# Temperature Preference of Juvenile Antarctic Fishes

ICBF 2022 Poster Presentation

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This work is still preliminary and has yet to undergo peer-review. However, I am always open to questions and comment on the research. Thank you for visiting!

## Background

For ectothermic organisms, those which cannot create their own body heat, the temperature of the environment can have important impacts upon their physiology, ecology and behavior. If conditions are too hot or too cold, then organisms may be unable to complete important aspects of their life history and may suffer non-lethal effects of stress. Just like you may have a preferred setting on the thermostat, organisms can also have preferred temperatures; temperatures which suit their physiological needs and theoretically improve organism fitness.

Fish of the Antarctic are unusually in being able to survive in sub-freezing temperature. To prevent the formation of ice within their bodies, Antarctic fish have evolved a suite of physiological responses to allow the to live in such frigid temperatures. It is though that these physiological responses are energetically expensive. Furthermore, the water temperature of McMurdo sound is exceptionally stable, thought to hardly change over millions of years. Due to global climate change, the temperature of the Southern Ocean and McMurdo Sound are increasing more rapidly than nearly anywhere on Earth, and how fish will respond to this change in the thermal landscape is unknown.

Our project had two goals. The first was to determine, for the first time, the temperature preference of two Antarctic fish species. The Emerald Rockcod (*Trematomus bernacchii*) and the Sharp-spined Notothen (*Trematomus pennellii*) are common, benthic species crucial to the depauperate food-web of the Ross Sea. The second goal of our project was to demonstrate the effectiveness of our Temperature Preference Apparatus (TPA) in a remote setting. Our device was first designed by **XXX (iNSERT CITATION)** and provides a stable thermal gradient within which the fish may select a preference. For our work in the Antarctic we miniaturized the device to better suite the size of our fish and the requirements of working in a remote setting.

## Hypotheses

We hypothesized that Antarctic fish species would prefer temperature which would minimize energy expenditure or that would reduce stress. Living in Antarctica, these two species have evolved to prevent the formation of ice crystals within their body, and therefore we speculated that living at sub-zero temperatures would be energetically stressful and fish may exhibit thermal preferences warmer than -2°C (The typical temperature of the Ross Sea) and perhaps even above freezing (0°C) thereby avoiding the formation of ice crystals.

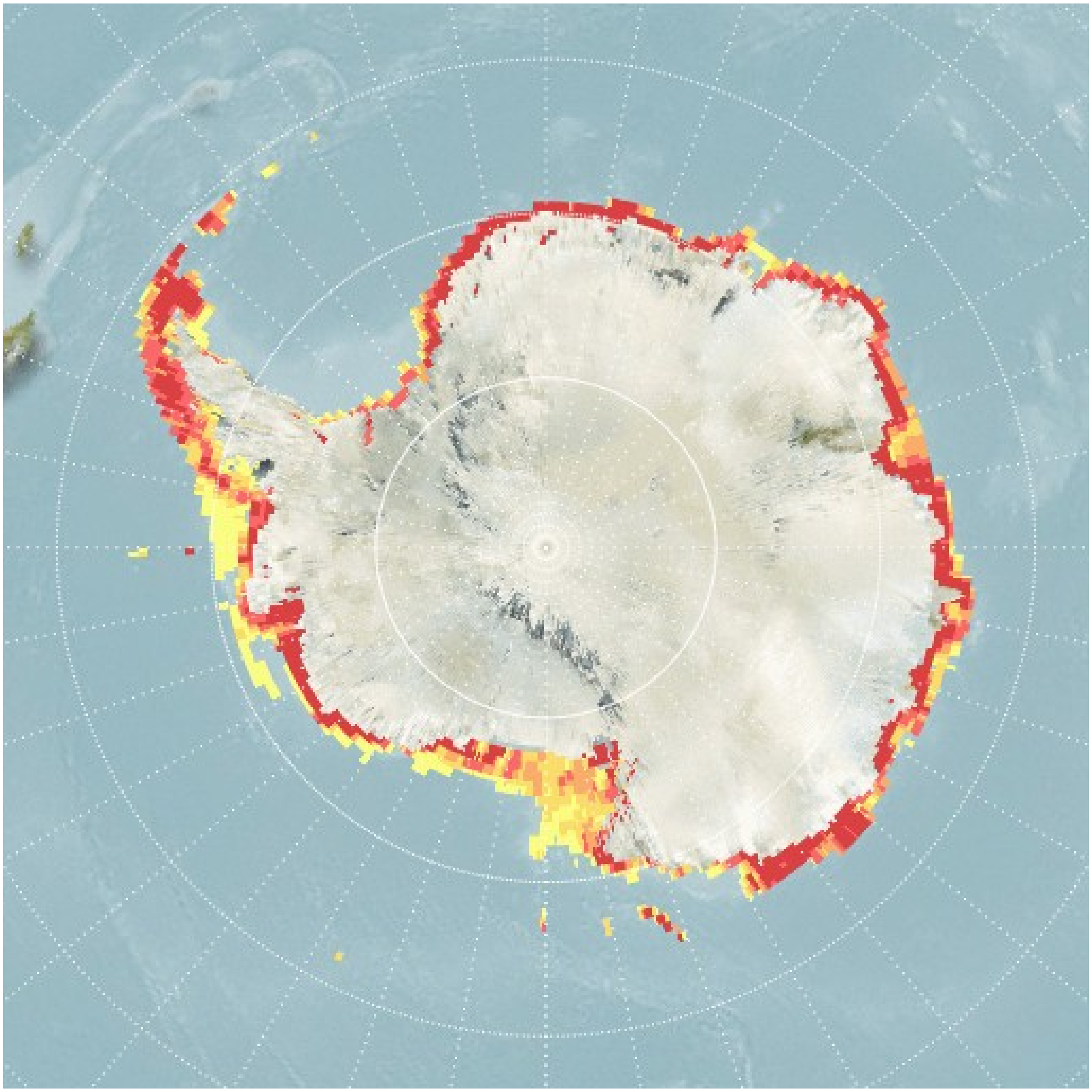


Figure 1: AquaMaps (2019, October). Computer generated distribution maps for Trematomus bernacchii (Emerald rockcod), with modelled year 2050 native range map based on IPCC RCP8.5 emissions scenario. Retrieved from https://www.aquamaps.org.

