physical condition – species). If possible, use with a life stage specifier (e.g., adult, juvenile).
Life stage/ interaction	Seed	To be used as a seed life stage specifier for aquatic or riparian vegetation. Always use with a species code (e.g., vegetation) and a species relationship code (species – species, flow – species, physical condition – species).
Life stage/ interaction	Seedling	To be used as a seedling life stage specifier for aquatic or riparian vegetation (e.g., young plant). Always use with a species code (e.g., vegetation) and a species relationship code (species – species, flow – species, physical condition – species).

Physical Condition	Depth	Relationship related to the depth of water in a stream or river. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Dimensionless	Relationship related to dimensionless parameters of physical conditions (e.g., scaling relationships). This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	General habitat	Relationship related to more than 3 physical habitat conditions, such as velocity, depth, light, etc. Use this code when physical habitat assessments are performed for a species and include multiple physical conditions. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Geomorphic	Relationship related to geomorphic features that are specific to a certain channel type (e.g., channel slope, contributing area). This code may also be used in reference to relationships that vary by location. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Light	Relationship related to the amount of light entering a stream or river, or in reference to the amount of shade. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Nutrients	Relationship related to instream nutrients (e.g., nitrogen, phosphorus). This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Sediment	Relationship related to instream sediment (e.g., fine sediment, boulders, sediment transport). This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Shear stress	Relationship related to shear stress experienced in streams and rivers. This code can be applied to any mention of erosion or scour. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).

Physical Condition	Temperature	Relationship related to air or water temperature. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	velocity	Relationship related to the velocity of water in streams or rivers. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Physical Condition	Width	Relationship related to the cross-sectional width in a stream or river. This code must always be used whenever a physical condition relationship code is used (e.g., physical condition – species, physical condition – physical condition, flow – physical condition).
Relationship	Flow – physical condition	A relationship specifier that denotes relationships of the flow regime (e.g., summer base flow, peak flow) and physical conditions (e.g., temperature, sediment). This code should always be accompanied by flow and physical conditions specifier codes.
Relationship	Flow – species	A relationship specifier that denotes relationships of the flow regime (e.g., summer base flow, peak flow) and aquatic species (e.g., steelhead, FYLF). This code should always be accompanied by flow and species specifier codes, and life stage/interaction codes if possible.
Relationship	Physical condition – physical condition	A relationship specifier that denotes relationships of physical conditions (e.g., water temperature) and other physical conditions (e.g., nutrients). This code should always be accompanied by physical condition codes.
Relationship	Physical condition – species	A relationship specifier that denotes relationships of a physical condition (e.g., water temperature) and an aquatic species (e.g., steelhead). This code should always be accompanied by physical condition and species codes, and a life stage/interaction code if possible.
Relationship	Species-physical condition	A relationship specifier that denotes a species – physical condition relationships (e.g., plant photosynthesis impacting DO). This code should always be accompanied by species (e.g., steelhead) and physical condition codes.
Relationship	Species – species	A relationship specifier that denotes species – species relationships. This code should always be accompanied by species (e.g., steelhead) and life stage/interaction codes.
Species	Algae	Relationship related to aquatic algae (e.g., Cladophora, macroalgae, epiphytes, etc.). This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.

Species	Aquatic macroinvertebrate	Relationship related to aquatic macroinvertebrates (e.g., caddisflies, midges, mayflies, etc.). This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Aquatic snail	Relationship related to an aquatic snail. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Bull Frog	Relationship related to the invasive bullfrog. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Chinook	Relationship related to Chinook salmon. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Coho	Relationship related to Coho salmon. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Cyanobacteria	Relationship related to the production of toxic cyanobacteria from aquatic algae. Always use with the Algae code. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	FYLF	Relationship related to the Foothill Yellow Legged Frog. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Lamprey	Relationship related to the Pacific Lamprey. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Mussel	Relationship related to aquatic mussels. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.

