

**California Institute for Water Resources
Annual Technical Report
FY 2017**

Introduction

Research Program Introduction

None.

Numerical Modeling of Local Intense Precipitation Processes

Basic Information

Title:	Numerical Modeling of Local Intense Precipitation Processes
Project Number:	2015CA368S
USGS Grant Number:	
Sponsoring Agency:	Nuclear Regulatory Commission
Start Date:	3/6/2017
End Date:	4/5/2017
Funding Source:	104S
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Climatological Processes, Water Use, Water Quantity
Descriptors:	None
Principal Investigators:	Levent Kavvas

Publications

1. Kavvas, M. L., Ishida, K., Mure-Ravaud, M. January 23-25, 2017. Numerical Simulation of Local Intense Precipitation. Presentation given at the 2nd Annual U.S.NRC Probabilistic Flood Hazard Assessment Workshop at U.S. NRC Headquarters Rockville, Maryland.
2. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 23, 2017. Reconstruction of the precipitation fields of intense historical Tropical Cyclones with the Weather Research and Forecasting (WRF) model in the simulation mode. Poster presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007
3. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 25, 2017. Reconstruction of the precipitation field in a Training Line/Adjoining Stratiform Mesoscale Convective System in the simulation mode with the Weather Research and Forecasting (WRF) model. Oral presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007
4. Kavvas, M. L., Ishida, K., Mure-Ravaud, M. January 23-25, 2017. Numerical Simulation of Local Intense Precipitation. Presentation given at the 2nd Annual U.S.NRC Probabilistic Flood Hazard Assessment Workshop at U.S. NRC Headquarters Rockville, Maryland.
5. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 23, 2017. Reconstruction of the precipitation fields of intense historical Tropical Cyclones with the Weather Research and Forecasting (WRF) model in the simulation mode. Poster presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007
6. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 25, 2017. Reconstruction of the precipitation field in a Training Line/Adjoining Stratiform Mesoscale Convective System in the simulation mode with the Weather Research and Forecasting (WRF) model. Oral presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007
7. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E. and Kanney, J., 2017. Reconstruction of the Precipitation Fields of Intense Historical Tropical Cyclones with the Weather Research and Forecasting (WRF) Model in the Simulation Mode. In Proceedings of the World Environmental & Water Resources Congress (EWRI) 2017.
8. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E. and Kanney, J., 2017. Reconstruction of

Numerical Modeling of Local Intense Precipitation Processes

the Precipitation Field in a Training Line/Adjoining Stratiform Mesoscale Convective System in the Simulation Mode with the Weather Research and Forecasting (WRF) Model. In Proceedings of the World Environmental & Water Resources Congress (EWRI) 2017.

9. Mure-Ravaud, M., Dib, A., Kavvas, M. L., and Yegorova, E., 2018, Maximization of the precipitation from tropical cyclones over a target area through physically based storm transposition, Manuscript under review for journal Hydrol. Earth Syst. Sci, MS No.: hess-2017-665.
10. Kavvas, M. L., Dib, A., Mure-Ravaud, M., December 4-5, 2017. Numerical Simulation of Local Intense Precipitation. Presentation given at the 3rd Annual U.S.NRC Probabilistic Flood Hazard Assessment Research Workshop at the U.S. NRC Headquarters in Rockville, Maryland.
11. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 25, 2017. Reconstruction of the precipitation field in a Training Line/Adjoining Stratiform Mesoscale Convective System in the simulation mode with the Weather Research and Forecasting (WRF) model. Oral presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25, 2007.
12. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 23, 2017. Reconstruction of the precipitation fields of intense historical Tropical Cyclones with the Weather Research and Forecasting (WRF) model in the simulation mode. Poster presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25, 2007.
13. Kavvas, M. L., Ishida, K., Mure-Ravaud, M. January 23-25, 2017. Numerical Simulation of Local Intense Precipitation. Presentation given at the 2nd Annual U.S.NRC Probabilistic Flood Hazard Assessment Research Workshop at U.S. NRC Headquarters Rockville, Maryland.