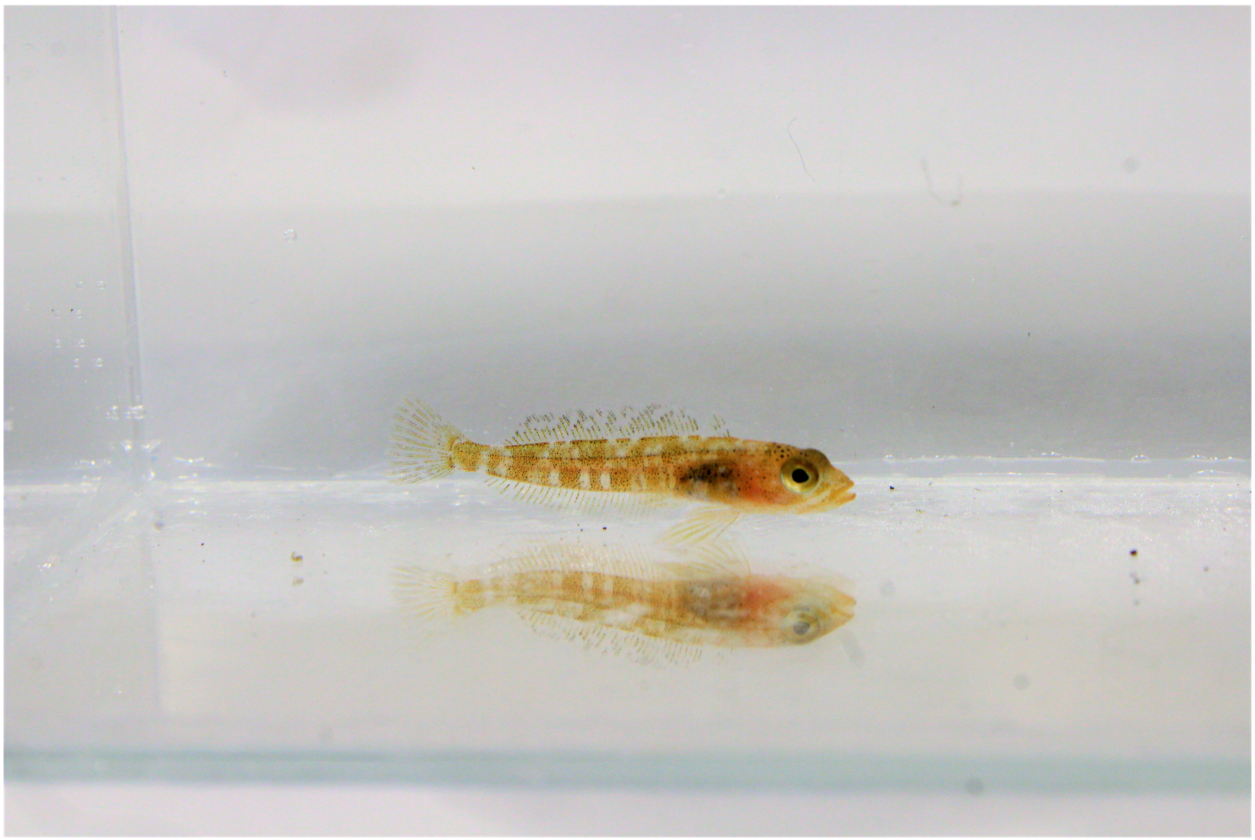


Figure 2: Juvenile *T. bernacchii*, K. Zillig

## Methods

The temperature preference apparatus (TPA) consists of a ring-shaped channel surrounded by concentric rings of mixing chambers. Water of three different temperatures is differentially supplied to the various mixing chambers. Water was partially recirculated with only the cold-water basin receiving new water from McMurdo sound. The medium and warm basins were heated using aquarium heaters. This creates a stable thermal gradient which does not confound temperature with tank architecture (e.g., depth or corners) which may serve as to attract or repell a fish, and thereby confound results. Fish position within the ring was recorded by overhead GoPro cameras and then footage was analyzed using ethovision (Noldus tm).

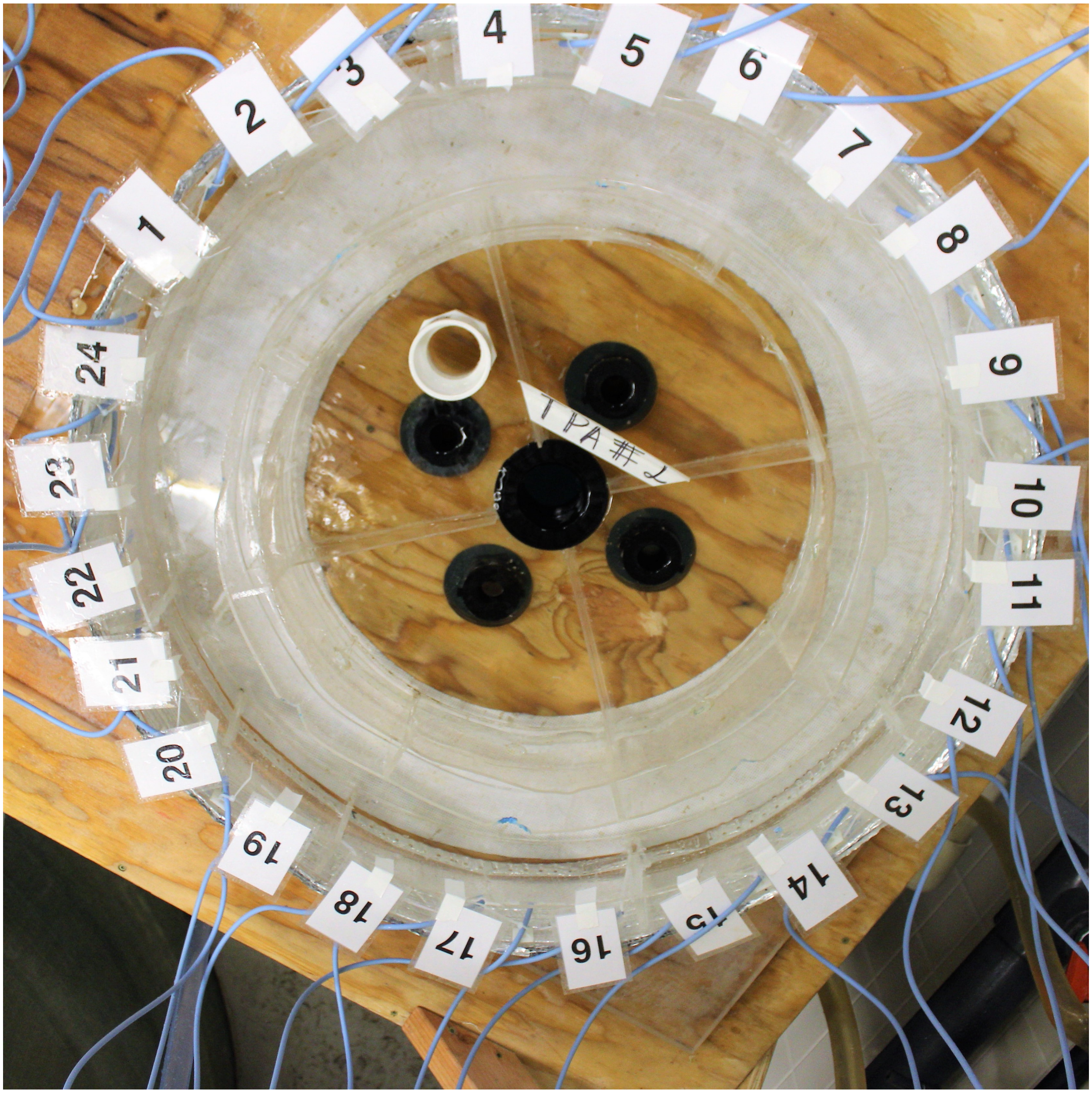



Figure 3: Temeprature Preference Device, Numbers indicate specific 'wedges' used for determining fish location in subsequent video analysis.

