Cool Fish 😊
Summary

. Introduction

. A minute of "history"

. Goodeid keeping and breeding (my own experience)

. Water temperature

. Lessons and plans for the future

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Introduction

Ideas to retain:

- For each living organism there is a thermal death point. High and low temperatures that are lethal to a species determines the natural distribution of it’s individuals and the adaptation to new environments.
- In addition to the organism survival, growth and reproduction have critical temperature ranges too.
- The effects of temperature upon life of a poikilotherm organism (cold blooded) are profound.
- The body temperatures of poikilothermic animals, such as fish, follow closely the temperature of their medium.
- Functional and biochemical rates are largely correlated with water temperature.
Cool Fish - Introduction

Ideas to retain:

➢ Temperature influences on fish physiology are numerous. From enzymatic reactions through hormonal and nervous control to digestion, from respiration and osmoregulation to all aspects of body performance, or even behavior.

➢ Actually, many "cold-blooded" animals, and fishes in particular, thermoregulate behaviorally and not physiologically.

➢ In relation to the survival of individual fish, the maximum critical temperature and minimum critical temperature, that define the total temperature gradient for the species, may be surpassed in rare cases. They represent temperatures that species can tolerate only for minutes to less than one hour long (lethal level).

➢ The range where species can survive more than minutes or hours is limited by minimum sub lethal temperature or incipient lower lethal temperature and maximum sub lethal temperature or upper incipient lethal temperature. This is also the warning thermal frontier.
Cool Fish - Introduction

Ideas to retain:

➢ Within this temperature gradient, are the temperatures of physiological stress. Inside these limits, fish activities are limited by temperatures that, in addition, can produce discomfort or even failure of important body systems.

➢ The period of time that a fish can live under physiological stress is straight related with how far the temperature is from the lethal level.

➢ Right in the middle of total temperature gradient for the species, there is a range in which the species can function at or near optimum. Ideal or optimal temperatures are roughly bordered by the incipient lethal temperatures array.

➢ This lecture purpose is to share with you my experience on the attempt to assess the compatibility of the local climate regarding some Goodeid specie’s thermal request. This has never been a way of pushing the fish’s temperature tolerance to the limits, as a way to acclimatize them or to search for evidence of a “non-natural” thermal adaptation!
Cool Fish - A minute of "history"

By the age of 6 years old, this was my first "fish"... raised (held) in jars (1971)

Image source: http://www.fotonatura.org/galerias/fotos/398594/
Cool Fish - A minute of “history”

By the age of 7 years old, this was my second “fish”... that suddenly born from enigmatic eggs that inexplicably have come to light in one of the containers. (1972)

Image source: Botha, Vidette; 2014, Ecomorphological guilds and diet of exotrophic anuran tadpoles
Cool Fish - A minute of "history"

... after all the second "fish" species it was not yet a fish either!?! 😞

Afrixallus aureus - Sapo Dourado (Golden Banana Frog)

Image source: http://frogmap.adu.org.za/ (A. Sharp)
Cool Fish - A minute of “history“

By the age of 7 years old, this was my first collected (real) fish species... kept and bred with success in (small) containers outdoor (from 1972 to 1975).

Poecilia reticulata - Guppy

Cool Fish - A minute of “history”

Between the age of 7 and 10 years old these were the fish species kept in a number of creative solutions (containers) outdoor in Mozambique:

✓ **Ambassis natalensis** - Slender Glassy
  [I have never got any offspring at all. Kept from 1973 to 1975]

✓ **Astronotus ocellatus** – Oscar (introduced; established in a public garden fish pond)
  [returned back to the public garden fish pond after I realized the species’ predation skills 1972]

✓ **Brycinus imberi** - Spot-tail Characin
  [I have never got any offspring at all. Kept from 1972 to 1974]

✓ **Nothobranchius orthonotus** – Spotted or Mozambique Killifish (rare - only in far rural areas)
  [Kept once (for 3 months in 1973) and never got offspring]

✓ **Oreochromis mossambicus** - Mozambique Tilapia
  [I have got breeding success over 2 generations. Kept from 1973 to 1975]

✓ **Poecilia reticulata** - Guppy (introduced; found a little bit every where in urban areas)
  [I have got breeding success over several generations. Kept from 1972 to 1975]
Cool Fish - A minute of “history”

Between the age of 12 and 28 years old...