Species	Native misc. fish	Relationship related to miscellaneous native fish (i.e., Roach). This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Pacific tree frog	Relationship related to the Pacific Tree Frog. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Pikeminnow	Relationship related to the non-native Sacramento pikeminnow. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Salamander	Relationship related to native aquatic salamanders. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Sculpin	Relationship related to sculpin. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Steelhead	Relationship related to steelhead trout. This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Terrestrial Macro	Relationship related to terrestrial macroinvertebrates (e.g., grasshoppers). This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.
Species	Vegetation	Relationship related to aquatic or riparian vegetation (e.g., Sedge, willows, Alder). This code must always be used whenever a species relationship code is used (e.g., physical condition – species, species – species, flow – species). If possible, use a life stage/interaction specifier code.

BAYESIAN NETWORK MODEL NODE STATES AND CONDITIONAL PROBABILITIES

Node States

Table S3. Bayesian network model node states

Variable	States	Metric	Source
Peak flow	Low	< bankfull Q	Taken direct from Power et al. (2008) [Unique_ID 68]
	High	≥ bankfull Q	
Algae bloom	Large	length ≥ 50 cm	Taken direct from Power et al. (2008) [Unique_ID 68]
	Small	length < 50 cm	
Fine sediment	Low	≤ 40% embeddedness	States (low, high) and ranges (%) subjectively denoted by author using empirical values in Suttle et al. (2004) as a reference [Unique_ID 75]
	High	41-100% embeddedness	
Fish growth	Low	≤ .14 mm/d	States (low, high) and ranges (mm/d) subjectively denoted by author using empirical values in Suttle et al. (2004) as a reference. [Unique_ID 75]
	High	≥0.15 mm/d	
Dry-season baseflow	Low	≤ 7Q10 flow	Common low flow statistic used by USGS. Annual 7-day minimum flow with a recurrence interval of 10 years
	High	> 7Q10 flow	
Temperature (ADM)	Low	<23 C	Taken direct from Schaaf et al (2017) [Unique_ID 71], who noted that 23C is a threshold for blackspot infection
	High	≥23 C	
Diseased individuals (proportion)	Low	<50%	Taken direct from Schaaf et al (2017) [Unique_ID 71], who noted reported infection in terms of "50%" infected
	High	≥50%	
Longitudinal connectivity	Low	≥ 50% pools isolated	Authors' judgement
	High	< 50% pools isolated	
Food supply	High	Vulnerable insect abundance > armored insect abundance	Conceptually based on Power et al (2008) [Unique_ID 70] and Marks et al (2000) [Unique_ID 55]
	Low	Vulnerable insect abundance < armored insect abundance	
Juvenile Steelhead condition	Good	Non-negative population growth rate	Authors' judgement
	Poor	Negative population growth rate	

Hydrologic Nodes

Table S4. Conditional probability table for the Peak Flow node, Moderate hydrologic conditions

Peak Flow		Source	Justification
Low	High	Hydrologic statistics	For any given year, the probability of reaching bankfull based on a recurrence interval of 1.5 years is 1/1.5 yrs., or 0.67 (round to 0.7). The probability of not reaching bankfull is 1- 0.7, or 0.3
0.3	0.7		

Table S5. Conditional probability table for the Dry-season Baseflow node, Moderate hydrologic conditions

Dry-season Baseflow		Source	Justification
Low	High	Hydrologic statistics	For any given year, the probability of reaching the 7-day, 2-year low flow volume is equal to 1/2 yrs., or 0.5
0.5	0.5		

Table S6. Conditional probability table for the Peak Flow node, Wet - Dry hydrologic conditions

Peak Flow		Source	Justification
Low	High	Authors' judgement	Wet-Dry conditions occur when a wet winter (peak flow ≥ bankfull flow) is followed by a dry summer (≤ 7-day, 2-year low flow volume)
0.05	0.95		

Table S7. Conditional probability table for the Dry-season Baseflow node, Wet - Dry hydrologic conditions

Dry-season Baseflow		Source	Justification
Low	High	Authors' judgement	Wet-Dry conditions occur when a wet winter (peak flow ≥ bankfull flow) is followed by a dry summer (≤ 7-day, 2-year low flow volume)
0.95	0.05		

Table S8. Conditional probability table for the Peak Flow node, Dry hydrologic conditions

Peak Flow		Source	Justification
Low	High	Authors' judgement	Dry conditions occur when a dry winter (peak flow < bankfull flow) is followed by a dry summer (≤7-day, 2-year low flow volume)
0.95	0.05		

Table S9. Conditional probability table for the Dry-season Baseflow node, Dry hydrologic conditions

