Consequences of an Altered Thermal Regime for Colorado River Native Fishes

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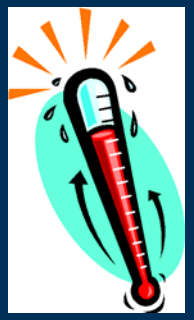
A Question that keeps resurfacing -

What controls/limits humpback chub populations around the Little Colorado River in Grand Canyon?

Which usually boils down to -

Is it water temperature or is it trout?



USGS

Is it water temperature or is it trout?

One assumption built into this question is that the mainstem Colorado River is important for HBC recruitment

(Keep in mind that lots of other things occurring within the Little Colorado River are also important for Humpback chub recruitment – spring flooding, monsoon flooding, density dependent interactions etc.)

USGS

Is it water temperature or is it trout?

My Answer -

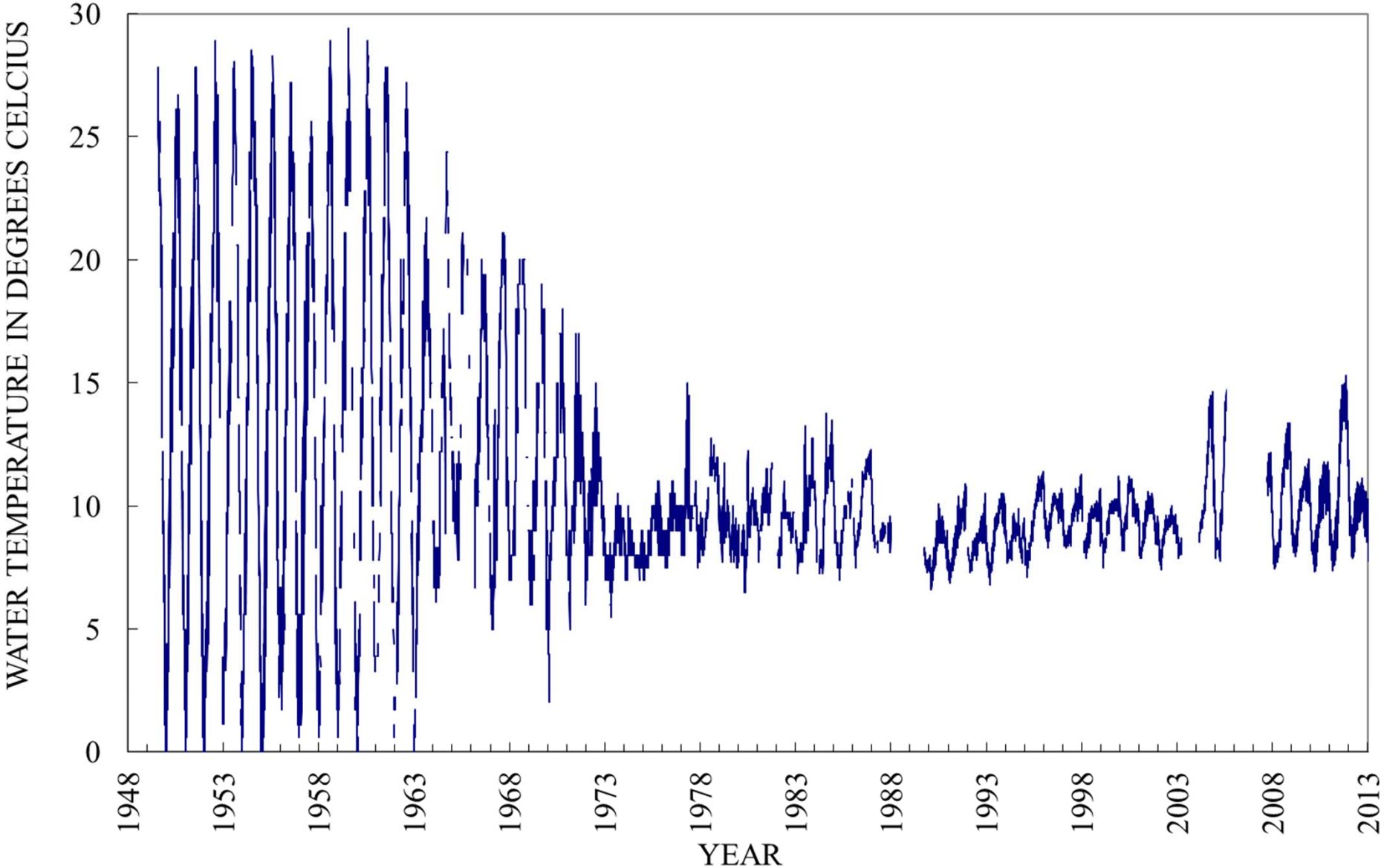
Below 12 °C its all water temperature

Above 12 °C its water temperature and trout

(And they are so linked that it does not make sense to try and separate them)

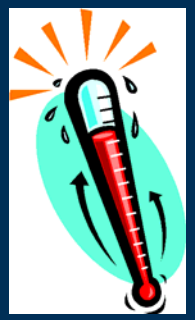
USGS

Lees Ferry Water temperature

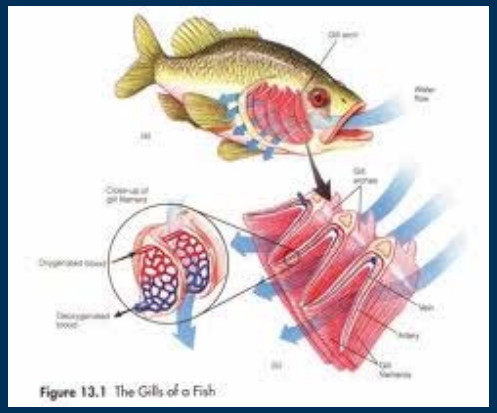


Compiled by Nick Voichick - USGS

Water temperature affects all aspects of fish life



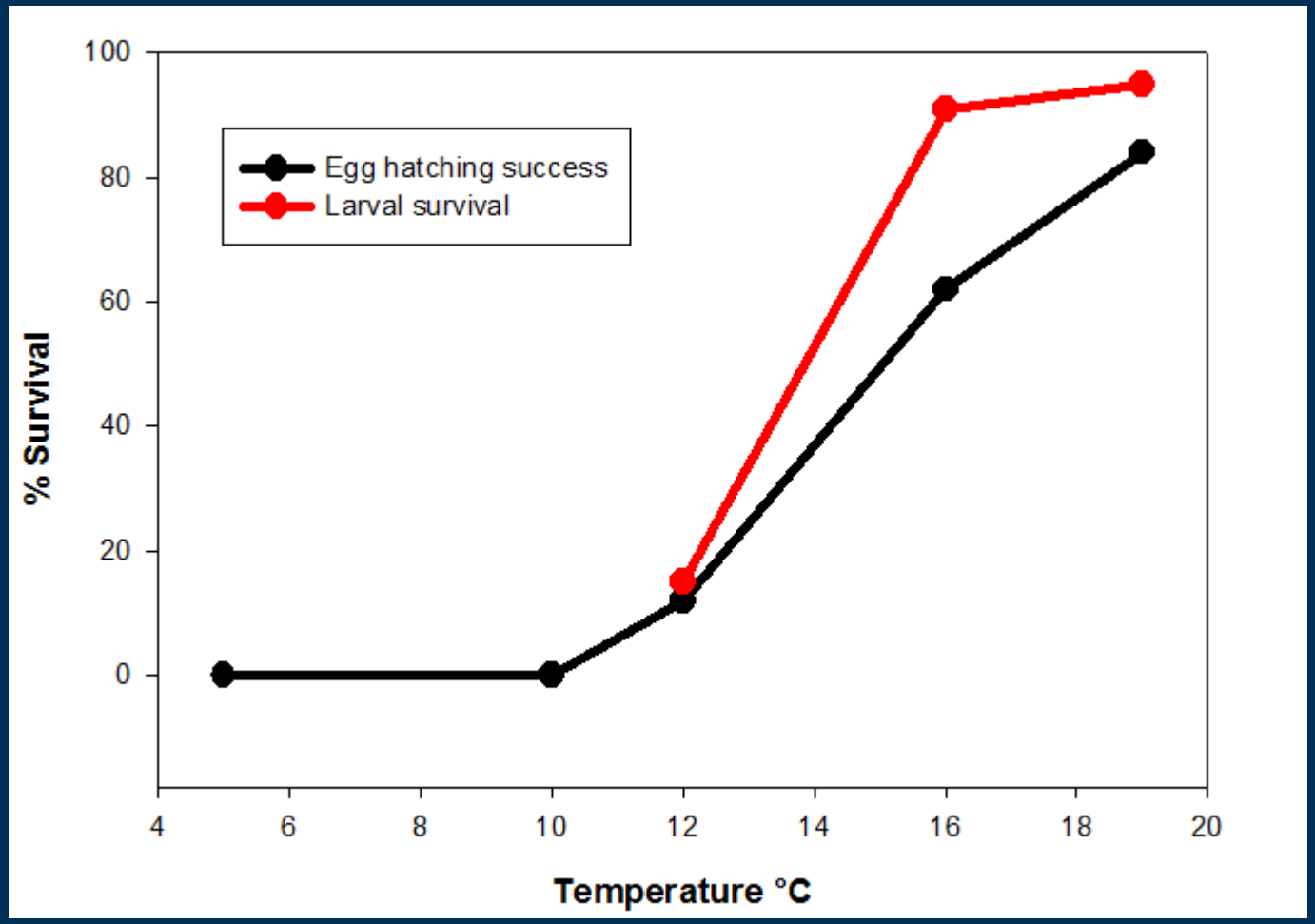
- Gamete development
- Egg hatching
- Bioenergetics/Metabolism
- Growth
- Swimming ability
- Predation Vulnerability



Gills are very efficient heat exchangers
Ensuring that all metabolic processes occur at ambient water temperature