We tested two species of Antarctic rockcod, *T. bernacchii* (n=29 ) and *T. penellii* (n =30). Fish were placed

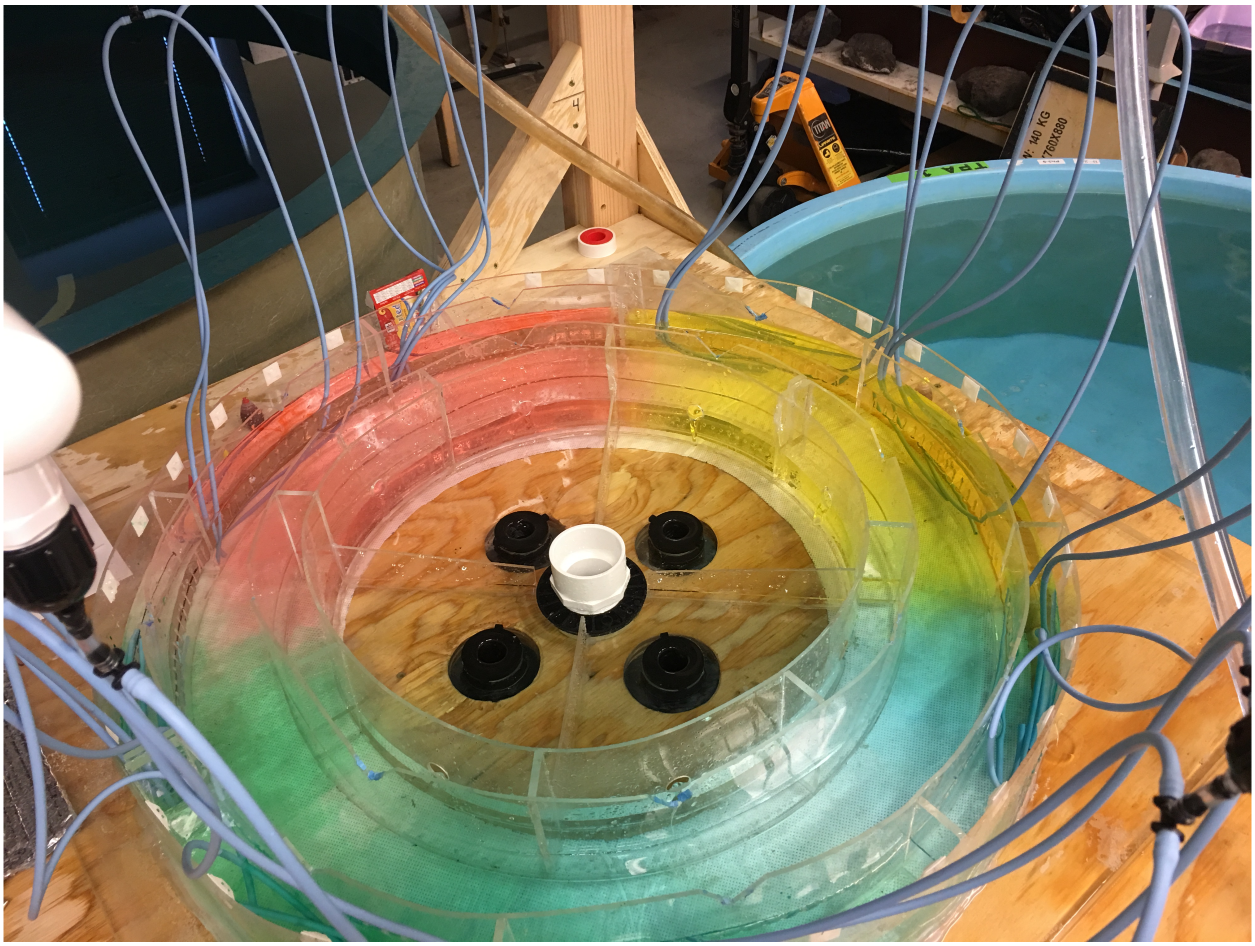


Figure 4: Temeprature Preference Device, Food dye was added to visulize the stability of the water currents.

in the coldest location in the ring and then given 20 minutes to acclimate to apparatus before data was collected, data during this period were not included in analysis. Trials then ran for 115 minutes. Each fish was trialed twice XX days apart in order to assess the repeatability of the temperature preference metric. After the second trial fish were weighed (units) and measured (units).

The fish's location throughout the ring is then matched with the temperature of that location. A fish's thermal preference is the MEDIAN temperature experienced by the individual during the trial. The median was chosen to reduce the effect of outliers as the fish transited the ring. We also measured the movement of the fish, counted as the number of transitions between neighboring wedges. Location of the fish in the ring was assessed 10 times per second.

Statistics were conducted in R using the package `brms` and images were modeled `ggplot2` and `tidybayes`. We used a linear mixed effects model implemented in a Bayesian framework to determine the mean temperature preference for both species. We used stepwise model selection and selected the lowest WAIC model for further discussion. The species level temperature preference was calculated as the mean of the individual medians.

**Methods Questions**

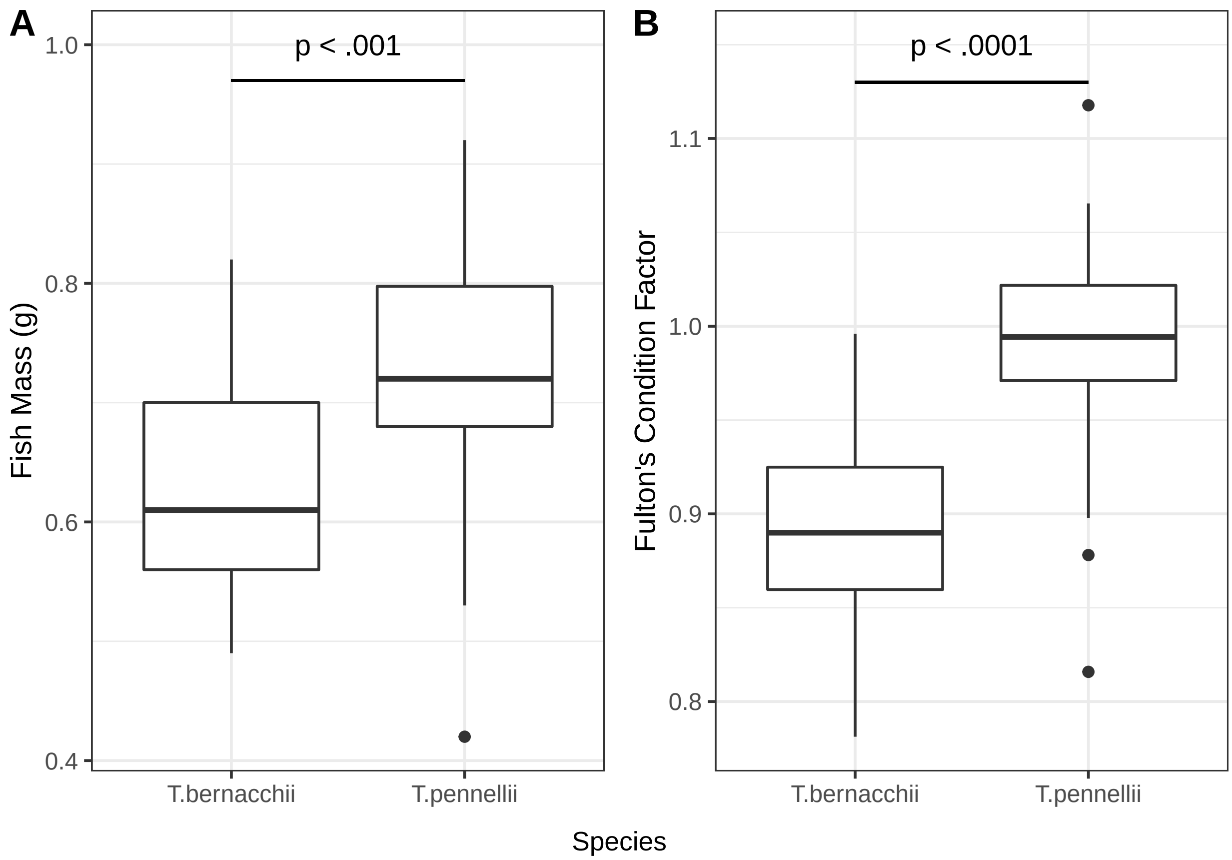
How long were the runs,
how long between runs,
how long for acclimation,
How long was the fasting?
Should I include the first 20 minutes in an assessment of how much the ring the fish experienced?
Should I limit trials to fish which explored at least 50% of the ring or some other number
I have a list of fish that were removed from the dataset, why would they have been? Some say there is no video data, which makes sense... but some just say unusuable trial...

