# Stressor: Stream Temperature (°C)

# Species: Steelhead

# Life Stage/Season: Summer Rearing (All Freshwater Life Stages)

## Citation

## *Beechie, T. J., C. Nicol, C. Fogel, J. Jorgensen, J. Thompson, G. Seixas, J. Chamberlin, J. Hall, B. Timpane-Padgham, P. Kiffney, S. Kubo, and J. Keaton. 2021. Modeling Effects of Habitat Change and Restoration Alternatives on Salmon in the Chehalis River Basin Using a Salmonid Life-Cycle Model. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC-CR-2021-01.*

## Stressor-Response Relationship

### Rationale

Steelhead have unique thermal tolerance profiles and performance windows for summer stream temperatures during the rearing period. Physiological stress is experienced when temperatures exceed upper limits. This SR function defines a generalized upper limit for the summer stream temperature profile for Steelhead. The function was previously used in Beechie et al. (2021) in the Chehalis River in Oregon as a productivity (survivorship) multiplier for Age-1+ stage classes. Stressor magnitude values are provided as the 7-day average daily maximum (7-DADM) stream temperature.

### Function

#### For Steelhead, Beechie et al. (2021) use an experimentally derived relationship between juvenile Rainbow Trout survival and stream temperature (Bear et al. 2007). Bear et al., (2007) exposed juvenile Rainbow Trout (110- 150 mm in length) to temperatures ranging from 8°C to 30°C in two-degree increments, and recorded mortality for each trial.

#### **Type:**

Empirical (Real data).

#### **Original Function:**

Where T is the 7-day average daily maximum stream temperature (in °C) from temperature models, and p is a productivity multiplier from 0-1. The productivity multiplier is used to adjust survivorship from baseline values (*e.g., if the baseline survivorship was 0.2 and the temperature effect is 0.7 then the resulting survivorship is 0.2\*0.7 = 0.14*).

## Known Covariates or Stressor Interactions

### Covariate(s)

Covariates embedded within stream temperature model (e.g., drainage area, channel slope, basin characteristics). Equivalent stream temperature models in British Columbia include estimates of MWAT from methods provided in Moore et al (2013).

## Considerations

See rubric in Appendix A for explanations of the data classifiers below.

Data Source: The function is applied to annual transitions (survivorship estimates) of all freshwater age classes (Age-1+, excluding fry). The original study derived empirical relationships between younger age classes; however, application to older age classes is theoretical. Data are based on a functional relationship with Rainbow Trout.

Data Type: Combination of Empirical Data & Theory/Mechanistic Model

Data Quality: Unknown

Confidence in SR function: Strength, direction and relative magnitude are well known, but less certain about absolute values. The SR function is based on a small amount of data from a single empirical study. Pacific Salmon and Steelhead are known to have a high degree of plasticity in the relationships between stream temperature across different systems. Local periodicity (timing) of critical rearing periods, watershed attributes, and the general availability of cold-water refuge may have large implications on the magnitude of local effects.

### Notes and User Recommendations

Local periodicity (timing) of critical rearing periods, watershed attributes, and the general availability of cold-water refuge may have large implications on the magnitude of local effects.

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## Stressor-Response Curve

**Figure 1:** Stressor-response relationship between 7-day average daily maximum stream temperature (°C) and the derived summer rearing productivity multiplier (0-1), interpreted as system capacity in the model. Data are from Beechie et al. (2021).

## Stressor-Response Table

**Table 1:** Discrete stressor-response relationship between raw stressor values and the mean system capacity (0-100%; scaled version of the productivity multiplier). The standard deviation of the mean system capacity is defined by the user and represents the inherent stochasticity or noise in the relationship. The set lower limit and upper limit of the mean system capacity are also presented. Mean system capacity (0-100%) is a standardized measure of wild adult recruits produced by the previous spawner cohort. Data are from Beechie et al. (2021).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Temperature** | **Mean System Capacity (%)** | **SD** | **Lower Limit** | **Upper Limit** |
| 8 | 100 | 0 | 0 | 100 |
| 10 | 100 | 0 | 0 | 100 |
| 12 | 100 | 0 | 0 | 100 |
| 14 | 99.99999989 | 0 | 0 | 100 |
| 16 | 99.99999392 | 0 | 0 | 100 |
| 18 | 99.99967684 | 0 | 0 | 100 |
| 20 | 99.98281573 | 0 | 0 | 100 |
| 22 | 99.09435509 | 0 | 0 | 100 |
| 24 | 67.51747599 | 0 | 0 | 100 |
| 26 | 5.690103118 | 0 | 0 | 100 |
| 28 | 2.189617868 | 0 | 0 | 100 |
| 30 | 2.121309894 | 0 | 0 | 100 |
| 32 | 2.120024629 | 0 | 0 | 100 |

## Additional References

Bear, E. A., McMahon T. T., & Zale A. V. 2007. Comparative thermal requirements for westslope cutthroat trout and rainbow trout: Implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society, 136(4), 1113-1121. doi: 10.1577/T06-072.1.

Moore, R. D., Nelitz, M., & Parkinson, E. 2013. Empirical modelling of maximum weekly average stream temperature in British Columbia, Canada, to support assessment of fish habitat suitability. Canadian Water Resources Journal, 38(2), 135-147.