USGS

Egg hatching/larval survival



Created from data in Marsh et al. 1985 and Hamman 1982

Growth of early juvenile HBC

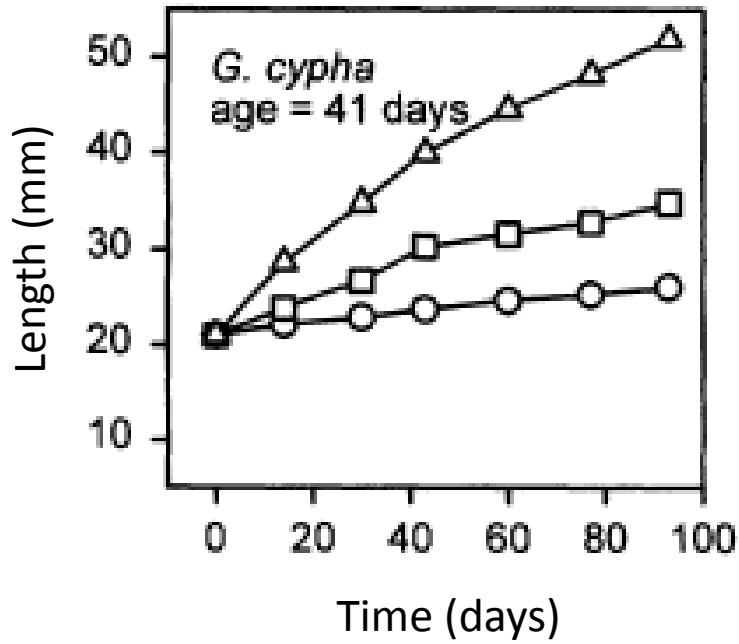


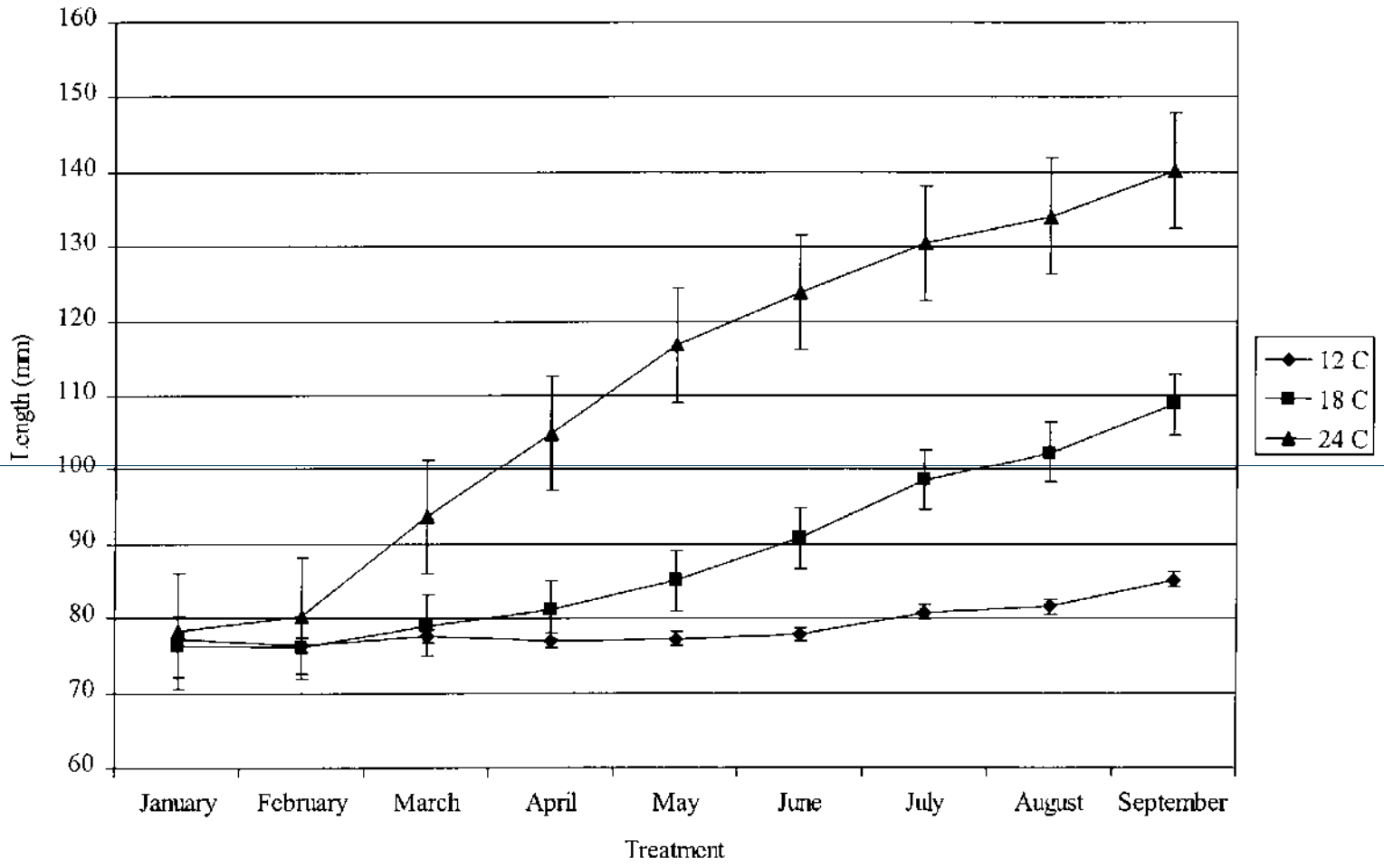
Fig. 1. Changes in length (TL) over time of early life stage big-river fishes reared at three temperatures. Points represent mean responses of each species; ages are days posthatch at initiation of experiment. Circles denote 10 C, squares 14 C, and triangles 20 C.

Clarkson and Childs 2000, Copeia 2000(2): 402- 412

"Our models indicated that age-0 fish migrating into a cold Colorado River would cease to grow" *(Based on 1991-1993 mainstem temps)*

Robinson and Childs 2001, NAJFM

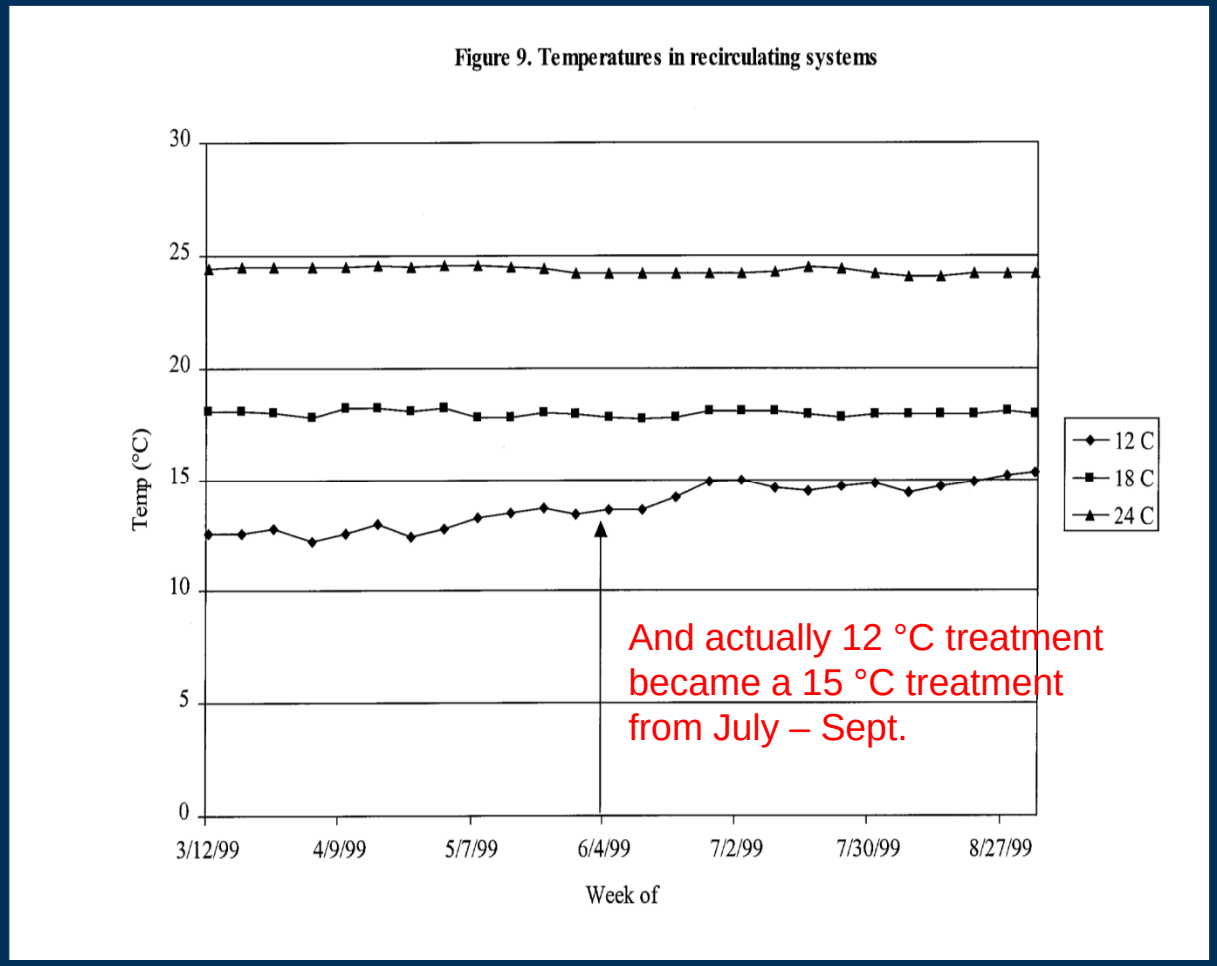
Growth of Juvenile Humpback Chub in the Laboratory



Very little growth at 12°C !

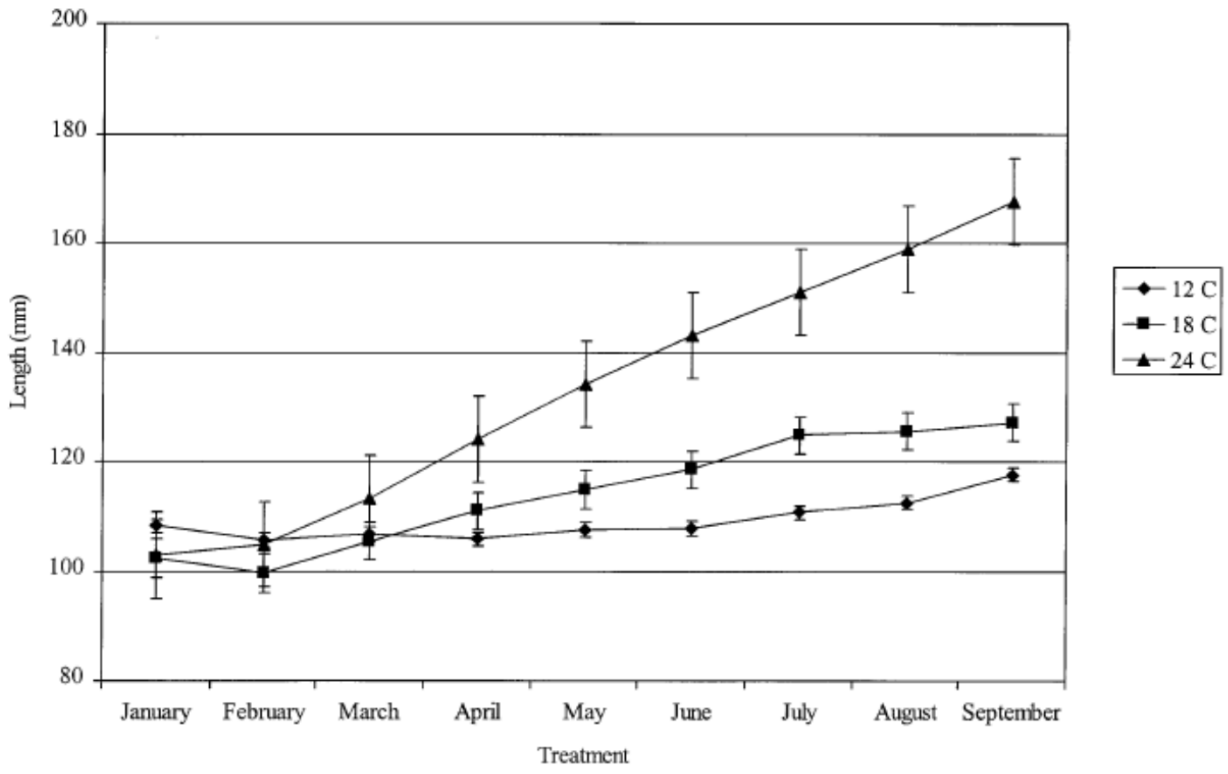
Gorman and Vanhoosen 2000

Growth of Juvenile Humpback Chub in the Laboratory



Gorman and Vanhoosen 2000

Growth of Juvenile Bonytail Chub in the Laboratory



Gorman and Vanhoosen 2000

A more recent study on growth of juvenile bonytail in the laboratory

THE SOUTHWESTERN NATURALIST 57(4): 421–429 DECEMBER 2012

THERMAL REQUIREMENTS OF THE BONYTAIL (*GILA ELEGANS*): APPLICATION TO PROPAGATION AND THERMAL-REGIME MANAGEMENT OF RIVERS OF THE COLORADO RIVER BASIN