## Results

First, well look at the simple mass and length data of our experimental animals.

Table 1: Table 1: Demographics of Experimental Fish. N is the nubmer of fish from each species which were tested, each fish was tested twice. Other traits are reported as means and standard deviations of the raw data.

| Species | N= | Mass (g) | Length (mm) | Condition Factor | Obs. Temperature Preference (°C) |
|---|---|---|---|---|---|
| T.bernacchii | 29 | 0.63 ± 0.08 | 41.29 ± 1.5 | 0.89 ± 0.05 | 0.47 ± 1.29 |
| T.pennellii | 30 | 0.72 ± 0.1 | 41.7 ± 1.59 | 0.99 ± 0.06 | 1.11 ± 1.06 |




**Mass (A) and Condition Factor (B) of Experimental Animals** We calculated Fulton's Condition Factor using a the fishes mass and length. *T. pennellii* is both heavier and has greater condition factor than *T. bernacchii*. Both traits can reflect energetic state, and therefore may influence a fish's temperature preference.

We conducted a straightforward t-test to look for population differences.

```
mass.m1 <- lm(data = TPA.dat.1 %>%
     filter(RUN_NUM == 1), ## Mass traits are the same across runs, so we limit to just one run
   MASS ~ SPECIES)

anova(mass.m1)
```

```
## Analysis of Variance Table
##
## Response: MASS
##           Df  Sum Sq  Mean Sq F value    Pr(>F)
## SPECIES    1 0.12738 0.127379  14.299 0.0003757 ***
## Residuals 57 0.50776 0.008908
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

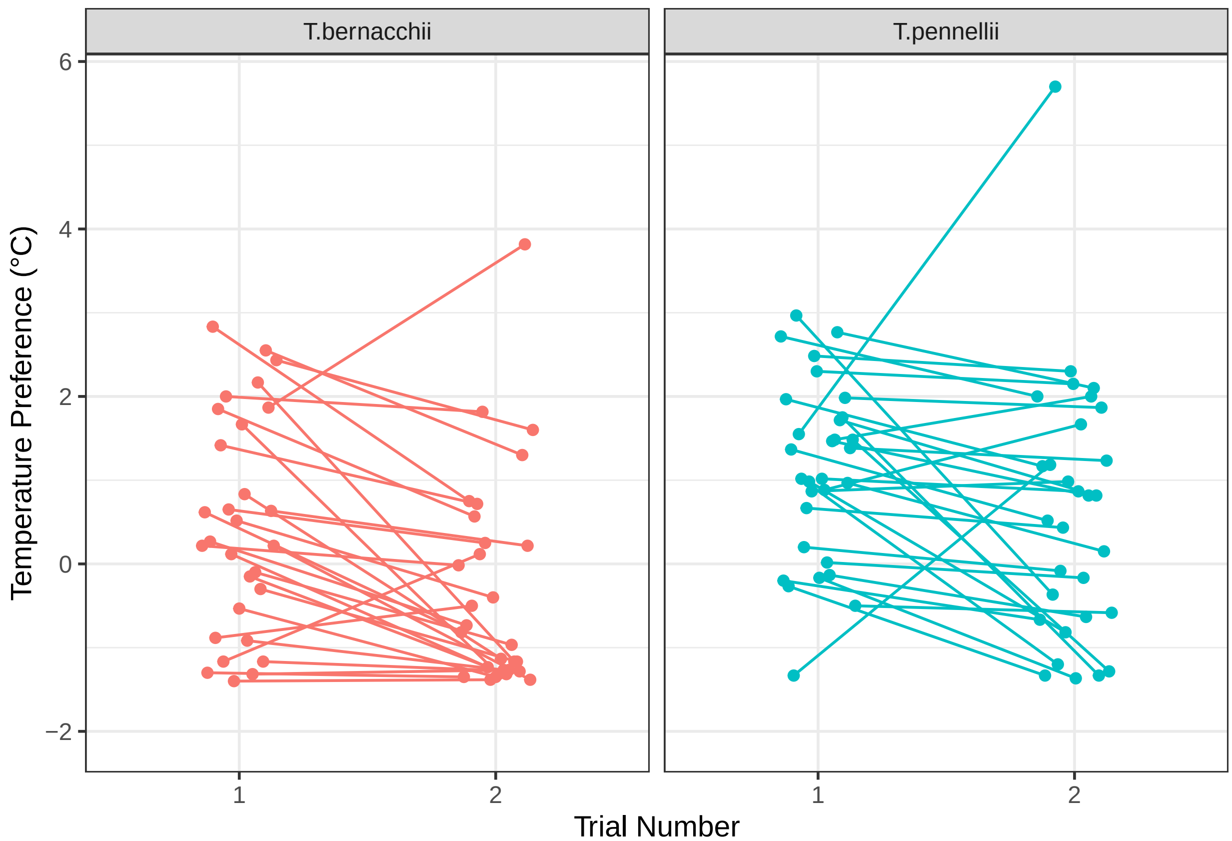
```
### p < .001

cond.fac.m1 <- lm(data = TPA.dat.1 %>%
```

```
                    filter(RUN_NUM == 1),
                  COND_FAC ~ SPECIES)

anova(cond.fac.m1)
```

```
## Analysis of Variance Table
##
## Response: COND_FAC
##           Df  Sum Sq  Mean Sq F value    Pr(>F)
## SPECIES    1 0.14444 0.144441  45.534 8.362e-09 ***
## Residuals 57 0.18082 0.003172
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