Dry-season Baseflow		Source	Justification
Low	High	Authors' judgement	Dry conditions occur when a dry winter (peak flow < bankfull flow) is followed by a dry summer (≤7-day, 2-year low flow volume)
0.95	0.05		

Table S10. Conditional probability table for the Peak Flow node, Wet hydrologic conditions

Peak Flow		Source	Justification
Low	High	Authors' judgement	Wet conditions occur when a wet winter (peak flow ≥ bankfull flow) is followed by a wet summer (>7-day, 2-year low flow volume)
0.05	0.95		

Table S11. Conditional probability table for the Dry-season Baseflow node, Wet hydrologic conditions

Dry-season Baseflow		Source	Justification
Low	High	Authors' judgement	Wet conditions occur when a wet winter (peak flow ≥ bankfull flow) is followed by a wet summer (>7-day, 2-year low flow volume)
0.05	0.95		

Base Conditional Probability Tables

Base Middle Nodes

Table S12. Conditional probability table (base) for the Algae Bloom node

Peak flow	**Algae Bloom**		Source	Justification
	Large	Small		
Low	0.17	0.83	Power et al. (2008)	Conditional probabilities taken directly from a probabilistic relationship in Power et al. (2008)
High	0.75	0.25		

Table S13. Conditional probability table (base) for the Fine Sediment node

Peak flow	**Fine Sediment**		Source	Justification
	Low	High		
Low	0.4	0.6	Authors' judgement	Flows exceeding bankfull move the majority of sediment in streams
High	0.7	0.3		

Table S14. Conditional probability table (base) for the Temperature node

Dry-season baseflow	**Temperature (ADM)**		Source	Justification
	Low	High		
Low	0.3	0.7	Authors' judgement	In an open and sunlight channel like the mainstem SFER, the relationship with dry-season baseflow and temperature is likely strong
High	0.7	0.3		

Table S15. Conditional probability table (base) for the Longitudinal Connectivity node

Dry-season baseflow	**Longitudinal Connectivity**		Source	Justification
	Low	High		
Low	0.65	0.35	Authors' judgement	In the SFER, pools are known to isolate in dry years when summer baseflow is low
High	0.3	0.7		

Table S16. Conditional probability table (base) for the Diseased Individuals node

Temp. (ADM)	**Diseased Individuals (proportion)**		Source	Justification
	Low	High		
Low	0.7	0.3	Schaaf et al., (2017)	Conditional probabilities estimated from a relationship in Schaaf et al (2017), who stated that at temperatures > 23C, 50% of fish would be infected.
High	0.2	0.8		

Table S17. Conditional probability table (base) for the Fish Growth node

Fine Sediment	**Fish Growth**		Source	Justification
	Low	High		
Low	0.2	0.8	Suttle et al. (2004)	Conditional probabilities estimated using a negative linear relationship between fine sediment embeddedness and fish growth.
High	0.8	0.2		

Table S18. Conditional probability table (base) for the Food Supply node

Algae Bloom	**Food Supply**		Source	Justification
	High	Low		
Large	0.6	0.4	Power et al. (2008) and Marks et al. (2000)	Conditional probabilities estimated from observational data, which state that the trophic levels are higher in flood years as more algal energy is directed towards vulnerable taxa (e.g., mayflies, macroinvertebrate predators) instead of armored grazers.
Small	0.4	0.6		

Base End Node

Table S19. Conditional probability table (base) for the Juvenile Steelhead Condition node

Food supply	Fish growth	Long. connectivity	Diseased individuals	**Juvenile Steelhead Condition**		Source	Justification
				Good	Poor		
High	Low	Low	Low	0.5	0.5	Authors' judgement	4/4 desirable is 0.5 good, 3/4 desirable is 0.7 good, 2/4 desirable is 0.5 good, 1/4 desirable is 0.2 good, 0/4 desirable is 0.15 good. Desirable conditions include "high" food supply, "high" fish growth, "high" longitudinal connectivity, and "low" diseased individuals
High	Low	Low	High	0.2	0.8		
High	Low	High	Low	0.7	0.3		
High	Low	High	High	0.5	0.5		
High	High	Low	Low	0.7	0.3		
High	High	Low	High	0.5	0.5		
High	High	High	Low	0.8	0.2		
High	High	High	High	0.7	0.3		
Low	Low	Low	Low	0.2	0.8		
Low	Low	Low	High	0.15	0.85		
Low	Low	High	Low	0.5	0.5		
Low	Low	High	High	0.2	0.8		
Low	High	Low	Low	0.5	0.5		
Low	High	Low	High	0.2	0.8		
Low	High	High	Low	0.7	0.3		
Low	High	High	High	0.5	0.5		