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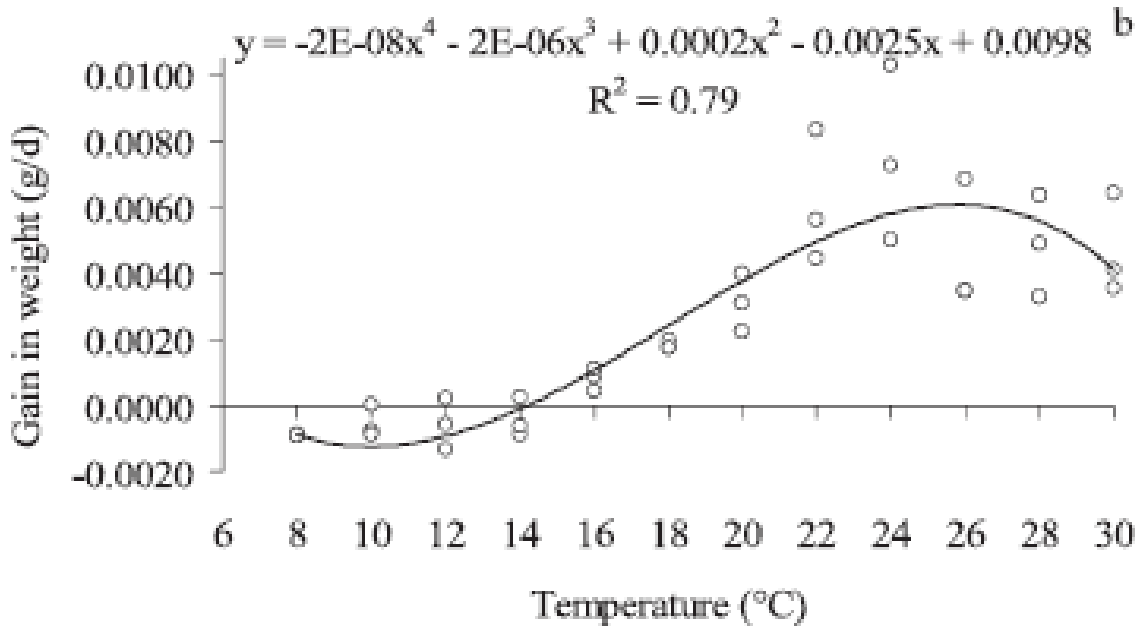
**Correspondent: kevin_kappenman@fws.gov*

Bonytail exposed to 8 – 30 °C for 112 days
3 replicate of each treatment 50-90 mm TL
40 fish per tank

USGS

No growth below 14°C



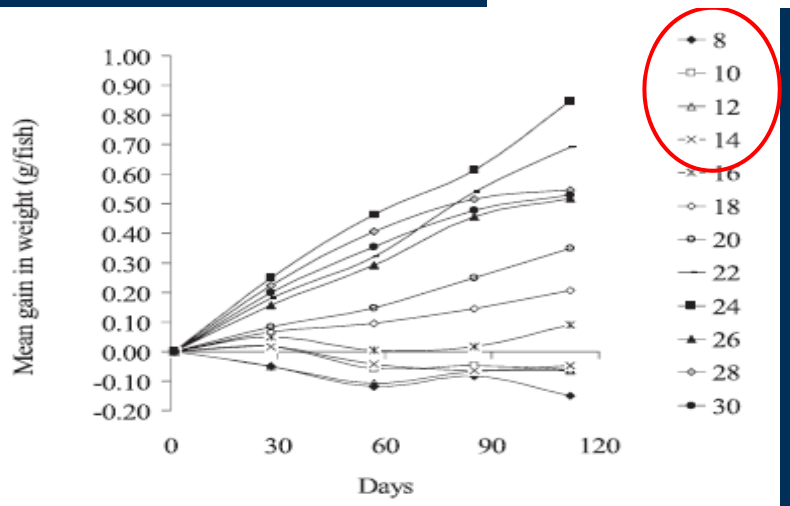


FIG. 1—Growth in mean weight (g/fish) of age-0 juvenile bonytails (*Gila elegans*) after 27, 55, 88, and 112 days of captive rearing at 12 temperatures (8–30°C). Symbols represent mean gain in weight for each treatment connected by smoothed lines.

Kappenman et al. 2012,
Southwestern Naturalist 57 (4): 421- 429

Growth of juvenile roundtail chub in the laboratory

Temperature °C ± 1	June 20, 2010 Total Length (mm) Mean Range	December 2, 2010 Total Length (mm) Mean Range	Average Growth (mm)
12.5	50.5 (40 - 65)	52.8 (40 - 68)	2.3
20	50.5 (40 - 67)	72.3 (55 - 103)	21.8

David Ward and Colton Finch – 2010 unpublished data from Bubbling Ponds Hatchery

Reared for 166 days

0.4 mm/month in Cold Water (12.5°C)

3.9 mm/month in Warm water (20°C)

Roundtail chub grown at three water temperatures in the laboratory for 9 months

C. Moran – PhD Student at NAU – 2013 unpublished data

USGS

15 °C still appears too cold for good growth of chub!

Lab data for multiple species of Colorado River chubs Indicates:

- **At temps <12 °C growth = 0**

Zero Growth = death for small chub!

It may take a while - but all small chub will die unless they grow!

Temps >15°C appear needed for good growth

USGS

In Terms of Bioenergetics

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Consumption = Metabolism + Waste + Growth

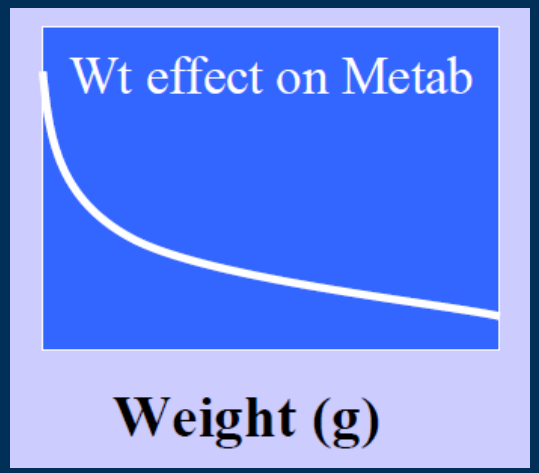


Figure adapted from Dave Beauchamp, U.S.GS

Why ?

– Metabolic rate is affected by fish size!

USGS

Kleiber's Law

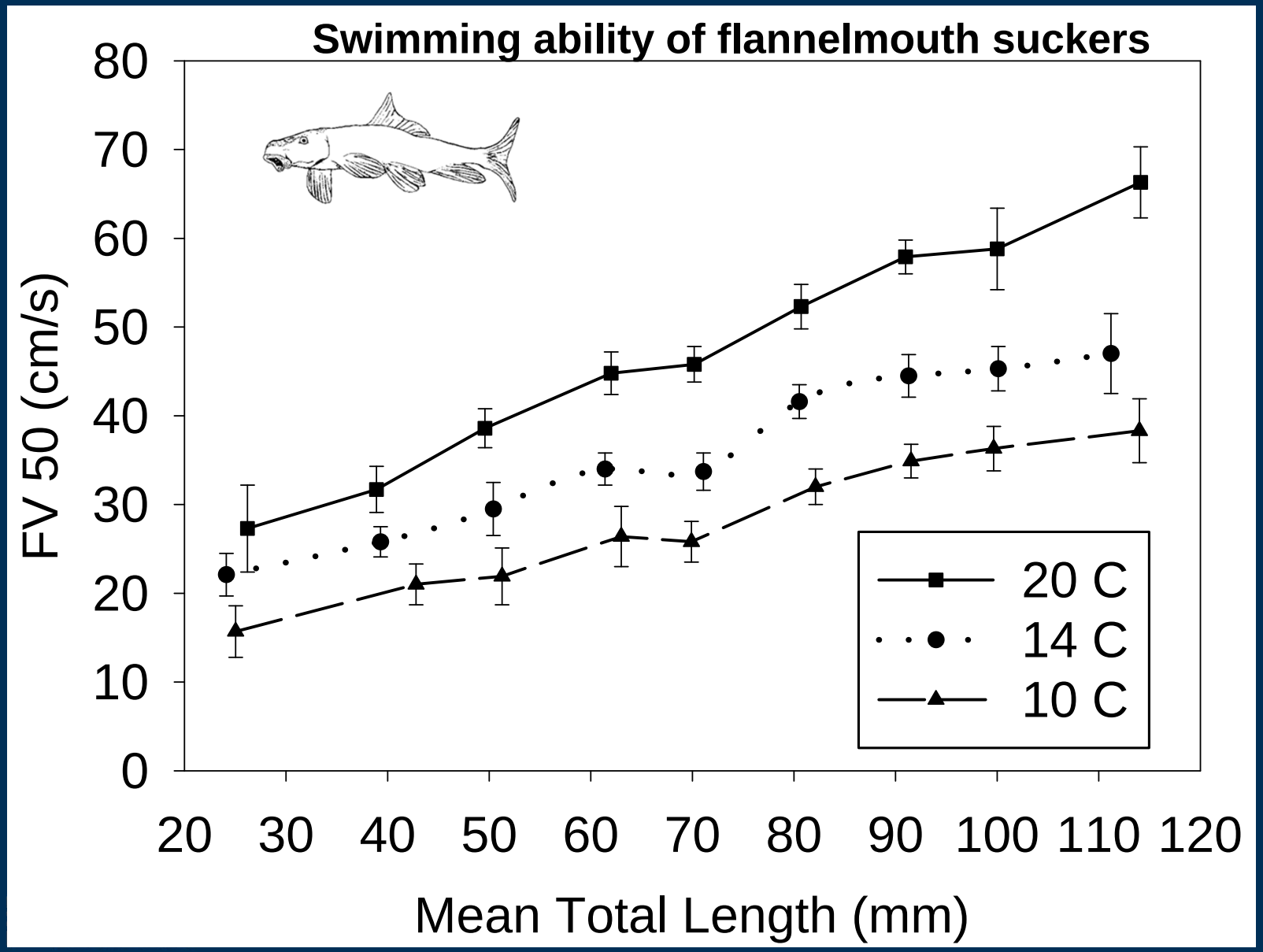
- **Larger individuals have relatively lower standard metabolic rates than smaller individuals – true for both endotherms and ectotherms**