✓ My first “real” aquarium it was a birthday present. It was a 25 litre water volume tank (1977)
✓ My first fish species kept in Portugal it was *Iberochondrostoma lusitanicum* (1977)
✓ My second fish species kept in Portugal it was *Gambusia holbrooki* (from 1979 to this date)
✓ My first tropical “community” fish tank it was a home made with 60 litre water volume (1981)
✓ My first garden fish pond it was hollowed by me and it was 8m x 4m x 0,60m (1983-1995)
✓ My largest water management (1993) > +/- 63.000 litres
  1 Fishpond - 8m x 4m x 0,60m (32m² and around 19.200 litres)
  1 Fishpond - 7m x 2m x 0,60m (14m² and around 8.400 litres)
  1 Fishpond - 3m x 3m x 0,90m (9m² and around 5.400 litres)
  1 Fishpond - 6m x 4m x 1,10m (24m² and around 26.000 litres)
  1 Children swimming pool - 2m x 2m x 0,40m (2m² and around 1.600 litres)
  2 Tanks with 25 litre water volume at an improvised fish room inside my father's garage
  1 Tank with 60 litre water volume at an improvised fish room inside my father's garage
  1 Tank with 80 litre water volume at an improvised fish room inside my father's garage
  1 Tank with 100 litre water volume at an improvised fish room inside my father's garage
  1 Tank with 300 litre water volume at an improvised fish room inside my father's garage
  1 Tank with 80 litre water volume at my own sleeping room

Miguel Andrade viviparos@viviparos.com
Cool Fish - A minute of “history “

From the age of 12 years old and the present date...

✓ 24 species kept (and many reproduced with success) between 1977 and 2004 in indoor aquarium (tropical stenotherm species). The shortest experience took place with *Nothobranchius guentheri* (6 months) and the longest one with *Amatitlania nigrofasciata* (15 years and over 20 generations). Most of these fish species were preserved and reared for more than 6 continuous years.

✓ 20 species kept and raised with success between 1977 and today in outdoor fish pond culture (temperate eurytherm species). The short experience was with *Pethia conchonius* (2 years) and the longest one with *Gambusia holbrooki* (39 years). From all these, 4 are indigenous species (and some endemic): *Cobitis paludica, Iberochondrostoma lusitanicum, Squalius alburnoides, Squalius pyrenaicus*, while 6 others are (unfortunately) introduced (typically invasive): *Australoheros facetus, Carassius auratus auratus, Cyprinus carpio, Gambusia holbrooki, Lepomis gibbosus* and *Micropterus salmoides*.

✓ From 1985 to this date, some fish ponds and the children´s swimming pools, were managed as multipurpose containers, specially prepared for fish breeding, either for tropical stenotherm species (from May to October), as well as for some temperate stenotherm species (from March to November or from March to June and again from September to December). Only a very small number of fish species were kept continuously in aquaria (4 species) and never had the chance to experience an outdoor period for breeding or simply to enjoy the benefits of a larger habitat in semi-natural conditioning.
In 1989 I discovered a new (at least for me) wonderful fish family throughout the available literature!...

✓ These fish species were, nonetheless, always absent from pet shops offer.

✓ No other hobbyists in Portugal, known by me, had the slightest suspicion about their existence.

✓ Internet (as we know it in the present) was still on the scientific fiction books and not available for commercial users.
Cool Fish - A minute of “history “

Red-tailed Goodeid

*Xenotoca eiseni* RUTTER, 1896

The live-bearing Red-tailed Goodeid (1) inhabits inland waters of the upland plain of Mexico, particularly the Río Lerma water systems. It was imported to Germany in 1974. Females grow to as much as 9 cm; males are somewhat smaller. Members of the family Goodeidae differ from common live-bearers of the family Poeciliidae in the morphology of their sexual organs and in their embryonal development. The male’s mating organ (andropodium or pseudophallus [2]) was formed through a transformation of the anterior part of the anal fin, while its posterior part has remained unchanged. Ripe females may be recognized by their enlarged ventral parts and the swollen region adjacent to the sexual orifice. They are removed into breeding cages made of a network of meshes 5 × 5 mm in size. The water should be clean, medium-hard, with a neutral to slightly alkaline reaction and a temperature of 22—24°C. The number of young varies from 20 to 60, depending on the female’s development level. The interval between the births of individual litters is six weeks, each birth being accompanied by a new insemination. The females are cannibalistic.