Scenario A Conditional Probabilities

Conditional probability tables for Middle and End nodes and their associated conditional probability ranges for Scenario A. The probability range denotes the lower and upper limits for random probability generation (30 samples with replacement) and the shading denotes the probability being manipulated.

Middle Nodes

Table S20. Conditional probability ranges (Scenario A) for the Fine Sediment node

Peak flow	**Fine Sediment**		Probability Range	
	Low	High	Lower	Upper
Low	0.4	0.6	0.55	0.75
High	0.7	0.3	0.65	0.8

Table S21. Conditional probability ranges (Scenario A) for the Temperature node

Dry-season baseflow	**Temperature (ADM)**		Probability Range	
	Low	High	Lower	Upper
Low	0.3	0.7	0.65	0.85
High	0.7	0.3	0.6	0.8

Table S22. Conditional probability ranges (Scenario A) for the Longitudinal Connectivity node

Dry-season baseflow	**Longitudinal Connectivity**		Probability Range	
	Low	High	Lower	Upper
Low	0.65	0.35	0.6	0.8
High	0.3	0.7	0.6	0.75

Table S23. Conditional probability ranges (Scenario A) for the Diseased Individuals node

Temperature (ADM)	**Diseased Individuals (proportion)**		Probability Range	
	Low	High	Lower	Upper
Low	0.7	0.3	0.7	0.85
High	0.2	0.8	0.7	0.85

Table S24. Conditional probability ranges (Scenario A) for the Fish Growth node

Fine Sediment	**Fish Growth**		Probability Range	
	Low	High	Lower	Upper
Low	0.2	0.8	0.65	0.8
High	0.8	0.2	0.7	0.85

Table S25. Conditional probability ranges (Scenario A) for the Food Supply node

Algae Bloom	**Food Supply**		Probability Range	
	High	Low	Lower	Upper
Large	0.6	0.4	0.6	0.8
Small	0.4	0.6	0.55	0.75

End Node

Table S26. Conditional probability ranges (Scenario A) for the Juvenile Steelhead Condition node

Food supply	Fish growth	Long. connectivity	Diseased individuals	**Juvenile Steelhead Condition**		Probability Range	
				Good	Poor	Lower	Upper
High	Low	Low	Low	0.5	0.5	0.4	0.65
High	Low	Low	High	0.2	0.8	0.15	0.3
High	Low	High	Low	0.7	0.3	0.6	0.8
High	Low	High	High	0.5	0.5	0.4	0.65
High	High	Low	Low	0.7	0.3	0.65	0.8
High	High	Low	High	0.5	0.5	0.4	0.65
High	High	High	Low	0.8	0.2	0.7	0.85
High	High	High	High	0.7	0.3	0.65	0.8
Low	Low	Low	Low	0.2	0.8	0.15	0.3
Low	Low	Low	High	0.15	0.85	0.1	0.2
Low	Low	High	Low	0.5	0.5	0.4	0.65
Low	Low	High	High	0.2	0.8	0.15	0.3
Low	High	Low	Low	0.5	0.5	0.4	0.65
Low	High	Low	High	0.2	0.8	0.15	0.3
Low	High	High	Low	0.7	0.3	0.65	0.8
Low	High	High	High	0.5	0.5	0.4	0.65

Scenario A run in R.

Table S27. Conditional probability combinations for Hydrologic, Middle, and End nodes in Scenario A. Runs 1-30 used Moderate conditional probabilities for Hydrologic Nodes, Base probabilities for Middle nodes with Level 2 uncertainty, and sets of randomly generated probabilities (A1, A2, etc.) for the remaining nodes. Middle and End node combinations from Runs 1-30 were repeated three times and evaluated under Wet-Dry (Runs 31-60), Dry (Runs 61-90), and Wet (Runs 91-120) hydrologic conditions.