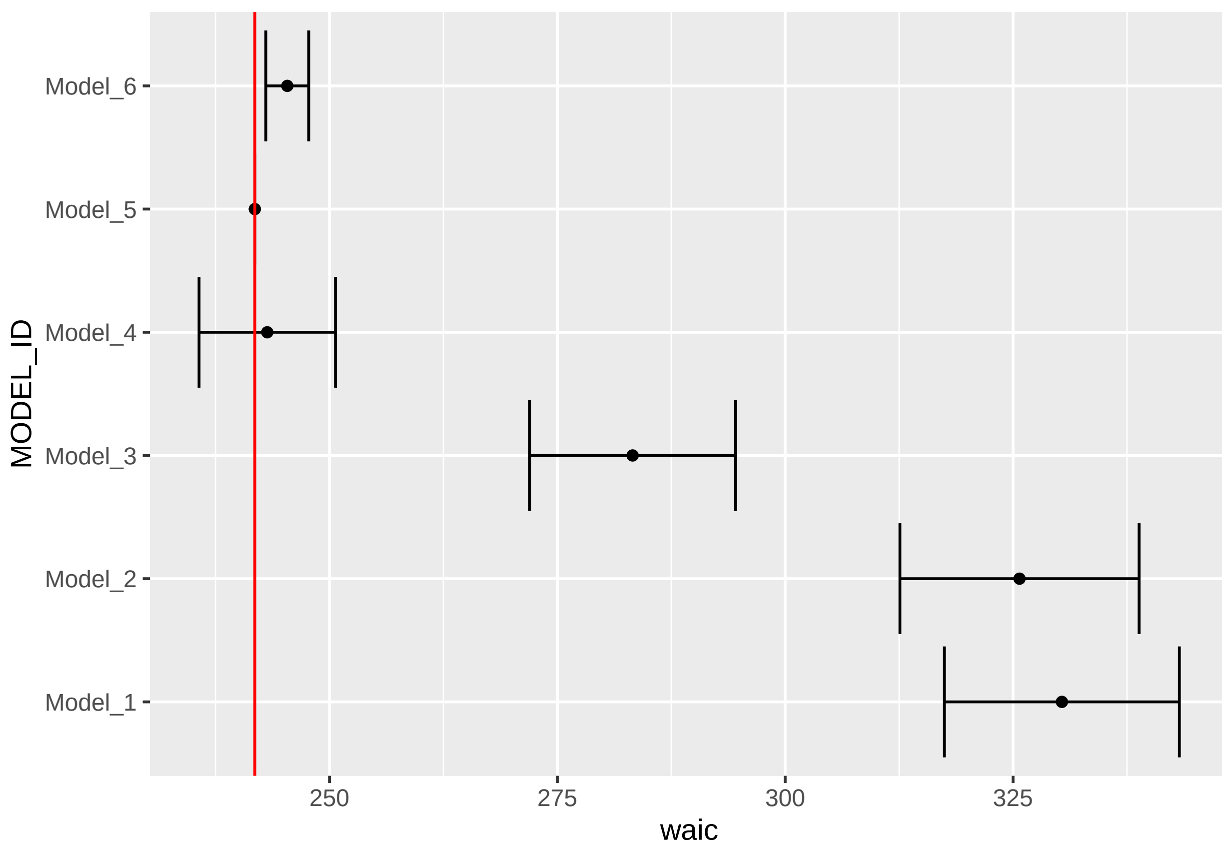



**Comparisons of Individual Fish Performance between the first and second trial.** Each facet of this plot is a specific species and each pair of points is an individual fish. The line traces how that fishes temperature preference changed between the first fish and the second trial.

We used the package 'brms' to fit Bayesian models to our data. Models estimating the temperature preference were built and selected using step-wise model selection, an abbreviated version is provided here.

```
Model_5 <- brm(
  family = gaussian,
  MEDIAN_PREF_S ~ 1 + SPECIES*MOVEMENT_S+RUN_NUM+COND_FAC_S+
```

```
    (1|FISH_ID)+(1|CALIB_FAC), # random intercepts prescribed to each fish and to that day's specific t
  ## weakly regularizing priors
  prior = c(prior(normal(0,1), class = Intercept),
            prior(normal(0,1), class = b),
            prior(normal(0,10), class =sigma)),
  data = model.dat,
  warmup = 1000, ## Number of burn-in samples
  iter = 4000, ## Total nober of model iterations
  chains =4,
  cores = 4,
  file = paste0("~/kenzillig.github.io/kenzillig.github.io/assets/rds/TPA_Median_M10.4.rds")
)
#summary(Model_5)
Model_5 <- add_criterion(Model_5, c("waic","loo")) ## calcualte the WAIC and LOO for this model
## Compare the WAIC scores of each model.
w <- loo_compare(Model_1, Model_2, Model_6, Model_3, Model_4,Model_5, criterion = "waic")
plot_model_waic(w)
```

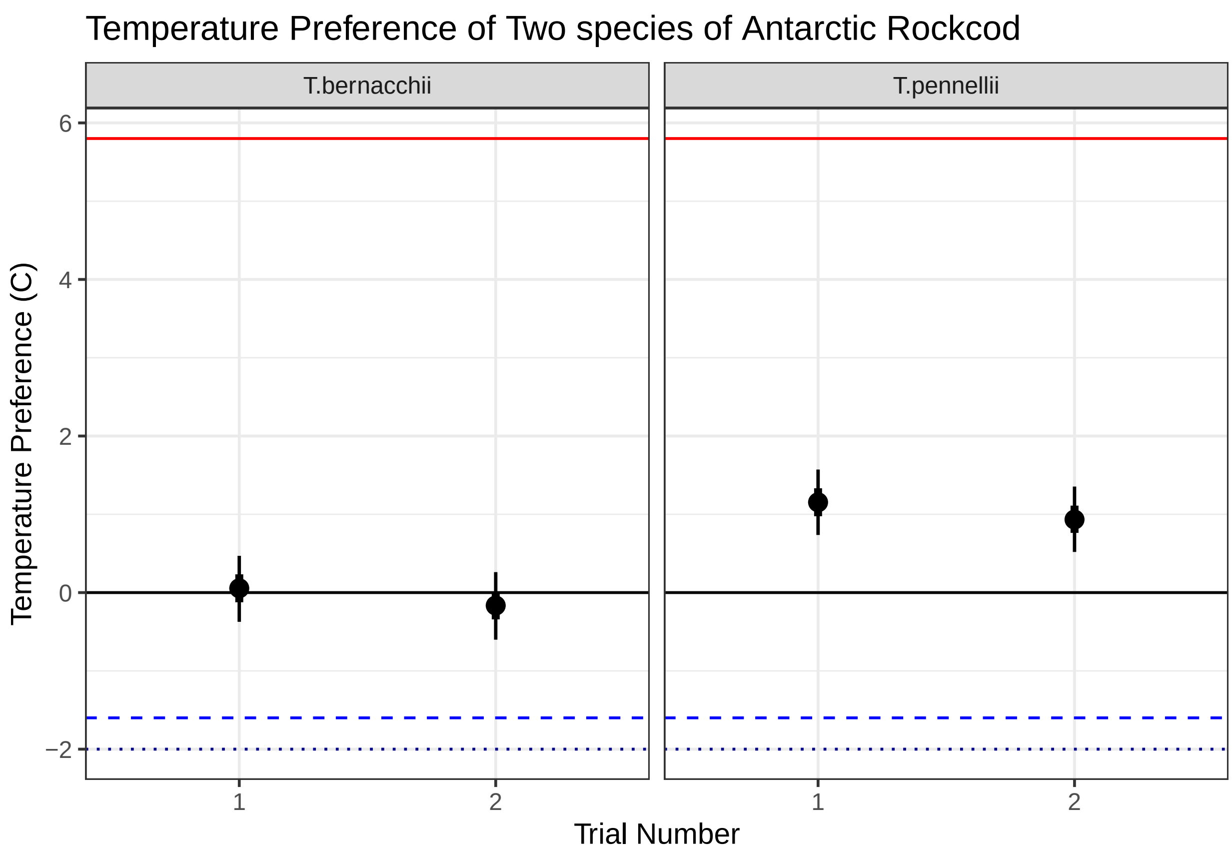



**Model Selection Plot** The above is just a plot of Widely Applicable Information Criterion (WAIC) for several statsical models attempting to determine the relationship between temperature preference and fish species. It identifies two models (10.4 and 10.1) as having the lowest. We will be using model 10.4 for further investigation.