As the eggs of these fish contain only a small supply of nutritive yolk, the embryos draw nourishment from their mother’s body by means of embryonic appendages, the so-called trophotaeniae, which are connected to the ovarian mucous membrane by villi. The trophotaeniae are observable in the young only shortly after birth; they are quickly absorbed.

The Red-tailed Goodeid likes to attack other piscine species, biting off their fins. This is why fish of this species should be kept separately. Their diet is miscellaneous.

A closely related fish is the *Ameca splendens* (3), bearing a name derived from the river Río Ameca. Its natural habitat is in the waters on the Mexican upland plain near the city of Guadalajara.
Cool Fish - Goodeid keeping and breeding (my own experience)

Why do I have a predilection for fish ponds?... and some essential ideas.

From the core idea or motto of my website:

“Any living pet (and fish in particular), must be held under the original habitat conditions simulated as possible, including: enough room, correct balanced diet, suitable water chemical values, as well as other original ecological parameters replication, whenever we raise them in any man made setting”.

✓ Species with especial needs of conservation should get more attention and care. Animals and plants who are currently endangered, threatened or already extinct in the wild, should be assisted and preserved with extreme caution.

Rule n.º 10 of my “10 Basic Rules for Sustainable Aquarium Hobby (suggestion)”. You can find it at my website here: http://www.viviparos.com/Aquariofilia/rules.htm
Why do I have a preference for keeping threatened species in fish ponds?

From the core idea or motto of my website:

“I hardly believe, from the deepness of my heart, that, unquestionably, the best place for any fish to be and to exist is where it belongs... on the wild waters where the species has been shaped by natural selection, during its natural evolution”.

✓ However... threatened species may only survive in *ex situ* safeguard, while the natural habitat it is not recovered and “healthier”, in order to receive them back again.

✓ In such case... hobbyists and institutions can help to “save” fish species from extinction while keeping long-term sustainable groups (minimum viable population) from segregated wild populations with identified original collecting location.

Miguel Andrade  viviparos@viviparos.com
How can we achieve such goals as those sentenced at my website?

The garden fish pond or the greenhouse pool is no doubt better than any conventional indoor aquarium to threatened species conservation?

- Water volume is often frequently quite larger (more room) in fish ponds or greenhouse pools than in indoor aquaria.
- Outdoor fish ponds are submitted to the valuable and positive natural light and other environmental elements that greenhouse pools and indoor tanks can’t benefit.
- Outdoor fish ponds are more vulnerable to fish predation and the local climate must be as “compatible” as possible with the one of those species' provenience.
- Outdoor fish ponds and greenhouse pools are more problematic regarding environmental control (particularly temperature adaptations), than indoor tanks.
- Fish tanks allow better and more comfortable observation, environmental parameters control and surveillance, than fish ponds or greenhouse pools.

In conclusion: garden fish ponds or greenhouse pools and conventional indoor aquaria are all required for a suitable conservation setup!

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My first approach (2004-2012):

In order to gradually dedicate myself, ever more and in a serious manner, to threatened species, giving up the ordinary hobby’s offer, my idea was to attempt a fish community composed by a small number of species (December of 1999).

✓ My selection of species had in mind those adapted to the garden ponds size and environment, taking into consideration each pond environment and the data base with daily temperature data recordings (collected by me since 1985, once a day).

✓ Besides local endangered endemic small cyprinids, there was not much offer at all. On the other hand, most of the local threatened species are protected by law, so they have become slowly “inaccessible” to hobbyists.

✓ Internet groups dedicated to serious fish keeping were uncommon in 1999. Threatened species were unreachable within the Portuguese hobbyists community.

✓ Killifish enthusiasts were the rare exception of a group keeping threatened species.

Brief note: in 1998 the Portuguese Killifish Association (APK) was on the way and had become a formal society in 2000. The first Convention was held in 2001... but only in 2005 I became aware about this society’s existence. My membership started in 2006.