For example: A 3kg salmon has a standard metabolic rate that is 1/5th that of a 1 g fry

Pritcher and Hart Fisheries Ecology, 2000

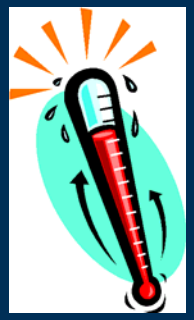
USGS

Water temperature also effects swimming ability



Ward et al. 2002, *Transactions of the American Fisheries Society*

Water temperature affects all aspects of fish life



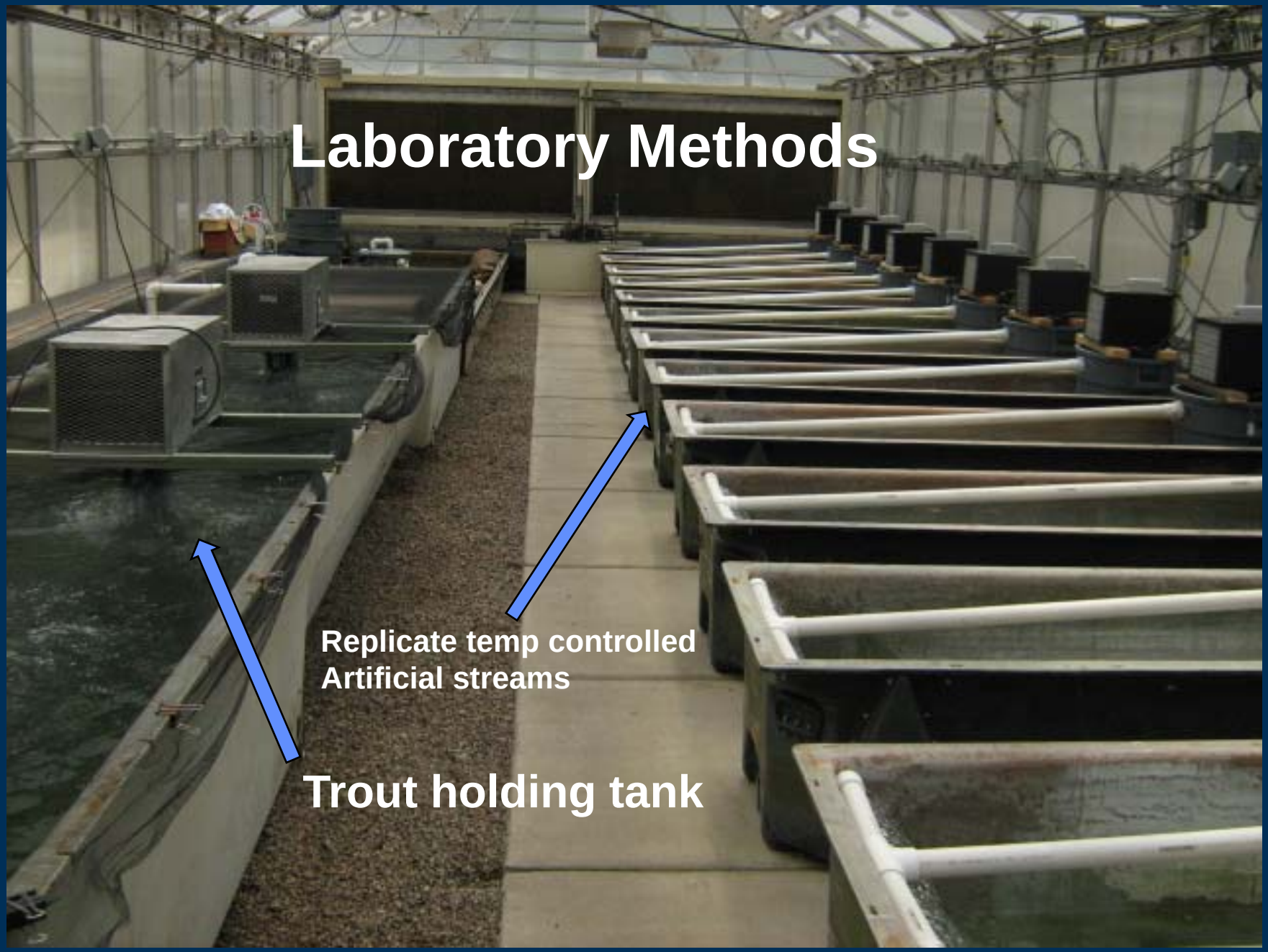
- ✓ Gamete development
- ✓ Egg hatching
- ✓ Bioenergetics/Metabolism
- ✓ Growth
- ✓ Swimming ability

- Predation Vulnerability

USGS

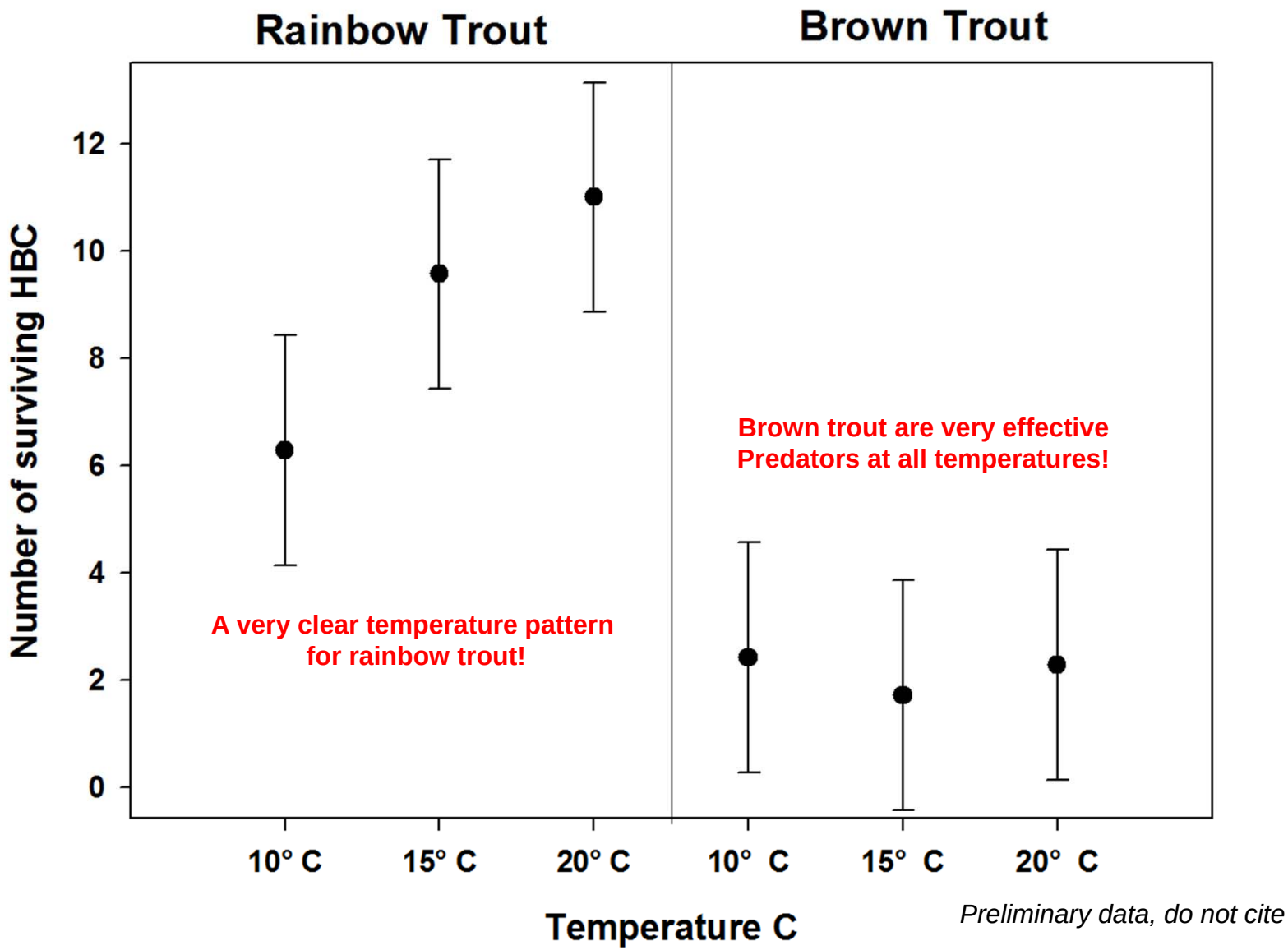
How does water temperature affect predation vulnerability?

USGS


Laboratory Methods
Replicate temp controlled
Artificial streams
Trout holding tank