Models including fish mass, temperature of in-lab acclimation, and interactions between trial number and species were tested but were not found to increase model fit, so these predictors were discarded. The final model included predictor variables an interaction between fish movement within the chamber, fish species, trial number and condition factor.

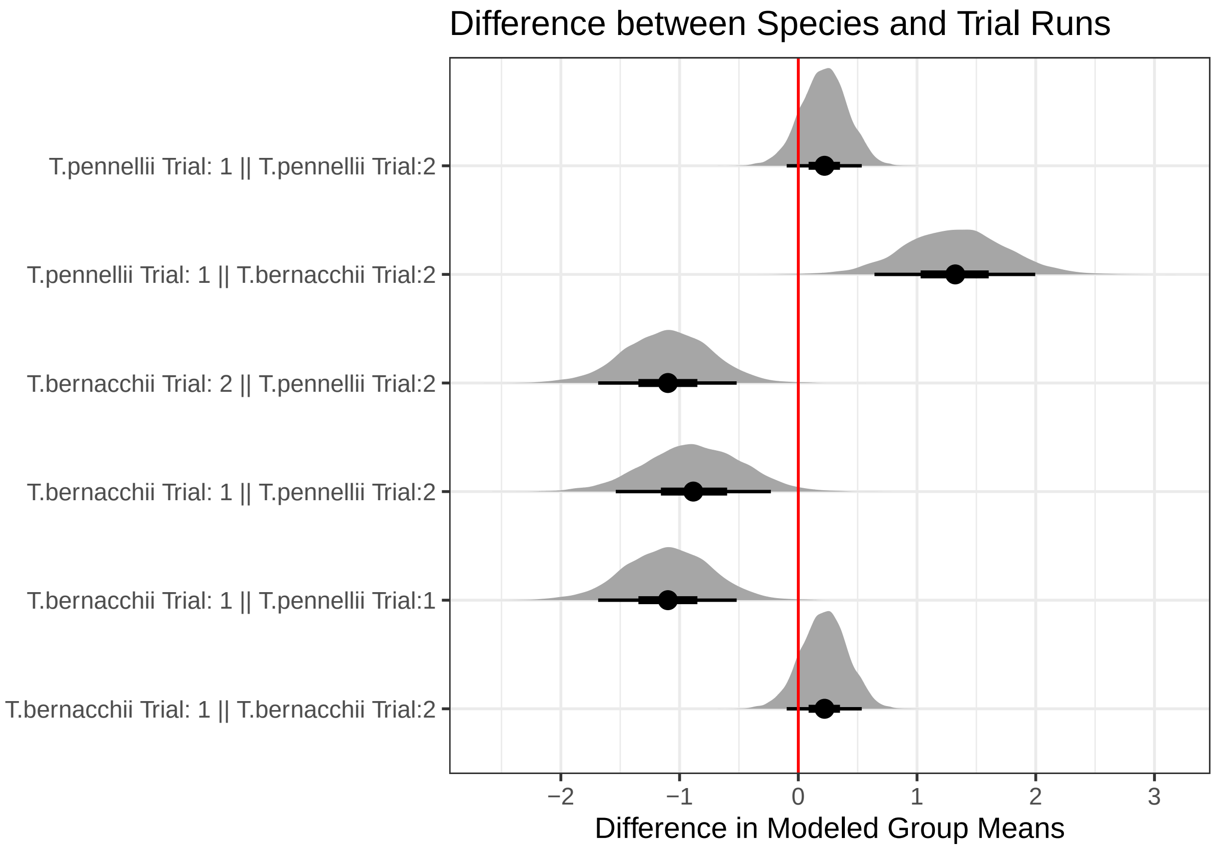
Random intercepts for each individual fish (repeated measures) and the TPA's particular temperature calibration (which fluctuated slightly day to day) were included. These random effects respectively accounted for 37% and 27% of the residual variation.

We used the package `emmeans` to estimate the Temperature Preference of each species during both the first or second trial.

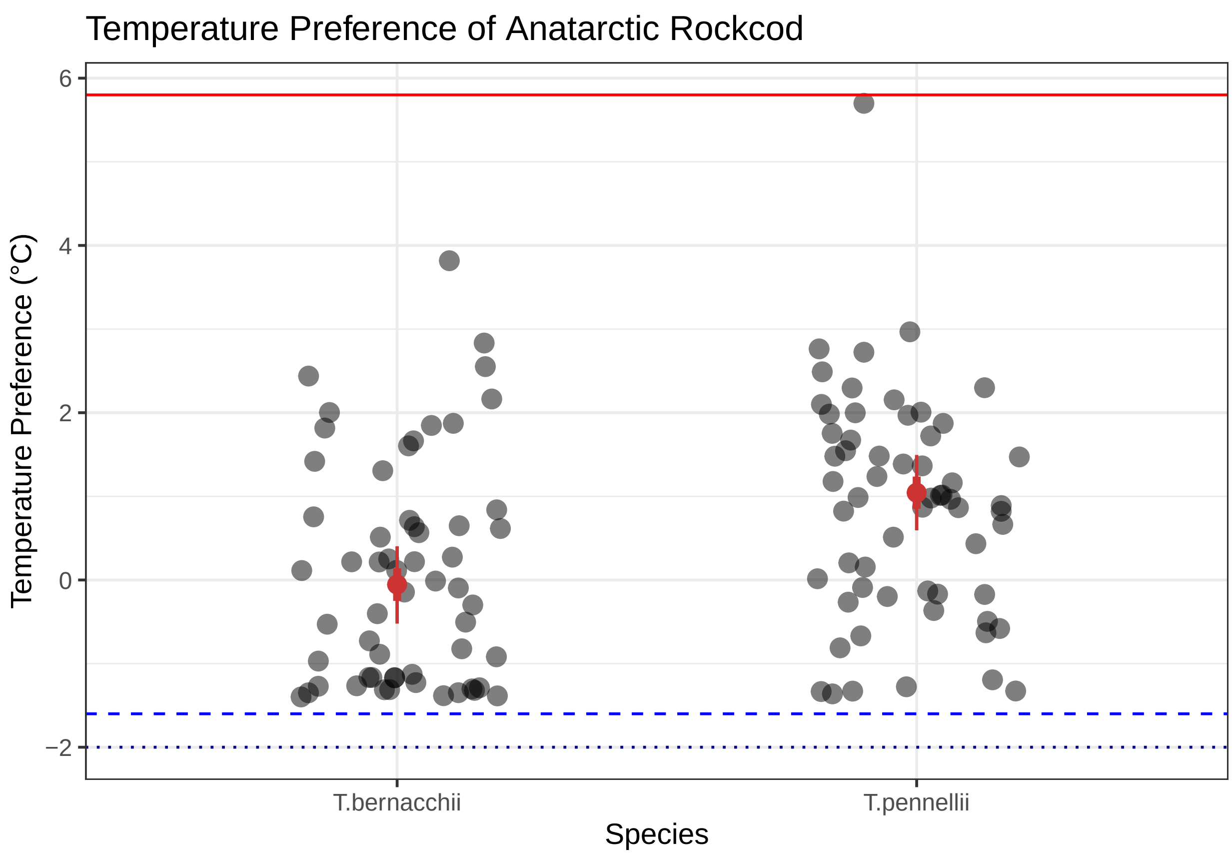



####Temperature Preference of Two Species of Antarctic Rockcod It appears that *T. Pennellii* have a higher temperature preference than *T. bernacchii.* Additionally, both species exhibit temperature preferences greater than their normal environment. It is also evident that the there is little effect of trial run on the temperature preference of either species of Antarctic rock cod.