RESEARCH PROGRAM:

The objective of this project is to assess the suitability of a regional numerical weather model in simulating local intense precipitation processes, and then to investigate the physical mechanisms of storm systems that lead to extreme precipitation. Tropical Cyclones (TCs) and Mesoscale Convective Systems (MCSs) are such storm systems that are recognized for their ability to generate intense precipitation which can create disastrous floods.

In this project, we have assessed the suitability of the Weather Research and Forecasting (WRF) model to simulate local intense precipitation processes within intense historical TCs and MCSs which have affected the United States. The NCEP Stage-IV precipitation dataset was used to select the severe storm systems that we simulated in this project, which spanned the period from 2002 to the present. The initial and boundary conditions for our simulations were obtained from the Climate Forecast System Reanalysis (CFSR) dataset.

For the simulations of the MCSs, the model's simulation nested domains were set up over a region in the Midwest so that the innermost domain covered the severe precipitation areas caused by these storm systems. However, several sets of nested domains were prepared for the simulations of the TCs because of the diversity in the paths of these systems. With these sets of nested domains, we configured the WRF model to obtain the best results for the simulation of each of the selected severe MCSs and TCs with respect to the simulated and observed precipitation fields.

We compared the simulation results with observations from the Stage-IV dataset. On the one hand, the simulation results were evaluated by means of several goodness-of-fit statistics: the relative error for the simulation inner-domain total precipitation, the overlap percentage between the simulated and observed fields, and the precipitation field area ratio for several precipitation thresholds. On the other hand, the simulated and observed precipitation fields were plotted to visually appreciate the similarities and differences in the fields' texture and structure. From this comparison, we found that under an appropriate choice of the model's options and initial/boundary conditions, the WRF model managed to reconstruct in the simulation mode (i.e., without any nudging or data assimilation) the precipitation fields of these severe historical TCs and MCSs.

We also worked on developing a physically based storm transposition method for the transposition of TCs. The objective of this method was to find the amount of shift which maximizes the precipitation depth over a given target area. The transposition method uses the WRF model to numerically simulate the transposed TC and its precipitation field, as such it has the fundamental advantage of conserving the mass, momentum, and energy in the system. This method is based on the shifting of the initial vortex of the TC at the simulation start date. The transposition method was applied to four hurricanes that had spawned torrential precipitation in the United States, and the drainage basin of the city of Asheville, NC was selected as the target. It was observed that the precipitation fields changed in both structure and intensity after transposition. The convergence of the

vertically integrated vapor transport (IVT) was found to play a central role in the generation of intense precipitation in these hurricanes.

Moreover, we also utilized a physically based method for the transposition of one MCS by using the WRF model. This method involved shifting the initial and boundary conditions of the WRF model domains. The objective of this exercise was to find the amount of shift which maximized the precipitation depth of a MCS over a target watershed. The target watershed chosen for the MCS transposition was Root River above Houston, located in the southeastern part of Minnesota. Similar to the transposition of TCs, this transposition exercise showed that such a physically based transposition method does not simply transpose the observed precipitation field over the target watershed. In fact, in addition to a higher precipitation depth caused over the target watershed, the transposition also caused the shape and intensity of the MCS to change.

INFORMATION TRANSFER/OUTREACH PROGRAM:

The project team participated in the 2017 World Environmental and Water Resources Congress in Sacramento, and in the U.S. NRC 3rd Annual Probabilistic Flood Hazard Assessment Research Workshop at Rockville, Maryland in order to present the project's results to date.