Miguel Andrade viviparos@viviparos.com
My first approach (2004-2012):

Phase I: the first endeavour was to convert the fish community. On the transition period of 5 years I have adapted the fish ponds to the new model (1999-2004):

- Meanwhile, *Ameca splendens* and "*Xenotoca* eiseni" become available for the first time in the aquarium hobby in Portugal. A large pet shop in Lisbon imported both species from Germany, in 2004, and from Czech Republic in 2005. I started to test my first colonies in aquaria on the 100 litre mono-species tanks.

- After 2 years of successful reproduction, some older fish and fry surplus started to be slowly released on the 26,000 litre fish pond, from late February to October.

- Some fish have escaped the October’s collecting actions and overwinter outdoor successfully, starting my temperature tolerance investigations with Goodeids.

- As these fish were from unknown populations and accessible on the fish trade, an increasing number of specimens from both species, started to be left on the fish pond on purpose all year round, after 2006, for temperature tolerance assessment.

- On the fish pond predation on new-born and young Goodeids was serious and an obstacle to population demography (extremely low recruitment).

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My first approach (2004-2012):

Some advents:

✓ Thanks to Paulo Alves I met João Gomes who donated me *Skiffia multipunctata* (Lago de Camécuaro) and *Characodon lateralis* (Ojo de Água de San Juan)… the remaining 2 Goodeid species kept in Portugal, back in 2005.

✓ *Skiffia multipunctata* was successfully raised on a *mix system* (indoor aquaria wintering from early November to late February and outdoor breed on the children’s swimming pool, from late February to early November).

✓ *Ameca splendens* and "*Xenotoca*” spec. *cf. eiseni* were also raised on the same *mix system* (indoor aquaria wintering from October to late March and outdoor bred on the fish pond, from late March to October).

✓ *Characodon lateralis* was raised on a 100 litre mono-species tank all year round.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My first approach (2004-2012):

The end of phase I:

✓ In 2007 my hobbyist activity suffers a significant roll-back. All the pet fish, except for those on the fish ponds, were donated to other colleagues in the course of that same year.

✓ After an accidental release of a single *Skiffia multipunctacta* female fry on the process, in one of the fish ponds, I have noticed that she was still alive all through the next 5 years (2007-2012). In the meantime the remaining fish of this species that were donated by me to other colleagues, in 2007, didn’t survive. Not a single one of them was able to maintain the species after my endowment.

✓ The *Characodon lateralis* outdoor winter trial was never attempted by me. This decision was based on the available information regarding the species minimum sub lethal temperature and following an unsuccessful experiment made by another colleague on a garden fish pond, in the Algarve Province.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My first approach (2004-2012):

Phase II: the revival of fish keeping hobby thanks to Goodeids and to the GWG in particular:

✓ Following the invitation to the GWG membership, in 2009, I have gained access to new species as well as to some of those on my “most wanted list” in particular.

✓ On the Pont L' Eveque meeting, in 2011, Dominique Dumas has donated me some specimens of *Skiffia multipuntacta* (Lago de Camécuaro) and I had the chance to win the bid for a *Xenoophorus captivus* (Jesus Maria) pair, from Jacques Sabatier. Michael Koeck also has donate me a pair of *Xenoophorus captivus* (Illescas).

✓ Since 2011, Michael Koeck, Kees de Jong, Laurent Gogulski, and more recently Liliana Cardoso and Gonçalo Costa (*Goodea atripinnis* captured on the expedition to Mexico in 2015), along with some convention’s auctions, have allowed me the honour of keeping (for longer or shorter periods), as far as 8 species of Goodeids.

✓ From 2004 to 2012 the selection of the species and populations had in mind the information about temperature tolerance available in Internet (up-to-date).

✓ On my first approach, the new fish were simply released on a fish pond. Prior to that release there was a quarantine indoor stage of a few months (the first winter).
My second approach (2013-2016):

After a few disappointing results, some urgent measures were taken...

✓ A new outdoor fish pond, specifically conceived for Goodeids keeping was planned and build in 2011. To test the thermal behaviour of this pond, it was first colonised with *Cyprinodon alvarezi* on an attempt to reproduce the species.

✓ From 2012 on, no more Goodeid species were introduced on the 26.000 litre fish pond due to predatory success on Goodeid’s new-born and young by other species earlier introduced.

✓ On the “second approach” the new fish species are breed first in aquaria. Only part of the “F1” generation adults are selected to evaluate the species (and population) tolerance to local climate. The idea is to keep always a *backup* group indoor!