We can use the posterior distributions to evaluate whether the two species exhibit the same temperature preference.




**Treatment Comparisons** Based upon these treatment contrasts we don't find an effect of trial number. The top and bottom contrasts (which compare the performance of a single species in the first or second trial) heavily overlap zero, indicating that differences between runs is non-significant. We do see support for differences between the two species of rock cod. The point-intervals estimate the mean difference between treatments (point) along with the 89% (thin) and 50% (thick) credible intervals. If the point interval overlaps zero, we conclude that the treatments are not significantly different.




**Temperature Preference of Antarctic Rock Cod:** In this plot both of a fish's two trials are represented, each by a black dot. The red point intervals capture the model estimated mean for each species along with the 89% (thin) and 50% (thick) credible intervals. The Red horizontal line indicates the highest temperature available within the temperature preference apparatus while the blue dashed line represents the coldest temperature available. The dotted line at -2°C indicates the typical temperature of the Ross Sea.

Table 2: Table 2: Model Estimated Temperature Preference (mean and standard error)

| Species | Temperature Preference (°C) |
|---|---|
| T.bernacchii | -0.06 ± 0.46 |
| T.pennellii | 1.04 ± 0.45 |

Qualitatively, we find that the number of fish selecting the coldest region of the TPA increases in the second trial, with more (n=7) *T. bernaccii* selecting the coldest region vs. *T. pennellii* (n= 4). There was one individual *T. pennellii* which selected the hottest wedge of the TPA (~5.6°C).

## Conclusion

Both species exhibited temperature preferences above the normal background temperature of McMurdo Sound, consistent with our hypothesis of fish selecting warmer temperature to mitigate energetic burden. WHY THE DIFFERENCE BETWEEN PENLLEI and BERNACS.
Warmer thermal preferences may indicate that Antarctic species will respond positively to predicted warming

in McMurdo Sound, especially if increased warming leads to reduced energetic burdens. However, temperature preference is a singular, organisms-specific trait, whether it is predictive of a species responses to broader ecological changes and extend physiological acclimation remains to be determined.

### Potential for Field Deployment

Our design of the TPA used primarily recirculating water source and aquarium heaters. Prior iterations required flow-through supply of cold, medium and hot water sources. Our modification on the design allowed us to deploy the TPA at McMurdo Sound and could be used to measure temperature preference in field locations around the world. Being able to determine temperature preference of fish in the wild, or near-wild, can allow new questions about the interaction of ecology and temperature preference to be tested.

## Credits

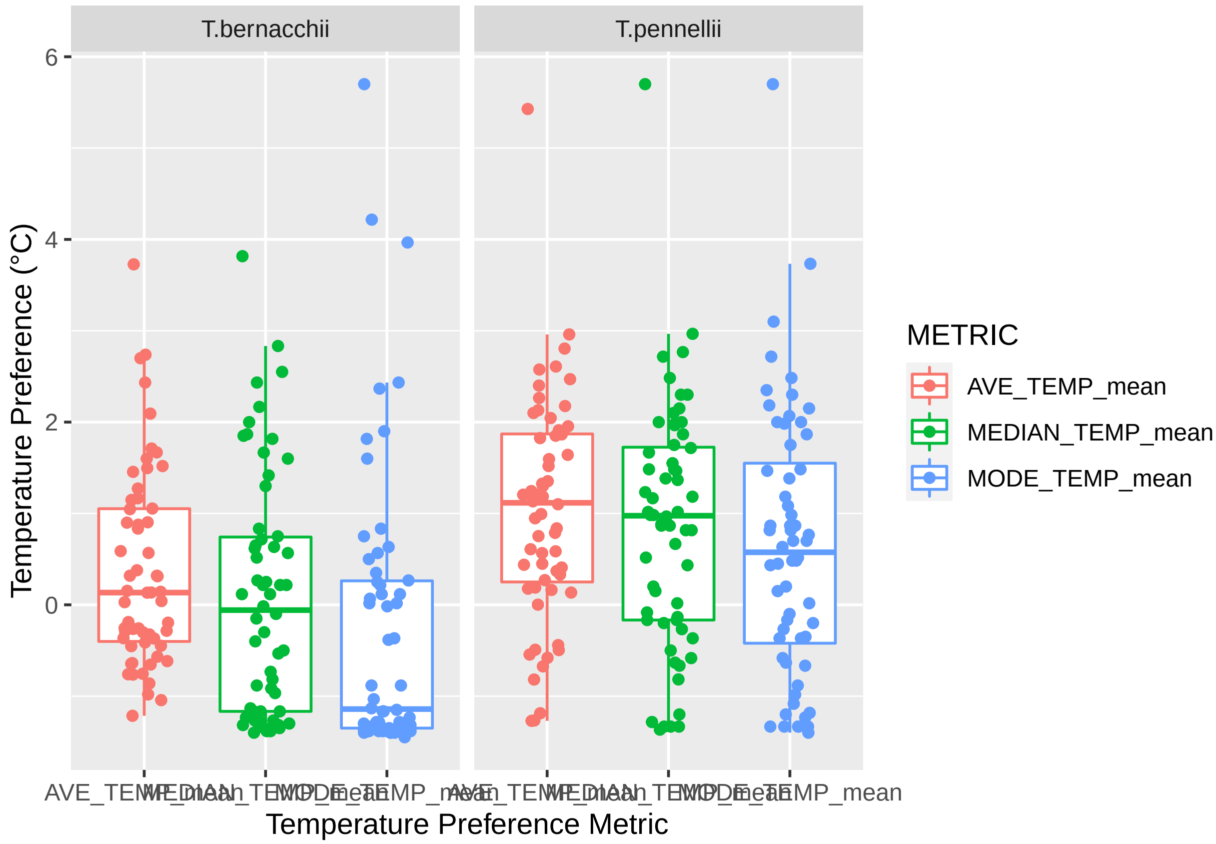
A huge thank you to Andrew Naslund, Amanda Frazier, Dr. Milica Mandic, and Dr. Anne Todgham. Additionally this work could not have been completed without the support of the McMurdo Station Crary Lab Support Staff who addressed the multitude of challenges associated with conducting work in the Antarctic. Thank you to Steve (LAST NAME) and Rob Robbins, and Mandy Frazier who braved the frigid waters to collect our research specimens. Finally, thank you to the fish of McMurdo sound without whose sacrifice we would be unable to conduct this work.