Laboratory Methods

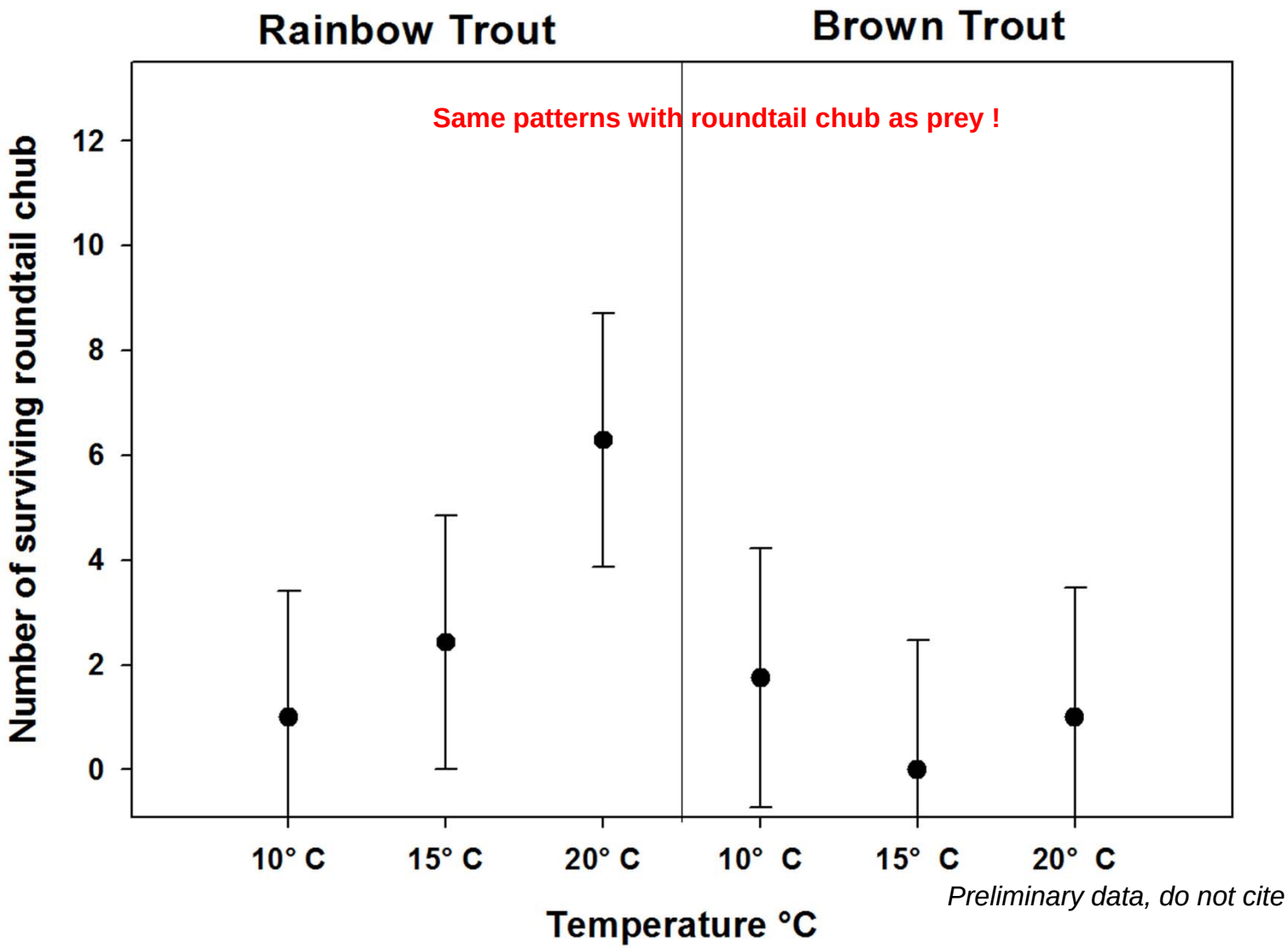
- 4 trout predators per tank
- 12 chub prey per tank (in baskets)
- Allowed to acclimate for 24- h
- Baskets tipped – Live fish counted 24 h later



Preliminary data, do not cite

Each point = 10 overnight trials, Error bars = 95% confidence intervals

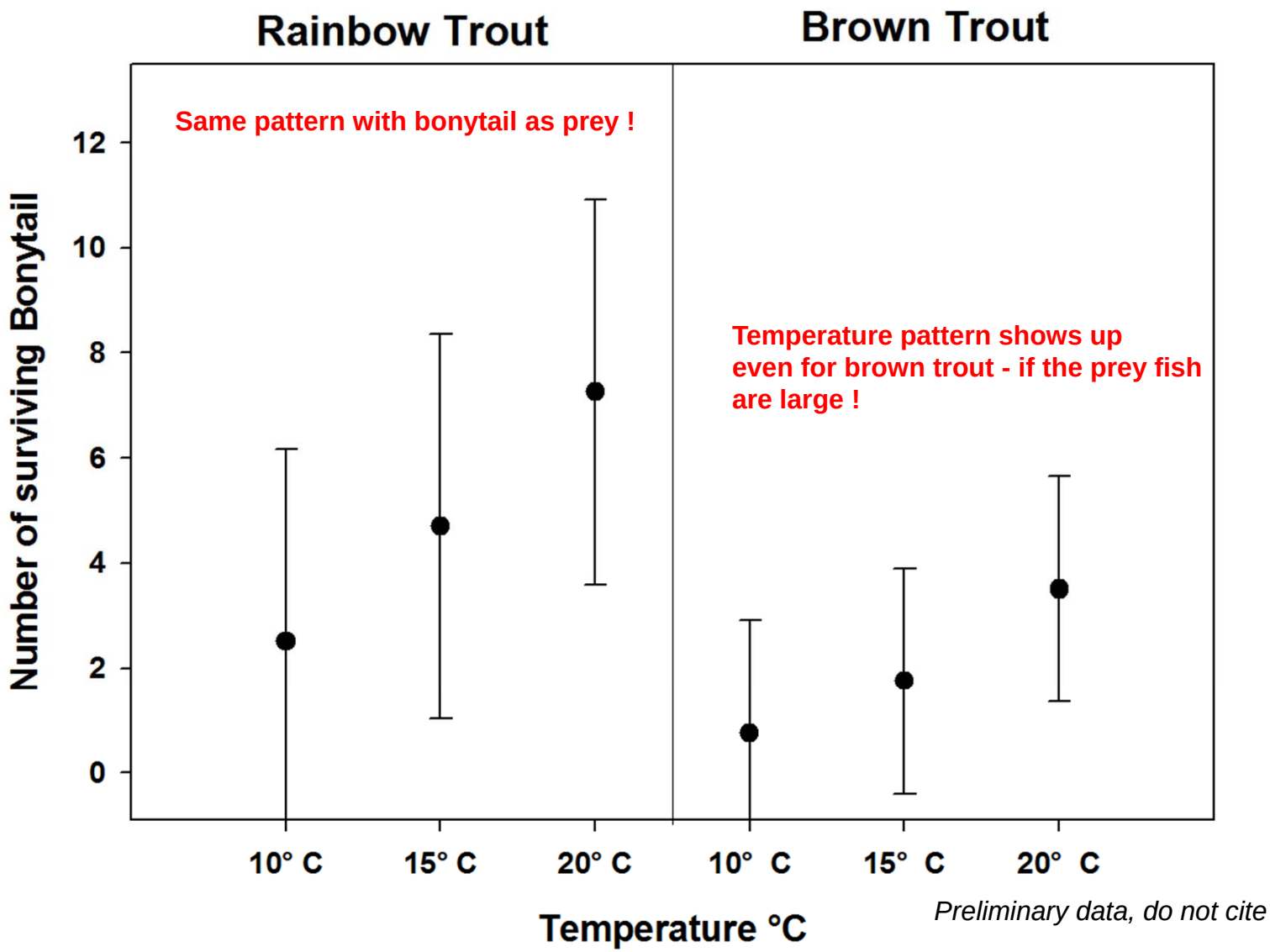
HBC mean size = 63 mm, Rainbow trout mean size = 328 mm, Brown trout mean size = 280 mm