The Influence of Incubation Temperature on Aerobic Swimming Performance of Juvenile Salmonids

Basic Information

Title:	The Influence of Incubation Temperature on Aerobic Swimming Performance of Juvenile Salmonids
Project Number:	2016CA365B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Categories:	Climatological Processes, Hydrology, Water Use
Descriptors:	None
Principal Investigators:	Amanda I Banet

Publications

1. One master's thesis in progress.
2. Balfour, Nicholas, Carlos Estrada, Rebecca Pilakowski, Dylan Stompe, and Amanda Banet, 2018, Impact of increased incubation temperature and thermal stress on the aerobic scope and thermal tolerance of juvenile rainbow trout (*Oncorhynchus mykiss*), CSU Chico College of Natural Sciences Poster Symposium, Chico, CA.
3. Balfour, Nicholas, Carlos Estrada, Rebecca Pilakowski, Dylan Stompe, and Amanda Banet, 2018, Impact of increased incubation temperature and thermal stress on the aerobic scope and thermal tolerance of juvenile rainbow trout (*Oncorhynchus mykiss*), American Fisheries Society Cal-Neva Conference, San Luis Obispo, CA.
4. Estrada, Carlos, Nicholas Balfour, and Amanda Banet, 2017, Impact of increased incubation temperature on the thermal tolerance of juvenile rainbow trout (*Oncorhynchus mykiss*), The National Diversity in STEM Conference (SACNAS), Reno, NV.
5. Banet, Amanda, February 24, 2018, What is it like to be a fish biologist? American Association of University Women Career Trek (Outreach event for 8th grade girls)

RESEARCH PROGRAM:

Background

Habitat degradation and the onset of climate change are introducing organisms to novel environmental conditions that they have not historically experienced. The ability of an organism to respond to these changes determines the persistence and success of a population in the future. In California, populations of salmonids have dramatically declined over the past century, with the greatest decrease occurring since the construction of major dams and water diversions in 20th century. These dams have blocked critical habitat for salmonids, and have led to altered water characteristics in the remaining habitat, including increases in water temperature. We know that increases in water temperature are tied to mortality and reduced reproductive success in these fish, but there is still much unknown about their capacity to deal with temperature stress on both an individual level and on a population level.

Some plasticity has been documented in salmonid life histories, meaning that they can exhibit different characteristics depending on the environmental conditions that they experience. In some cases plasticity can be adaptive, allowing an organism to immediately respond to environmental conditions, unlike genetic changes that occur at the population level on a slower generational time scale. However, one recent study has indicated that while Pacific salmon do exhibit plasticity in response to high temperatures during egg incubation, this plasticity is maladaptive. Rather than inducing physical changes that increased their ability to function in high temperature environments, fish that were exposed to high temperatures early in development had lower thermal tolerances later in life. Another body of research has suggested that thermal tolerance is a function of an organism's ability to successfully deliver oxygen to its cells. Based on this, we hypothesized that the aerobic capacity be reduced in fish that were exposed to high incubation temperatures, and that this difference would be magnified if the fish were swimming in high temperature waters. Reduced aerobic performance can be harmful to an organism because it reduces the amount of energy an organism can devote to activities related to survival and reproduction, such as foraging, growth, migration, and escaping from predators.

This research examines the thermal tolerance and swimming metabolism of *Oncorhynchus mykiss* (rainbow trout) and *Oncorhynchus tshawytscha* (Chinook salmon) that were incubated at a range of temperatures. First we tested whether the relationship between incubation temperature and thermal tolerance in our fish was similar to that observed in studies of closely related species. We then examined whether fish incubated at high temperatures had a lower aerobic scope than those incubated at low temperatures, and whether this difference was magnified when swimming at warmer temperatures. Methods and results for *O. mykiss* are reported here. Trials with *O. tshawytscha* are ongoing.

Methods

We collected fertilized *O. mykiss* eggs from the Mt Shasta hatchery and transported them to the California State University, Chico salmon facility for incubation. Eggs were incubated at 10, 12.8, and 15.6°C. After hatching, juvenile fish were transferred to 10°C holding tanks. When fish were approximately three months old, their critical thermal maximum (CT_{max}) was tested by slowly increasing the water temperature until the fish lost equilibrium. Oxygen consumption (MO₂) was measured on a different subset of fish using a Loligo Systems mini-swim respirometer (www.loligosystems.com). For each swimming trial, a fish was introduced to the working section of the respirometer and allowed to acclimate overnight at a low water speed. After the acclimation period, resting oxygen consumption (MO_{2rest}) was measured. Subsequently, fish were exposed to progressive incremental increases in swimming speed until they fatigued. Maximum oxygen consumption (MO_{2max}) was estimated using the highest MO₂ measured during the swimming trial. Aerobic scope of the individual was calculated as (MO_{2max} - MO_{2rest}). Each fish

was tested at a range of temperatures between 10 and 15.6°C in order to examine the interaction between incubation temperature and aerobic performance across a range of temperatures after hatch.