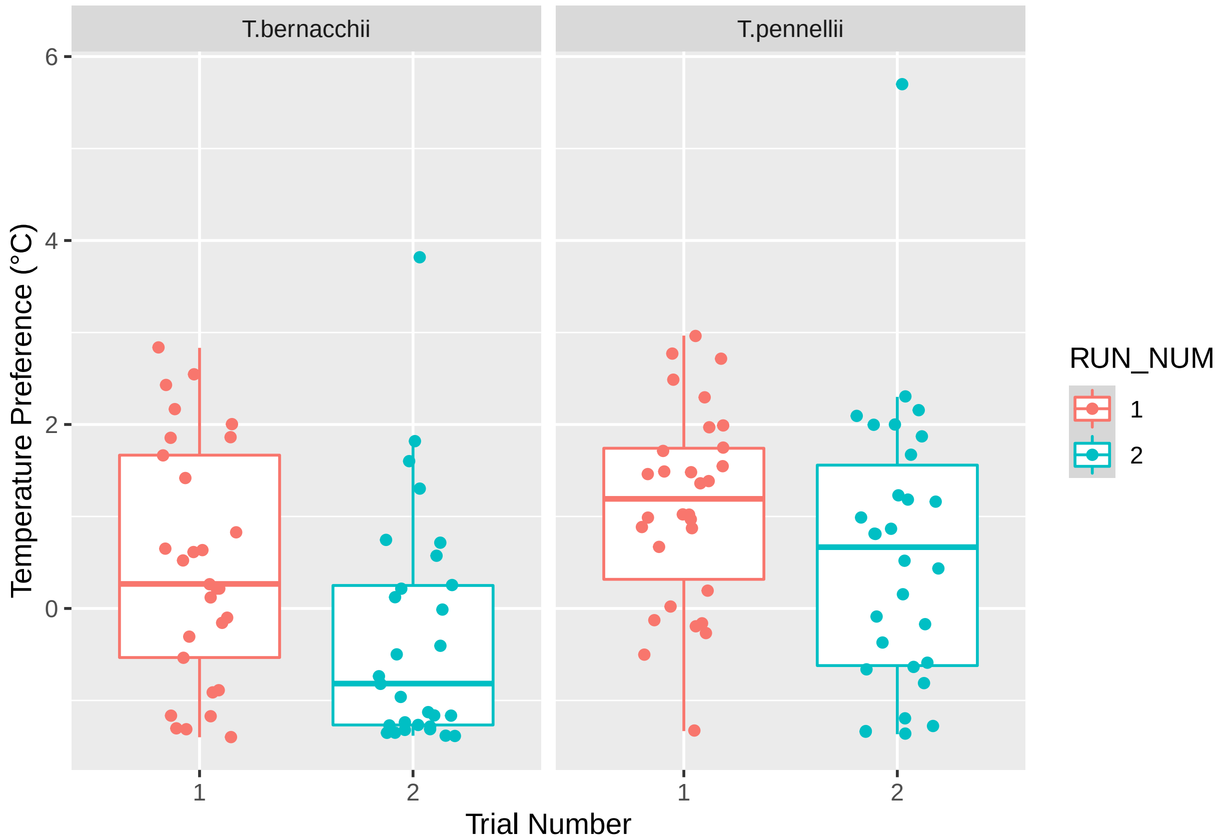
## Questions for B207

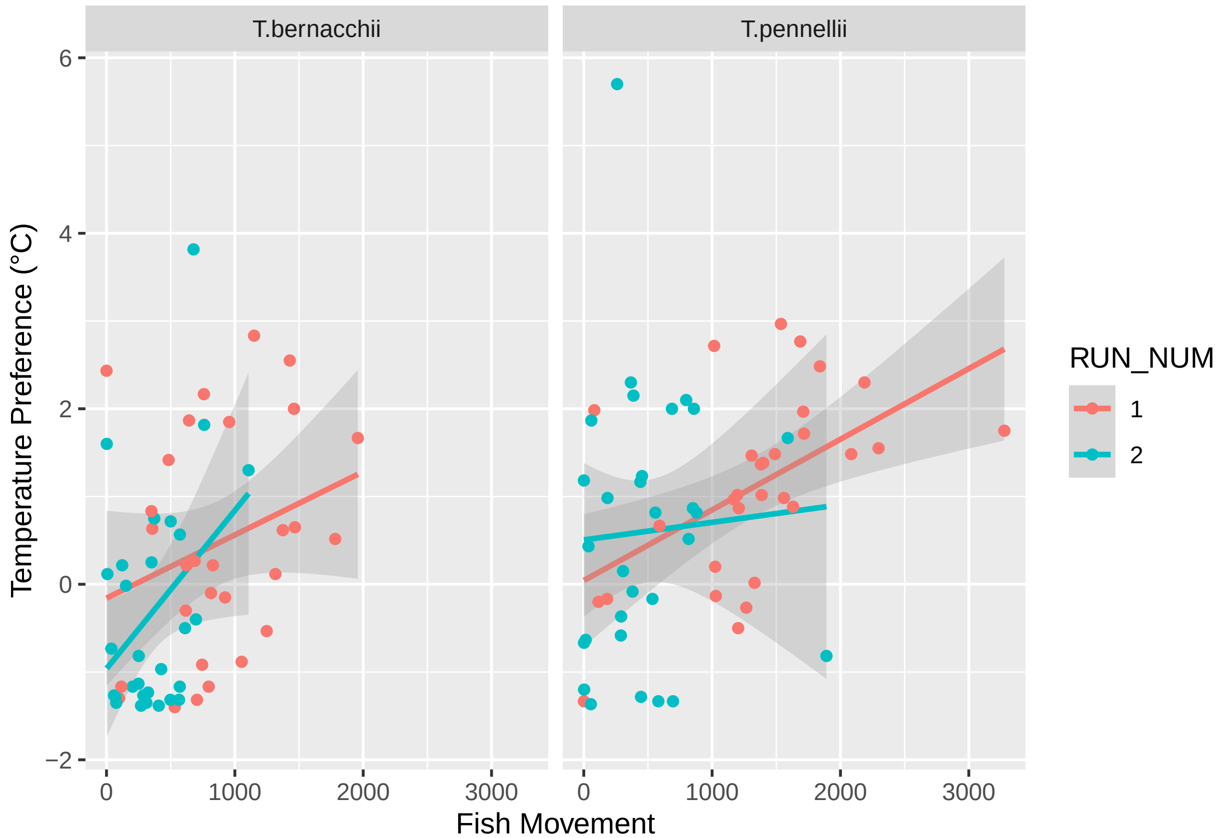
**What was Steve's last name, any other staff I should specifcally aknowledge?**

## Other Plots

Any of these seem relelvant to add to this story/poster?


T.bernacchii
T.pennellii
Temperature Preference (°C)
6
4
2
0
AVE_TEMP_mean
MEDIAN_TEMP_mean
MODE_TEMP_mean
AVE_TEMP_mean
MEDIAN_TEMP_mean
MODE_TEMP_mean
Temperature Preference Metric
METRIC
AVE_TEMP_mean
MEDIAN_TEMP_mean
MODE_TEMP_mean


T.bernacchii
T.pennellii
Temperature Preference (°C)
6
4
2
0
1
2
1
2
Trial Number
RUN_NUM
1
2




### Notes for Ken

Make link to website and other poster markdown include photo credit to the wikipekida header pic: Christopher Michel - Wikimedia, or replace with one of my pics. add affiliation