Preliminary data, do not cite

Each point = 4 overnight trials, Error bars = 95% confidence intervals

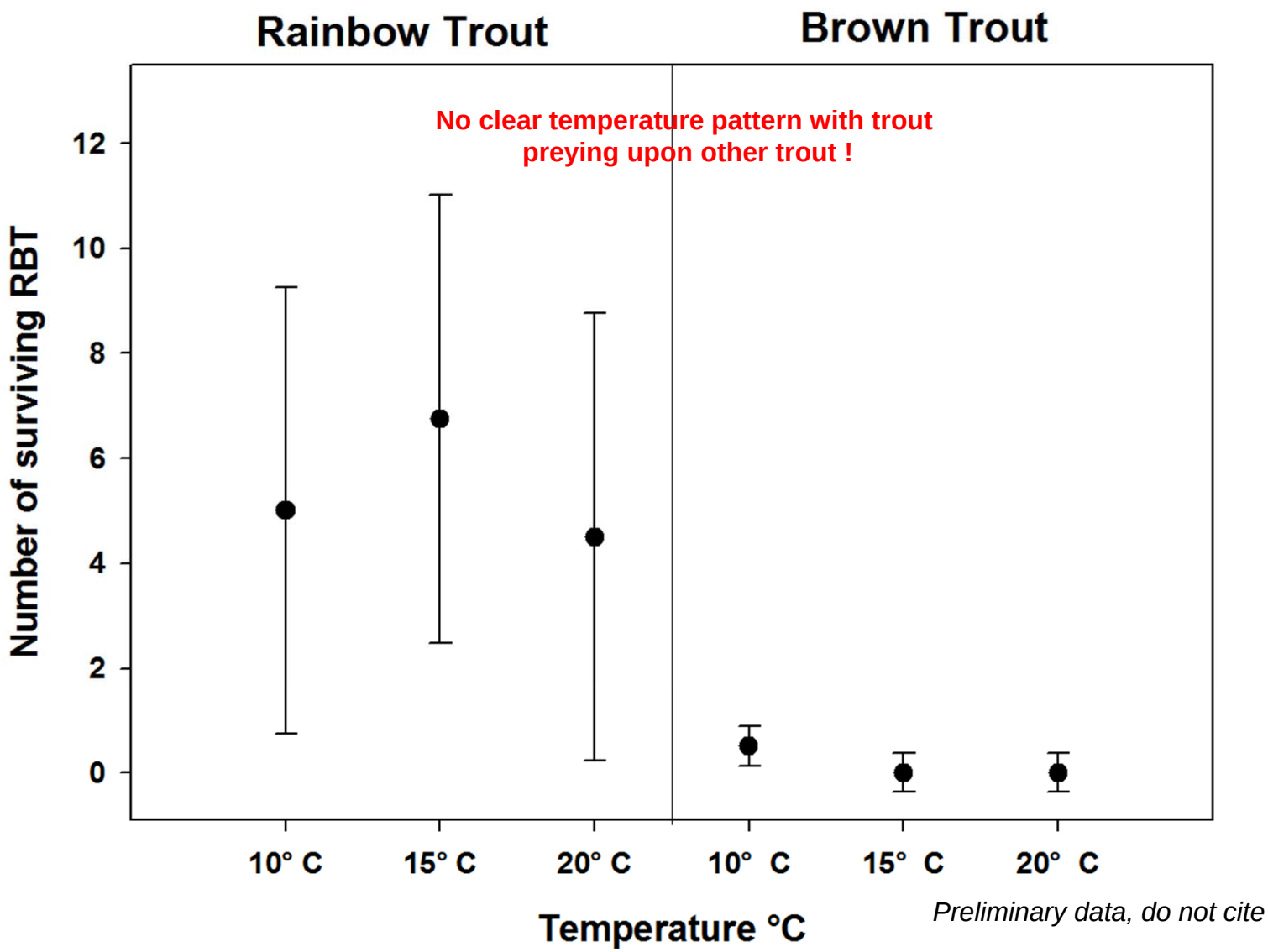
RTC mean size = 55 mm



Preliminary data, do not cite

Each point = 4 overnight trials, Error bars = 95% confidence intervals

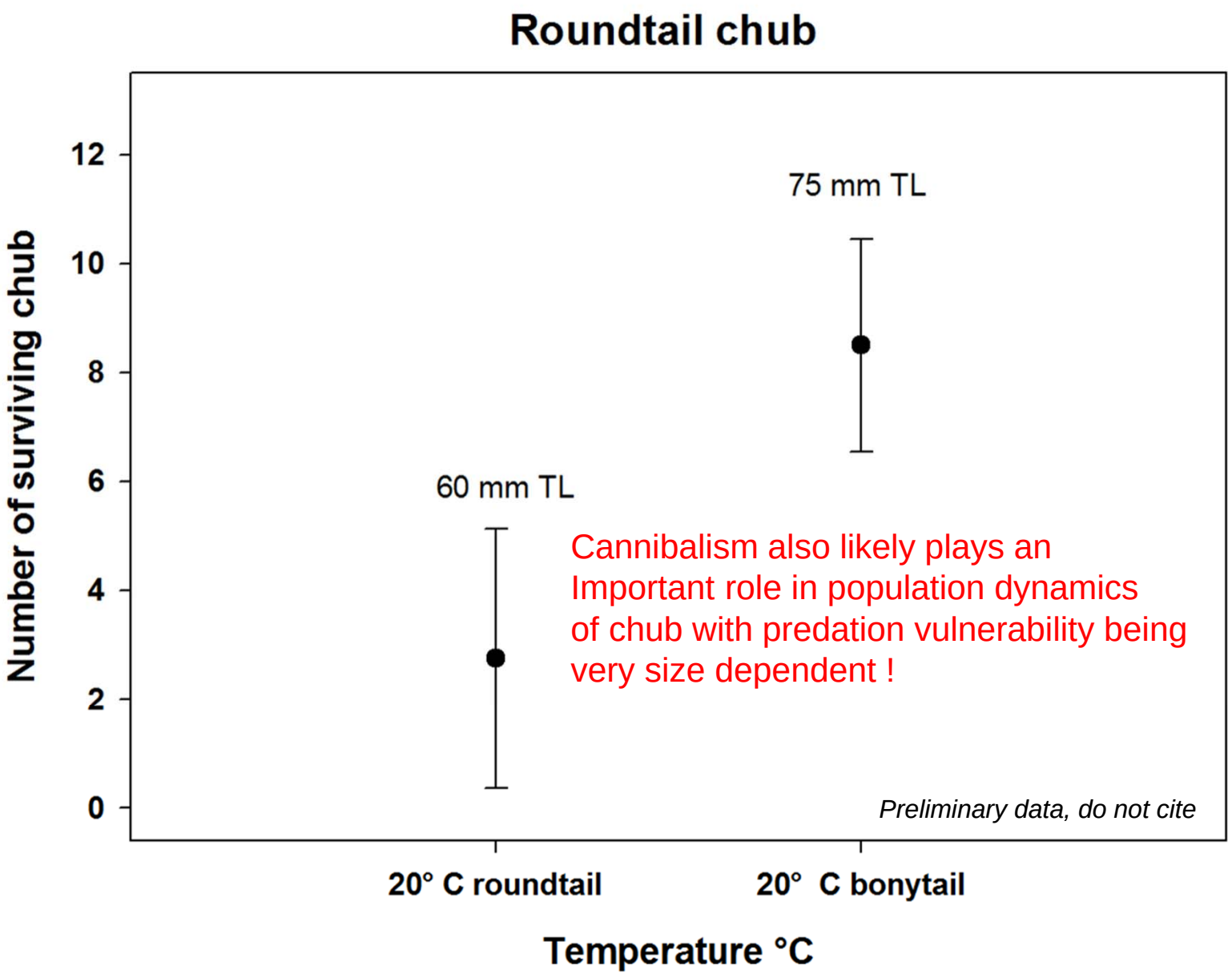
BTC mean size = 75 mm,



Preliminary data, do not cite

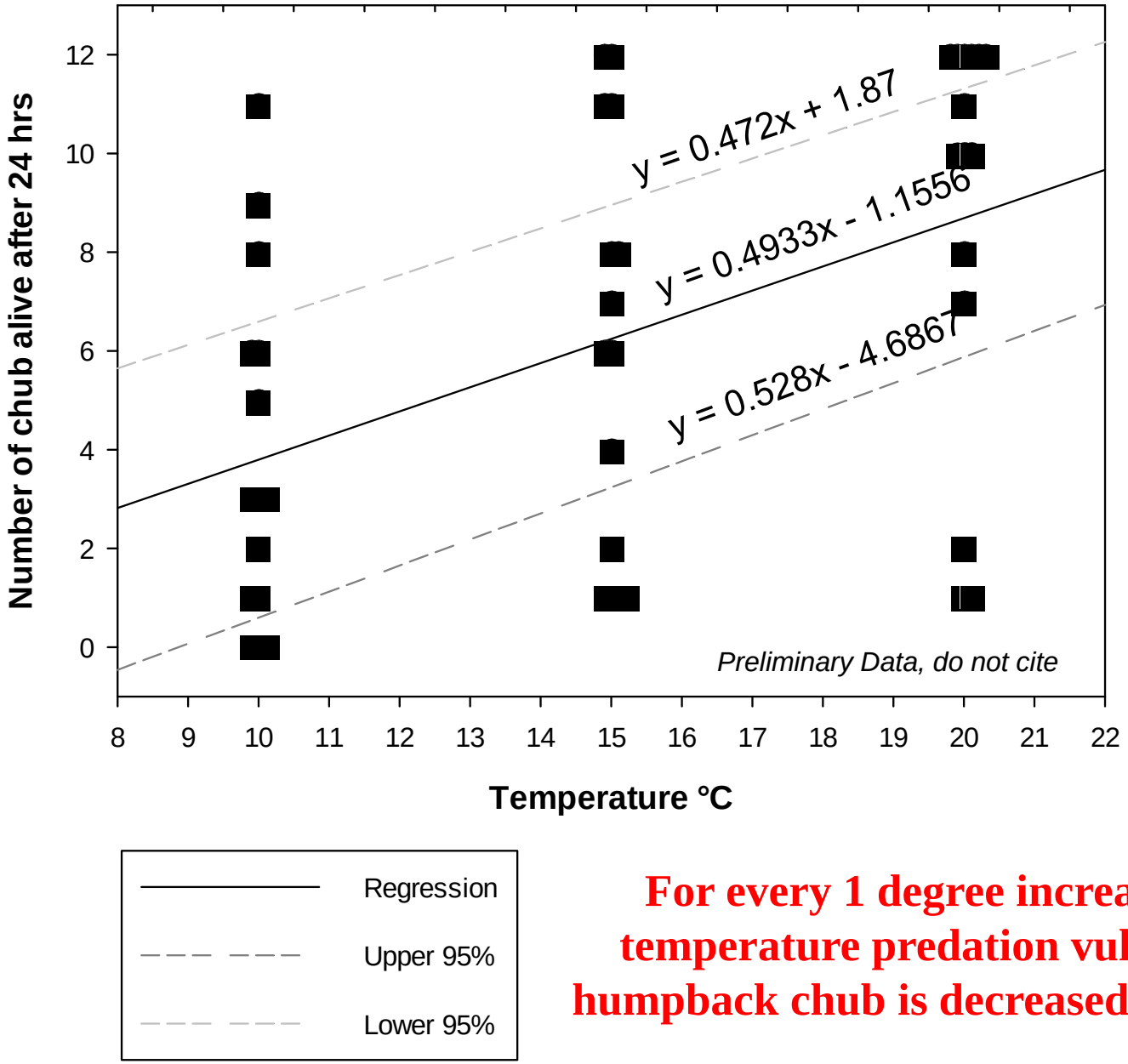
Each point = 4 overnight trials, Error bars = 95% confidence intervals

RBT prey mean size = 65 mm,



Each point = 4 overnight trials, Error bars = 95% confidence intervals

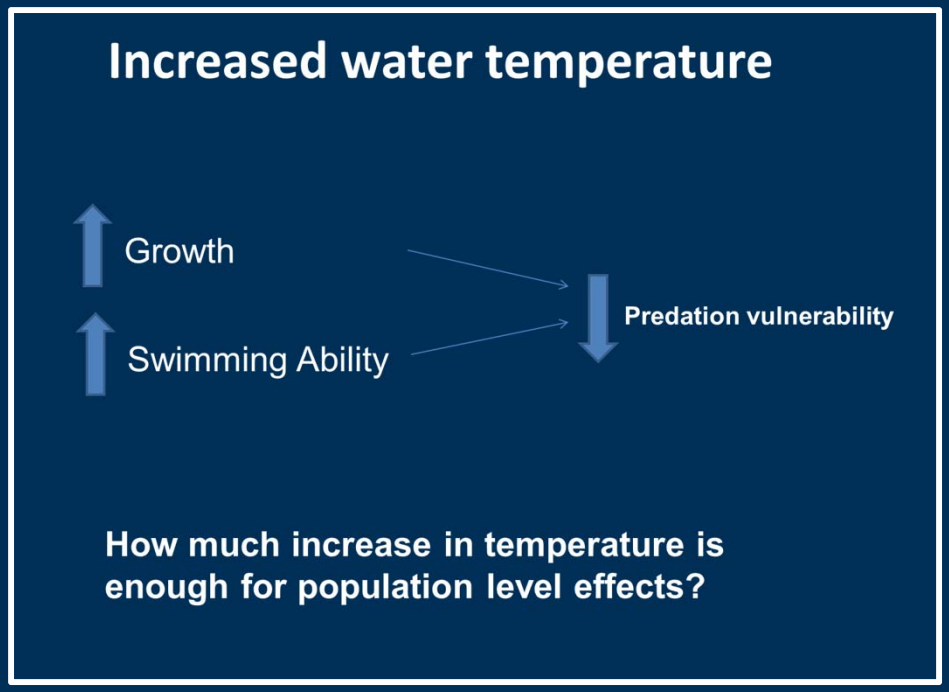
Summary of all Laboratory results for rainbow trout predation on chub



For every 1 degree increase in water temperature predation vulnerability of humpback chub is decreased by about 5% !

The Lab data does not tell us what humpback chub predation vulnerability is in the mainstem of the Colorado River

- but the lab data does tells us how it likely varies with temperature!



