

StreamThermal:

A Software Package for Calculating Thermal Metrics from Stream Temperature Data

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Improving quality and better availability of continuous stream temperature data allow natural resource managers, particularly in fisheries, to understand associations between different characteristics of stream thermal regimes and stream fishes. However, there is no convenient tool to efficiently characterize multiple metrics reflecting stream thermal regimes with the increasing amount of data from continuously recording data loggers. This article describes a software program packaged as a library in R to facilitate this process. With this freely available package, users will be able to quickly summarize metrics that describe five categories of stream thermal regimes: magnitude, variability, frequency, timing, and rate of change. The installation and usage instruction of this package, the definition of calculated thermal metrics, as well as the output format from the package are described, along with an application showing the utility for multiple metrics. We believe that this package can be widely utilized by interested stakeholders and can greatly assist future fisheries studies.

StreamThermal: un software para calcular medidas térmicas a partir de datos de temperatura en ríos

Mejorar la calidad y disponibilidad de datos continuos de temperatura en los ríos permite a manejadores de recursos naturales, particularmente en pesquerías, entender la relación entre diferentes características de regímenes térmicos en los ríos y los peces que los habitan. No obstante, no existe una herramienta conveniente para caracterizar de forma eficiente diferente métricas que reflejen regímenes térmicos fluviales mediante la creciente cantidad de datos provenientes de dispositivos de registro continuo. En este artículo se describe un software programado en lenguaje R con el fin de facilitar dicho proceso. Con este software de acceso gratuito, los usuarios serán capaces de resumir rápidamente las métricas que describen cinco categorías de regímenes térmicos en ríos: magnitud, variabilidad, frecuencia, sincronización y tasa de cambio. Se describe la instalación e instrucciones de uso, la definición de las métricas utilizadas y el formato de salida de los archivos del programa; así mismo se ofrece una aplicación que muestra la utilidad de diferentes métricas. Creemos que este paquete puede ser ampliamente utilizado por usuarios interesados y puede ser de ayuda en un futuro para estudios de pesquerías.

StreamThermal: un progiciel de calcul des valeurs thermiques à partir des données de température des cours d'eau

L'amélioration de la qualité et une meilleure disponibilité des données en continu de la température des cours d'eau permet aux gestionnaires de ressources naturelles, en particulier dans les pêcheries, de comprendre les associations entre les différentes caractéristiques des régimes thermiques des cours d'eau et les poissons de ruisseaux. Cependant, il n'existe pas d'outil pratique pour caractériser efficacement plusieurs paramètres reflétant les régimes thermiques des cours d'eau avec une quantité croissante de données provenant d'enregistreurs de données en continu. Cet article décrit un logiciel conditionné en package sous R pour faciliter ce processus. Avec ce package, disponible gratuitement, les utilisateurs seront en mesure de résumer rapidement les paramètres décrivant cinq catégories de régimes thermiques des cours d'eau : l'amplitude, la variabilité, la fréquence, le temps, et le taux de changement. Les instructions d'installation et d'utilisation de ce package, la définition des paramètres thermiques calculés, ainsi que le format de sortie du package sont décrits, et une application montre l'utilité de plusieurs paramètres. Nous croyons que ce package peut être largement utilisé par les parties intéressées et peut grandement aider les futures études sur les pêches.

MULTIPLE CHARACTERISTICS OF STREAM THERMAL REGIMES MATTER TO STREAM FISHES

A stream's thermal regime includes characteristics of water temperatures summarized over time periods of interest. Characteristics can include those used to define streamflow regimes like magnitude, timing, frequency, duration, and rate of change (e.g., Poff et al. 1997), and they may include variability in magnitudes and predictability of thermal patterns over time (e.g., Arismendi et al. 2013). Though many studies have shown how stream fishes respond to water temperatures characterized by magnitude, recent studies reveal how timing of and fluctuations in thermal events may also affect fishes (e.g., Wehrly et al. 2003; Mora and Maya 2006). Together, these ideas underscore the need for better understanding of relationships between stream fishes and multiple characteristics of stream thermal regimes.

SUMMARIZING MULTIPLE CHARACTERISTICS OF THERMAL REGIMES: A CHALLENGE

Though use of thermometers recording maximum and minimum temperatures over time periods of interest (days, months, seasons) offers insights into extreme conditions, expanding use of continuously recording data loggers offers additional information for characterizing multiple properties of thermal regimes. Currently, natural resource management

agencies and researchers throughout the United States incorporate the collection of water temperature data with continuously recording loggers as part of stream assessment efforts, with individual record collection occurring in short time intervals (i.e., every second, every 15 minutes, hourly). This practice yields massive amounts of data for characterizing different aspects of thermal regimes. Paired with the growing understanding of influences of multiple characteristics of thermal regimes on fishes, such data can be used to explore relationships between stream fishes and many temperature metrics. However, managing these large data sets for a given site and synthesizing information from multiple sites requires a substantial time commitment to generate comparable metrics.

STREAMTHERMAL

To aid in efforts to more fully characterize stream thermal regimes, one of us (Yin-Phan Tsang) developed a coding package, StreamThermal version 1.0, for use in "R," a language and an environment for running statistical and analytical processes (R Core Team 2014). R is publicly available and free to use, making it applicable for many users. StreamThermal synthesizes daily average, maximum, and/or minimum stream temperature records into thermal metrics for a time period of interest, including months or user-defined seasons. Multiple thermal metrics may be generated from StreamThermal and grouped into five categories describing different aspects