Results

1. Survival to button-up was marginally higher in the low incubation temperature treatment (10°C = 92.4%, 12.8°C = 89.3 %, 15.6°C = 89.2%)
2. Incubation temperature did not significantly influence thermal tolerance (CT_{max}) after hatching (Figure 1A, one-way ANOVA: $F_{2,57} = 0.846$, $p=0.435$, $\eta^2=0.029$)
3. Fish mass had a small, but significant positive relationship with CT_{max} (Figure 1B, Linear Regression: $F_{1,58}=4.158$, $p=0.046$, $R^2=0.067$)

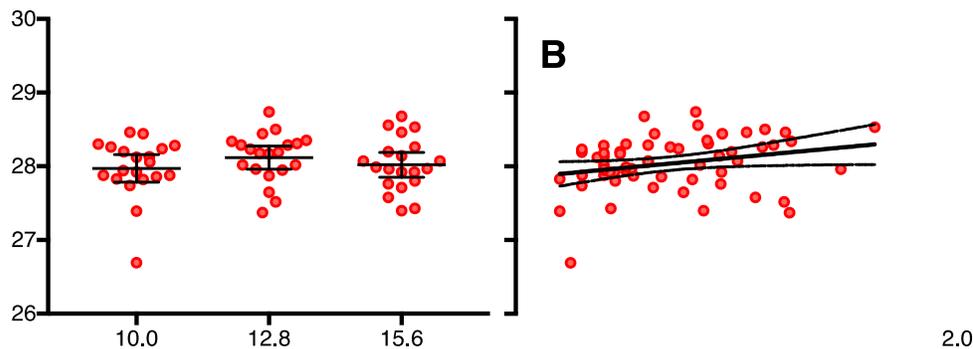


Figure 1. Thermal tolerance (CT_{max}) was not affected by incubation temperature (A), but it did have a small, significant positive relationship with fish mass (B).

4. Within the temperatures examined in this study, incubation temperature did not significantly affect MO₂rest (slopes: $F_{2,16} = 0.7174$, $p=0.5031$; elevations/intercepts $F_{2,18} = 2.773$, $p=0.0892$), MO₂max (slopes: $F_{2,16} = 0.1847$, $p=0.8331$; elevations/intercepts $F_{2,18} = 1.796$, $p=0.1944$), or aerobic scope (slopes: $F_{2,16} = 0.04551$, $p=0.9556$; elevations/intercepts $F_{2,18} = 0.2907$, $p=0.7512$) of juvenile *O. mykiss* after hatching. Because of this, incubation temperature treatment groups were pooled to examine the effect of aerobic trial temperature.
5. Within the temperatures examined in this study, MO₂rest and MO₂max increased as aerobic trial temperature increased (Figures 2A & 2B, Linear Regressions. MO₂rest: $F_{1,20} = 8.565$, $p=0.0083$, $R^2=0.2999$; MO₂max: $F_{1,20} = 5.578$, $p=0.0284$, $R^2=0.2181$). Aerobic scope was not significantly influenced by temperature (Figure 2C, Linear Regression: $F_{1,20} = 0.9265$, $p=0.3473$, $R^2=0.04427$).