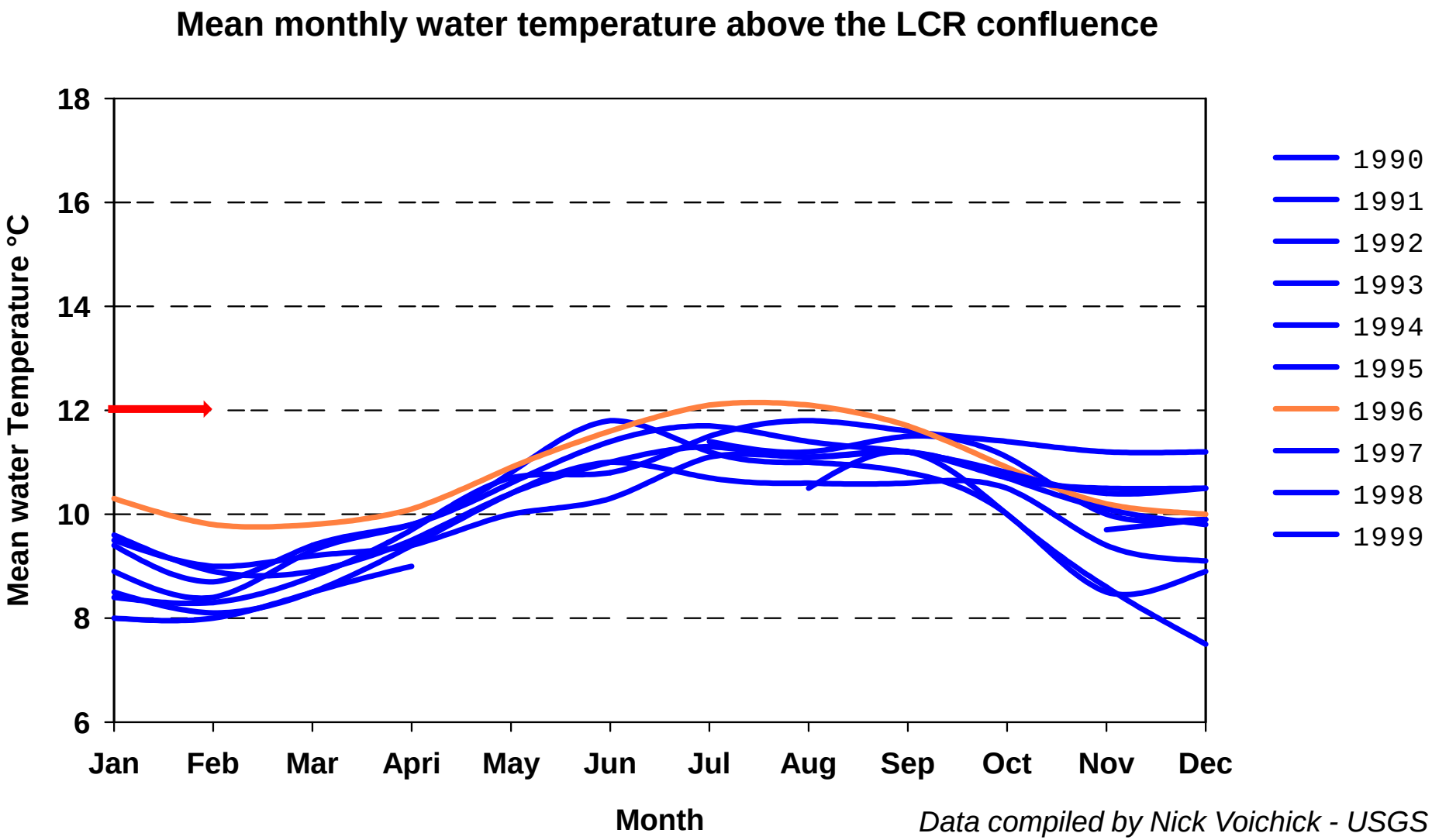
USGS

What does all of this mean?

Lets attempt to put all the pieces together!

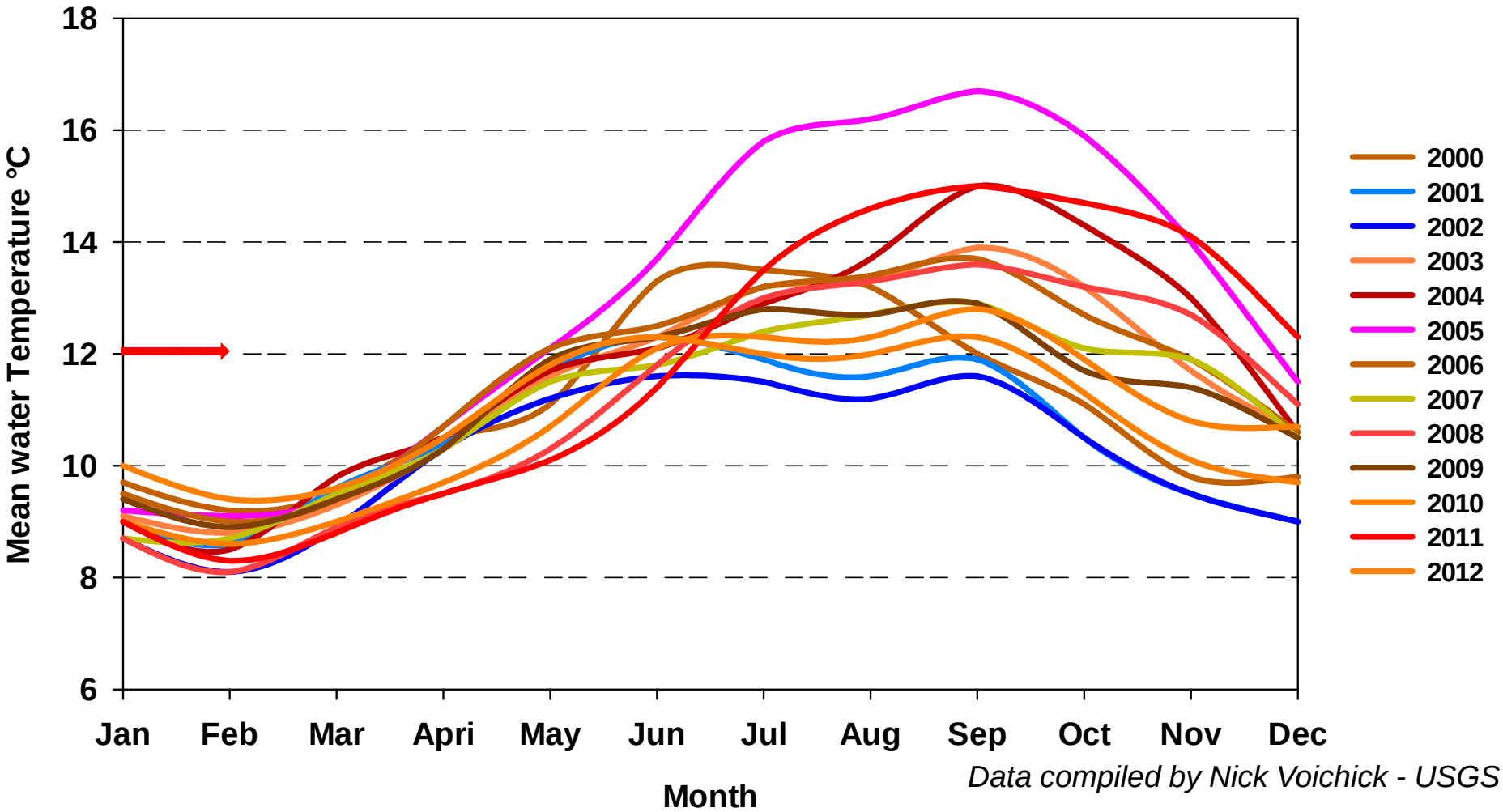
(In relation to the water temps we see in the mainstem Colorado River at the confluence of the Little Colorado River)

USGS



10 years of cold water !

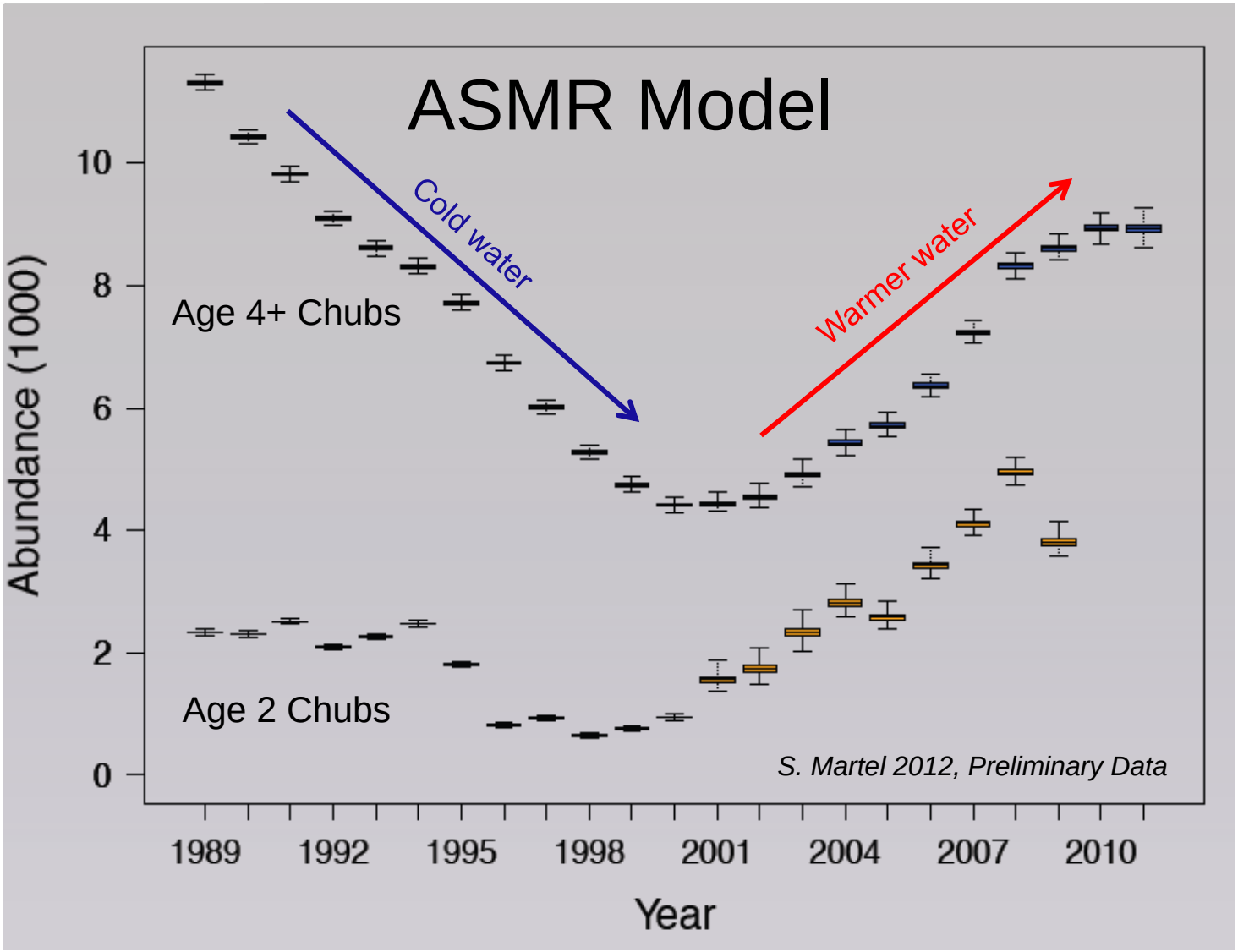
Mean monthly water temperature above the LCR confluence



Data compiled by Nick Voichick - USGS

10 years of warmer water !