✓ The rather irregular feeding routines on the Goodeid’s fish pond, along with my long periods of absence (nearly 2 months on each pause), are an obvious obstacle not only to a proper field observation but for the best fish keeping practices in particular.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My second approach (2012-2016): The Goodeid’s pond (4,000 litres)

This second but minor pond location, as well as its dimensions (2 metre wide x 2 metre long and 1 metre deep), were planned on purpose to achieve the expected thermal response (especially cool temperatures in the heat of summer months).
Cool Fish - Goodeid keeping and breeding (my own experience)

My second approach (2012-2016): The Goodeid’s pond with the “cycling” species

To test the thermal behaviour of this pond, same was first colonised with *Cyprinodon alvarezi* on an attempt to reproduce this endangered fish.
Cool Fish - Goodeid keeping and breeding (my own experience)

My second approach (2012-2016): The Goodeid’s pond sun light shield (summer)

The sun light shield was responsible not only for a cool environment, but has also avoided tree and bush leaves to drop into the water. In 2014 this cover was removed as you will realize, further on, at the yearly data logging graphical outcomes.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Goodeid keeping and breeding (my own experience)

My second approach (2012-2016): the thermal response of the Goodeid’s pond in summer (yellow line), when compared with the main pond (blue line).
Cool Fish - Goodeid keeping and breeding (my own experience)

My second approach:

✓ The water temperature on the 150 litre indoor tank became strictly controlled, since 2014, in order to keep the summer temperature inside the optimum range and to simulate, safely, the outdoor winter records, on elected species.

✓ Also, subsequently to 2014, any new Goodeid species selected to outdoor temperature tolerance assessment is previously and prudently observed in aquaria, under a vigilant winter simulation, for at least 2 cold seasons, prior to definitive judgement and further released on the fish pond.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Water temperature

Data logging

✓ From January 1985 to December 1996, temperature readings were made with mercury-in-glass thermometer (aquaria type) at water surface.

✓ Data collections usually took place between 8:00 and 9:00. On the odd occasions, some readings have been recorded between 18:00 and 19:00, depending on convenience or weather conditions.

✓ From January 1999 to December 2006, the mercury-in-glass thermometer was replaced by a digital electronic device - Hanna Instruments HI 8424 (pH, mV, °C).

✓ From January 2011 until the present, several submersed EL-USB-1 data loggers (http://www.lascarelectronics.com/pdf-usb-datalogging/data-logger0656045001254903180.pdf) are permanently acquiring and recording data (temperature readings) every 60 minutes, at 15 cm deep. Between 2011 and 2013 temperature readings at the bottom of the ponds were also collected and registered. From January 2011 to this date, also, air temperatures are permanently recorded within the same 60 minute interlude.

✓ In all the 3 period, temperatures are been registered in a data base.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Water temperature

Data logging (present time)

The automatic recording data logger EL-USB-1
Cool Fish - Water temperature

Data logging (present time)

The automatic recording data logger EL-USB-1
Cool Fish - Water temperature

Data logging (present time)

The automatic recording data logger EL-USB-1 (capsuled and ready for submersion)
Cool Fish - Water temperature

Data logging results 1985 > 2006 – 24 hours gap temperature records
Cool Fish - Water temperature

Data logging results 1985 > 2006 (accuracy contrast)
Cool Fish - Water temperature

Data logging results 2011: Water temperatures at 26,000 and 4,000 litre ponds + air
Cool Fish - Water temperature

Data logging results 2012: Water temperatures at 26,000 and 4,000 litre ponds + air
Cool Fish - Water temperature

Data logging results 2013: Water temperatures at 26,000 and 4,000 litre ponds + air.
Cool Fish - Water temperature

Data logging results 2014: Water temperatures at 26,000 and 4,000 litre ponds + air
VII International Convention of the Goodeid Working Group  Lisbon 01/10/2016
Encontro Nacional 2016 do Grupo ViP  Lisboa 01/10/2016

Cool Fish - Water temperature

Data logging results 2015: Water temperatures at 26.000 and 4.000 litre ponds + air
Cool Fish - Water temperature (introduction)

✓ In 2009 my attempts to get information from other GWG members about the minimum and maximum critical temperatures or the minimum and maximum sub-lethal temperatures for Goodeids, were first regarded as potential risk for more alien species introduction in Europe.