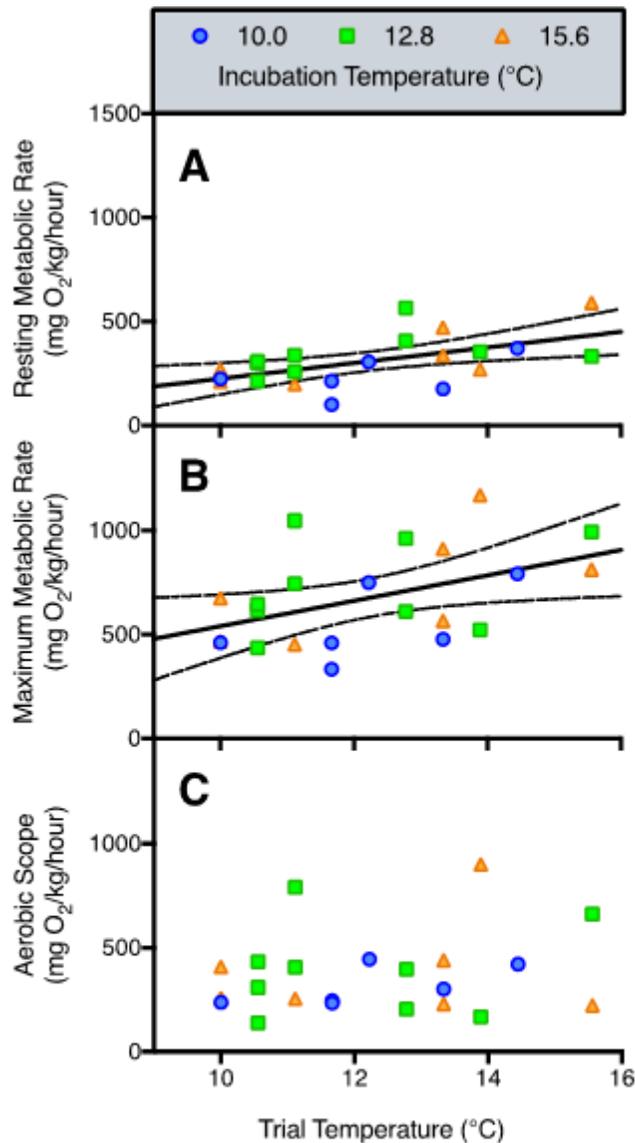


Figure 1. Resting and maximum metabolic rates increased with aerobic trial temperature (A & B), but aerobic scope was not affected by aerobic trial temperature. Incubation temperature did not have a significant effect on any aerobic performance metric.

Discussion

Contrary to expectations, incubation temperature had no effect on thermal tolerance or aerobic performance of the *O. mykiss* in our study. One possible explanation for this is that the effect of incubation temperature could vary between different salmonid species, populations, and latitudes. In addition, due to logistic constraints associated with obtaining eggs from the hatchery, our thermal treatments did not begin immediately at fertilization. Therefore, these fish may have already passed a critical point when they might be sensitive to higher temperatures. Our continuing research with *O. tshawytscha* will be able

to address this, because eggs were fertilized on site and underwent four incubation treatments: high temperature, low temperature, high then low temperature, and low then high temperature. This study provides insight into the physiological effects of temperature on juvenile salmon, which can be used to help inform water management decisions.

INFORMATION TRANSFER/OUTREACH PROGRAM:

No additional information beyond what is presented in the table.

Can habitat restoration mediate predator-prey interactions to increase juvenile salmon survival in California's central valley?

Basic Information

Title:	Can habitat restoration mediate predator-prey interactions to increase juvenile salmon survival in California's central valley?
Project Number:	2017CA369B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	44
Research Category:	Ground-water Flow and Transport
Focus Categories:	Water Use, Hydrology, Agriculture
Descriptors:	None
Principal Investigators:	Eric Palkovacs

Publications

1. Sabal, Megan C., Joseph E. Merz, Eric P. Palkovacs, In Review, Predation risk influences migration speed differently for wild and hatchery salmon. Proceedings of the Royal Society B.
2. Sabal, Megan C. 2018. Ready, set, go! Racing salmon to learn about migration and predator avoidance. Coastal Sustainability Guest Blog. Available at <http://kristy-kroeker.squarespace.com/new-blog/2018/1/24/ready-set-go-racing-salmon-to-learn-about-migration>
3. Sabal, Megan C. 2017. How to Scare a Salmon? YouTube video available at <https://www.youtube.com/watch?v=uB7d7J0PqoQ>