Run #	Hydrologic Nodes	Middle Nodes		End Node
		Level 2 uncertainty	Level 3 uncertainty	
1	Moderate	Base	A1	A1
2	Moderate	Base	A2	A2
3	Moderate	Base	A3	A3
…	…	…	…	
29	Moderate	Base	A29	A29
30	Moderate	Base	A30	A30
31	Wet-Dry	Base	A1	A1
32	Wet-Dry	Base	A2	A2
33	Wet-Dry	Base	A3	A3
…	…	…	…	
59	Wet-Dry	Base	A29	A29
60	Wet-Dry	Base	A30	A30
61	Dry	Base	A1	A1
62	Dry	Base	A2	A2
63	Dry	Base	A3	A3
…	…	…	…	…
89	Dry	Base	A29	A29
90	Dry	Base	A30	A30
91	Wet	Base	A1	A1
92	Wet	Base	A2	A2
93	Wet	Base	A3	A3
…	…	…	…	…
119	Wet	Base	A29	A29
120	Wet	Base	A30	A30

Scenario B Conditional Probabilities

Middle Nodes: Increased Certainty

Table S28. Conditional probability table (Scenario B, Middle) for the Fine Sediment node

Peak flow	**Fine Sediment**	
	Low	High
Low	0.05	0.95
High	0.95	0.05

Table S29. Conditional probability table (Scenario B, Middle) for the Temperature node

Dry-season baseflow	**Temperature (ADM)**	
	Low	High
Low	0.05	0.95
High	0.95	0.05

Table S30. Conditional probability table (Scenario B, Middle) for the Longitudinal Connectivity node

Dry-season baseflow	**Longitudinal Connectivity**	
	Low	High
Low	0.95	0.05
High	0.05	0.95

Table S31. Conditional probability table (Scenario B, Middle) for the Diseased Individuals node

Temperature (ADM)	**Diseased Individuals (proportion)**	
	Low	High
Low	0.95	0.05
High	0.05	0.95

Table S32. Conditional probability table (Scenario B, Middle) for the Fish Growth node

Fine Sediment	**Fish Growth**	
	Low	High
Low	0.05	0.95
High	0.95	0.05

Table S33. Conditional probability table (Scenario B, Middle) for the Food Supply node

Algae Bloom	**Food Supply**	
	High	Low
Large	0.95	0.05
Small	0.05	0.95

End Node

Table S34. Conditional probability table (Scenario B, E1) for the Juvenile Steelhead Condition node under assumptions that longitudinal connectivity is the limiting factor

Food supply	Fish growth	Long. connectivity	Diseased individuals	**Juvenile Steelhead Condition**		Source	Justification
				Good	Poor		
High	Low	Low	Low	0.20	0.80	Authors' judgement	If longitudinal connectivity is "desirable" (i.e., high), there is a 70% likelihood of "good" juvenile steelhead conditions, even if other variables are undesirable. If long. connectivity is desirable (high) and 2 or more other variables are desirable, the likelihood of "good" juvenile steelhead condition increases to 80%. If long. connectivity is low (even if other variables are desirable), the likelihood of "good" steelhead condition is 20%.
High	Low	Low	High	0.20	0.80		
High	Low	High	Low	0.80	0.20		
High	Low	High	High	0.70	0.30		
High	High	Low	Low	0.20	0.80		
High	High	Low	High	0.20	0.80		
High	High	High	Low	0.80	0.20		
High	High	High	High	0.80	0.20		
Low	Low	Low	Low	0.20	0.80		
Low	Low	Low	High	0.20	0.80		
Low	Low	High	Low	0.70	0.30		
Low	Low	High	High	0.70	0.30		
Low	High	Low	Low	0.20	0.80		
Low	High	Low	High	0.20	0.80		
Low	High	High	Low	0.80	0.20		
Low	High	High	High	0.70	0.30		

Table S35. Conditional probability table (Scenario B, E2) for the Juvenile Steelhead Condition node under assumptions that food supply and fish growth are the limiting factors