✓ So far, the information available on the Internet regarding the water temperatures on the original biotopes all year round and all day long is still extremely rare, very diffuse and disparate.

✓ Juan Miguel Artigas Azas, on the Vienna meeting (2012) was the first person who gave me excellent indications regarding the Mexican plateau natural water temperatures and the incipient lower lethal temperatures for some Goodeid species.

✓ Thanks to Christian Reusch, I have got a good source of information about biotope’s water temperatures, also at the Vienna meeting (2012) – the fantastic book “Die Hochlandkärpflinge”, from Harro Hieronimus (unfortunately for me in German).

✓ Thanks to Kees de Jong, I have gained access to an extensive bibliography about Goodeids.

✓ On the websites of the GWG (http://www.goodeidworkinggroup.com/) and Guenter Ellenberg’s Goodeiden.de (http://www.goodeiden.de/index.html) I have been rewarded with remarked precious information regarding ideal water temperatures for Goodeid species.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Water temperature (introduction)

What is the importance of water temperature?

✓ Temperature is responsible for behavioral, and physiological responses in fish. It affects the activity, feeding, growth, and reproduction. «Water temperature has been described as the “abiotic master factor” for fishes» (Brett, 1971).

✓ The «thermal tolerance in an organism is determined by a wide variety of biotic and abiotic factors, with acclimation temperature and thermal history being among the most important» (Chung, 2001).

✓ The temperature rules metabolic activities and has lasting effects even on predator avoidance. «Temperature controls and limits all physiological and behavioral parameters of ectotherms» (Fry, 1947).

✓ Fish are vulnerable to rapid changes in temperature. «Rapid decreases in water temperature may result in a number of physiological, behavioral and fitness consequences for fishes termed “cold shock”» (Ronaldson et al., 2008).

✓ «Optimal temperature ranges, as well as upper and lower lethal temperatures, vary widely between and among species and are dependent on genetics, developmental stage and thermal histories» (Beitinger et al., 2000; Somero, 2005).

✓ Temperature also determines the amount of dissolved gases (oxygen, carbon dioxide, etc.) in the water.
Cool Fish - Water temperature

How does it works?

✓ «The thermal sensitivity of ectotherm performance is often described by a thermal performance curve, which increases with temperature to a maximum (the temperature at maximum performance is defined as the optimum temperature, Topt), and declines at higher temperatures» (Payne, 2016).

The first known fish with whole-body endothermy:

(...) Here, we describe a whole-body form of endothermy in a fish, the opah (*Lampris guttatus*), that produces heat through the constant “flapping” of wing-like pectoral fins and minimizes heat loss through a series of counter-current heat exchangers within its gills. Unlike other fish, opah distribute warmed blood throughout the body, including to the heart, enhancing physiological performance and buffering internal organ function while foraging in the cold, nutrient-rich waters below the ocean thermocline.


Image source: http://d3e3jwjal5zk9x.cloudfront.net/content/jexbio/218/12/1956/F1.large.jpg
What about Goodeids?

✓ A number of Goodeid species are temperate stenotherm, others are tropical stenotherm.
✓ Some examples of optimal temperature range:

(Sources: [http://goodeiden.de/](http://goodeiden.de/) and Die Hochlandkarpflinge)

\[
\begin{align*}
\text{Allophorus robustus} & : 16 \, ^\circ\text{C} > 22 \, ^\circ\text{C} \\
\text{Allotoca dugesii} & : 18 \, ^\circ\text{C} > 24 \, ^\circ\text{C} \\
\text{Ameca splendens} & : 22 \, ^\circ\text{C} > 28 \, ^\circ\text{C} \ (32 \, ^\circ\text{C}) \\
\text{Ataeniobius toweri} & : 26 \, ^\circ\text{C} > 28 \, ^\circ\text{C} \\
\text{Chapalichthys encaustus} & : 18 \, ^\circ\text{C} > 22 \, ^\circ\text{C} \\
\text{Characodon lateralis} & : (21 \, ^\circ\text{C}) \ 22 \, ^\circ\text{C} > 24 \, ^\circ\text{C} \\
\text{Girardinichthys viviparus} & : (16 \, ^\circ\text{C}) \ 17 \, ^\circ\text{C} > 20 \, ^\circ\text{C} \\
\text{Goodea atripinnis} & : 18 \, ^\circ\text{C} > 20 \, ^\circ\text{C} \\
\text{Ilyodon furcidens} & : 18 \, ^\circ\text{C} > 26 \, ^\circ\text{C} \\
\text{Skiffia multipunctata} & : 17 \, ^\circ\text{C} > 22 \, ^\circ\text{C} \\
\text{Xenoophorus captivus} & : 22 \, ^\circ\text{C} > 24 \, ^\circ\text{C} \ (26 \, ^\circ\text{C}) \\
\text{"Xenotoca" spec. cf. eiseni} & : 22 \, ^\circ\text{C} > 26 \, ^\circ\text{C} \ (25 \, ^\circ\text{C}) \\
\text{Xenotaenia resolanae} & : 20 \, ^\circ\text{C} > 25 \, ^\circ\text{C} \\
\text{Zoogoneticus tequila} & : (18 \, ^\circ\text{C}) \ 19 \, ^\circ\text{C} > 22 \, ^\circ\text{C} \ (20 \, ^\circ\text{C})
\end{align*}
\]
Cool Fish - Water temperature