RESEARCH PROGRAM:

Problem: Many juvenile salmon die while they migrate from freshwater to marine environments. Mortality comes from a variety of stressors including nonnative predators, habitat alterations, and water management. Understanding how these stressors interact to shape behavioral decisions in migrating juvenile salmon is important in understanding the mechanisms that ultimately lead to mortality.

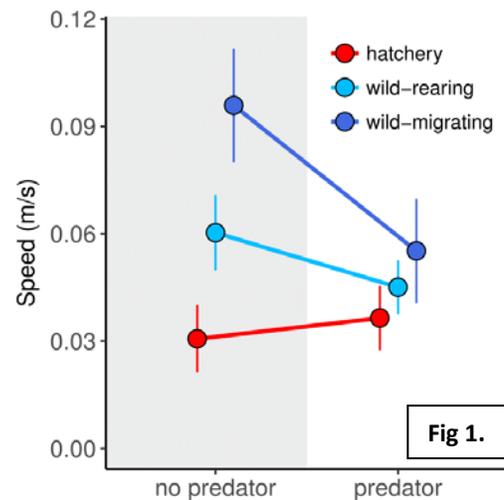
Objectives: In spring 2018, we tested whether salmon migration speed changed in the presence of predator cues and determined how responses varied by salmon origin (hatchery vs. wild), migration life stage (rearing vs. migrating), and physical traits (size, condition, ATPase activity).

Methods: We timed juvenile Chinook salmon (*Oncorhynchus tshawytscha*) swimming downstream in a flume with and without predator cues present. The flume was 2.1 m long and 0.45 m in diameter, which we placed in the Mokelumne River. It was bisected by three PIT tag antennas, which detected the tagged salmon as it swam through. Each individual salmon was run twice—with and without predator cues present. Predator cues were provided by a plastic largemouth bass with associated odor cues. Both wild and hatchery salmon were used in the experiment. Nested within wild salmon, were salmon that were still rearing on the floodplain upstream (wild-rearing), and salmon that were actively migrating downstream (wild-migrating).

Results:

- Wild salmon slowed when faced with predator cues, while hatchery salmon did not change their speed (Fig. 1).
- Wild-migrating salmon reacted more strongly to the predator cues compared to wild-rearing salmon (Fig. 1).
- Wild-migrating salmon were fastest, followed by wild-rearing, and hatchery salmon (Fig. 1).
- Salmon with elevated ATPase activity swam slower through the flume.
- Salmon with higher body conditions swam faster through the flume.

Significance: These results suggest that predators can affect migratory behavior in salmon in addition to survival. In turn, this could have consequences on fitness of salmon at subsequent life stages. Both hatchery and salmon contribute to managed populations, therefore it is important to understand how they may behave differently.



INFORMATION TRANSFER/OUTREACH PROGRAM:

- American Society of Naturalists Meeting, 5-9 January 2018, oral presentation
- SWFSC, NMFS, Data theory seminar, 20 February 2018, oral presentation
- American Fisheries Society, CalNeva Chapter Meeting, 1-2 March 2018, oral presentation*
- Guest Blog on UCSC Coastal Sustainability Blog
- Create educational video published on YouTube

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Notable Awards and Achievements

2015CA368S, Levvent Kavvas: The project team successfully reconstructed the precipitation field in 14 MCSs whereas these systems are very complicated and difficult to simulate. Besides, the project team performed the physically based storm transposition of four TCs and one MCS in the United States, which had never been done in the past.

2017CA369B, Eric Palkovacs: • M. Sabal awarded 1st place for student oral presentations at 2018 AFS CalNeva conference • M. Sabal awarded the Delta Science Fellowship for continued support to execute and expand this project • Submitted manuscript for publication