Food supply	Fish growth	Long. connectivity	Diseased individuals	**Juvenile Steelhead Condition**		Source	Justification
				Good	Poor		
High	Low	Low	Low	0.70	0.30	Authors' judgement	If both fish growth and food supply are desirable (i.e., high), the likelihood of "good" steelhead condition is 80%. If only one out of the two (fish growth or food supply) are desirable and one or more other condition are desirable, the likelihood of "good" steelhead condition is 70%. If only one of fish growth or food supply are desirable, and no other conditions are desirable, the likelihood of a good steelhead outcome is 60%. If food supply and fish growth are undesirable (even if other variables are desirable), the likelihood of "good" steelhead condition is 30%.
High	Low	Low	High	0.60	0.40		
High	Low	High	Low	0.70	0.30		
High	Low	High	High	0.70	0.30		
High	High	Low	Low	0.80	0.20		
High	High	Low	High	0.80	0.20		
High	High	High	Low	0.80	0.20		
High	High	High	High	0.80	0.20		
Low	Low	Low	Low	0.30	0.70		
Low	Low	Low	High	0.30	0.70		
Low	Low	High	Low	0.30	0.70		
Low	Low	High	High	0.30	0.70		
Low	High	Low	Low	0.70	0.30		
Low	High	Low	High	0.60	0.40		
Low	High	High	Low	0.70	0.30		
Low	High	High	High	0.70	0.30		

Table S36. Conditional probability table (Scenario B, E3) for the Juvenile Steelhead Condition node under assumptions that Disease is the limiting factor

Food supply	Fish growth	Long. connectivity	Diseased individuals	**Juvenile Steelhead Condition**		Source	Justification
				Good	Poor		
High	Low	Low	Low	0.70	0.30	Authors' judgement	If disease is desirable (i.e., low), there is a 70% likelihood of "good" juvenile steelhead conditions, even if other variables are undesirable. If disease is desirable (low) and 2 or more variables are desirable, the likelihood of "good" steelhead condition increases to 80%. If disease is undesirable (high), the likelihood of "good" steelhead condition is 30% (even if other variables are desirable).
High	Low	Low	High	0.30	0.70		
High	Low	High	Low	0.80	0.20		
High	Low	High	High	0.30	0.70		
High	High	Low	Low	0.80	0.20		
High	High	Low	High	0.30	0.70		
High	High	High	Low	0.80	0.20		
High	High	High	High	0.30	0.70		
Low	Low	Low	Low	0.70	0.30		
Low	Low	Low	High	0.30	0.70		
Low	Low	High	Low	0.70	0.30		
Low	Low	High	High	0.30	0.70		
Low	High	Low	Low	0.70	0.30		
Low	High	Low	High	0.30	0.70		
Low	High	High	Low	0.80	0.20		
Low	High	High	High	0.30	0.70		

Scenario B runs in R

Table S37. Scenario B probability combinations

Run #	Hydrologic Nodes	Middle Nodes		End Node
		Level 2 uncertainty	Level 3 uncertainty	
1	Moderate	Base	Base	Base
2	Wet-Dry	Base	Base	Base
3	Dry	Base	Base	Base
4	Wet	Base	Base	Base
5	Moderate	Base	Increased certainty	Base
6	Wet-Dry	Base	Increased certainty	Base
7	Dry	Base	Increased certainty	Base
8	Wet	Base	Increased certainty	Base
9	Moderate	Base	Base	E1
10	Wet-Dry	Base	Base	E1
11	Dry	Base	Base	E1
12	Wet	Base	Base	E1
13	Moderate	Base	Base	E2
14	Wet-Dry	Base	Base	E2
15	Dry	Base	Base	E2
16	Wet	Base	Base	E2
17	Moderate	Base	Base	E3
18	Wet-Dry	Base	Base	E3
19	Dry	Base	Base	E3
20	Wet	Base	Base	E3
21	Moderate	Base	Increased certainty	E1
22	Wet-Dry	Base	Increased certainty	E1
23	Dry	Base	Increased certainty	E1
24	Wet	Base	Increased certainty	E1
25	Moderate	Base	Increased certainty	E2
26	Wet-Dry	Base	Increased certainty	E2
27	Dry	Base	Increased certainty	E2
28	Wet	Base	Increased certainty	E2
29	Moderate	Base	Increased certainty	E3
30	Wet-Dry	Base	Increased certainty	E3
31	Dry	Base	Increased certainty	E3
32	Wet	Base	Increased certainty	E3