HBC trends appear to have responded to temperature differences



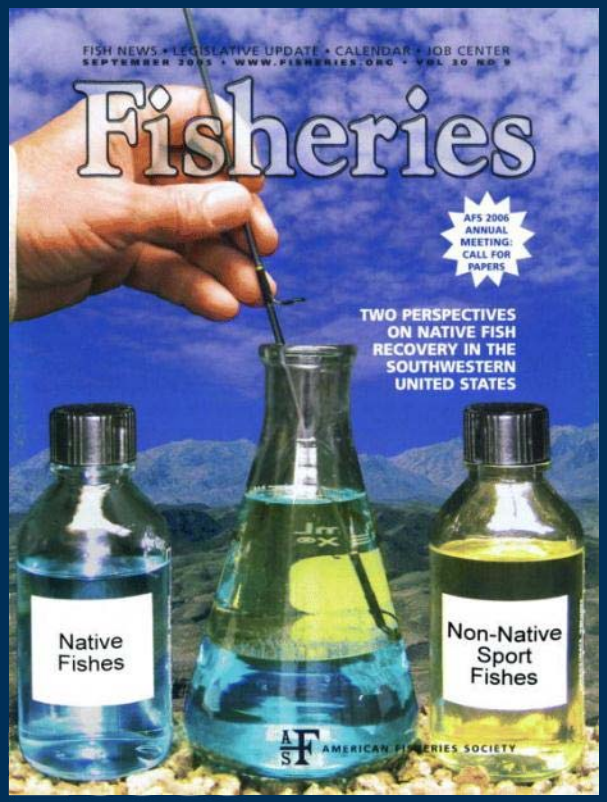
Native fish currently appear to be doing quite well in the mainstem Under the last 10 years of warmer water !

School of flannelmouth suckers at RMI 145

Photos taken on Grand Canyon Youth Trip in 2012

But too warm is also bad

- **Warm water non native fish and warm water native fish will not coexist at the same location for very long!**



Marsh and Pacey 2005
Clarkson et al. 2005
Mueller 2005

Lots of examples throughout
The southwest in multiple rivers

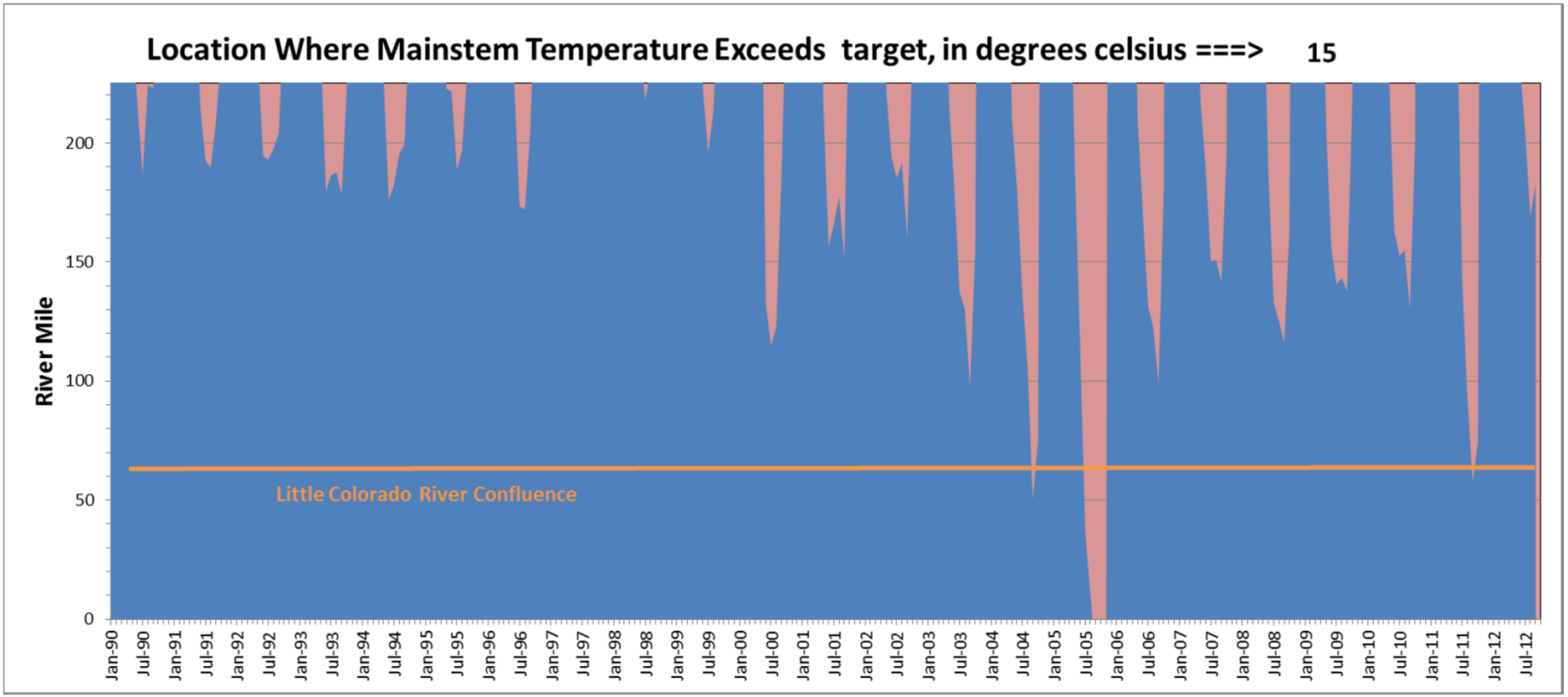
Temperature Conundrum for Colorado River Native Fishes

Cold Water < 12°C is Bad (physiological effects) vs **Warm Water > 16°C is Bad (Invasive fish effects)**

If it persists !

USGS

What about warm water every once in a while ?



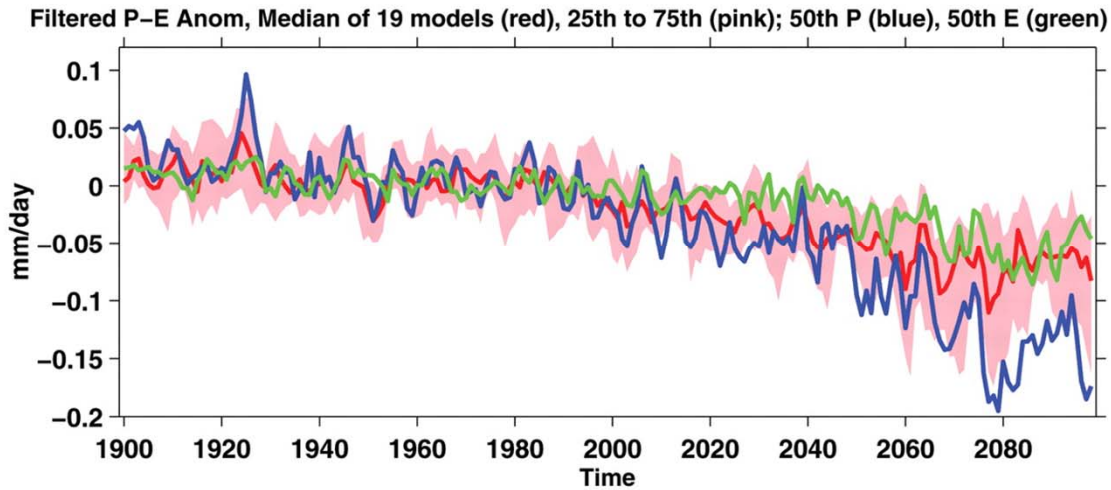
Long life span of Colorado River native fishes allows for interval between warm water events to be relatively long

6 years between warmer water events in recent years !

But what about climate change and drought induced warming?

- Climate forecasts indicate: Continued drying in the southwest

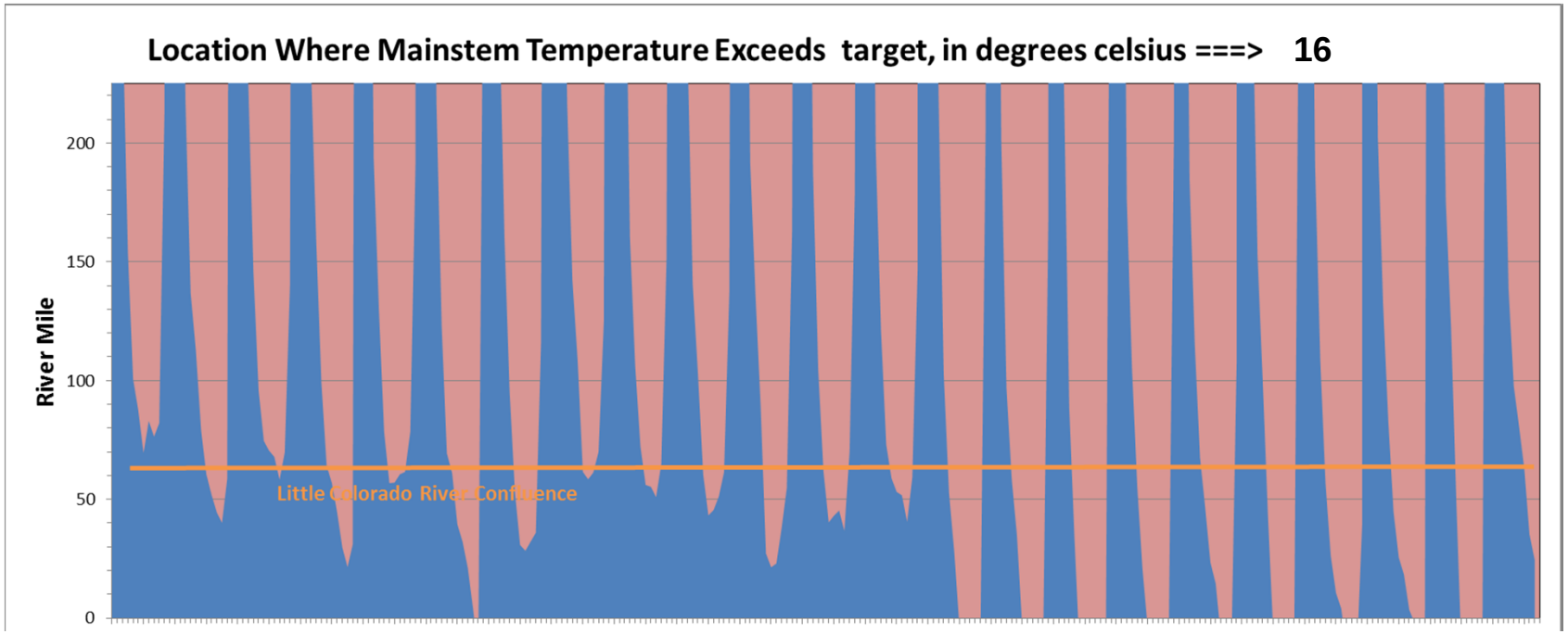
Fig. 1. Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125°W to 95°W and 25°N to 40°N, land areas only), averaged over ensemble members for each of the 19 models.



R Seager et al. Science 2007;316:1181-1184

Published by AAAS

If the future looks like this we may be in trouble !



Time

Introduced fish will become established!

Conclusions

- Continuous cold water (<12 ° C) is detrimental to native fish populations

- For every 1 °C increase in water temperature predation vulnerability of humpback chub is decreased by about 5%

Conclusions

- Interval of drought induced warming may play a critical role in the persistence of native fish in Grand Canyon

- Cold water most of the time - although detrimental to Grand Canyon native fishes, may be the best way to conserve them