How can we define limits?

✓ 「Responses to environmental stress are broadly grouped into three categories:

- Primary (e.g. neuroendocrine response and corticosteroid–catecholamine release).
- Secondary (e.g. metabolic, cellular, haematological, osmoregulatory and immunological changes).
- Tertiary (e.g. whole organism physiological and behavioral stress responses).

Mazeaud et al., 1977; Barton, 2002.

Note 1: My attempt to determine and access the temperature tolerance of some Goodeid species to local climate as focused mainly on lower limits, revealed as more lethal ones (so far).

Note 2: Before 2016, stress episodes related with high temperatures were rarer and mortality even more odder. The 2016 July mortality event may has been related to other reasons than a simple direct relation with temperature (as we will see later on).
Cool Fish - Water temperature

How do I define the temperature limits?

- Within the ideal temperature range the species can function at or near optimum. Inside this array reproduction takes place. Feed conversion efficiency is at it’s maximum and it is the ideal for growth and fitness of the fish. Fish are at standard metabolic rate.

- At sub-optimum temperature range, as the water cools, the fish start slowing down. Respiration, food consumption, growth and reproduction are reduced.

Note: in my fish ponds this is a seasonally slow process in preparation for a period of semi-dormancy, as expected in some temperate climate species selected for their cold tolerance.

- At lower temperatures the digestive and immune systems decelerate. Fish are not capable of digesting some types of food items they search during the warmer period, so they start to show a diet change and sometimes becoming vulnerable to disease (depending on the general fitness and water quality).

Miguel Andrade  viviparos@viviparos.com
How do I define the (lower) temperature limits?

✓ In order to determine the **minimum sub-lethal temperature** or incipient lower lethal temperature, I have observed a series of behavioral aspects or happenings, after fish stop feeding:

. Searching for heat sources or higher temperature water pockets;
. Darkening of the skin (some species)
. Increasing immobilization periods (diapause?);
. Clamped fins;
. Body trembling;
. Constant *wave like* swimming, while unmoving;
. Erratic and uncoordinated swimming (or lack of control);
. Partial loss of equilibrium (ionic balance is disturbed when fish are stressed due to extreme temperatures).
Cool Fish - Water temperature

How do I define the (lower) temperature limits?

✓ In order to determine the **minimum critical temperature**, I am familiar with a series of proceedings **before death occurs**:

  . Total immobilization and little response to stimuli (fish are even unable to escape);
  . Fish lay down from side on the bottom or drift at surface with prevalent loss of equilibrium (probably related with osmoregulatory failure);
  . Little evidence of operculum movements and no response to stimuli - after extended exposure to low temperatures, fish enter a comatose state.
  . The first individuals start to die (never recover from the comatose state) in more or less one hour.
Cool Fish - Water temperature

Portugal’s Climate

Temperatures below 7.2 °C
Number of hours registered between 01/10/2015 and 18/04/2016

In Santo André the record of hours below 7.2 °C in the same period of time it was 94 hours.

Note: you can find a copy of the Iberian Climate Atlas at the documentation folder.

Csb, temperate climate with dry and mild summer.
Csa, temperate dry climate with warm summer.
BSK, Arid Climate - type B subtype BS (cold steppe climate of mid-latitude)
Cool Fish - Water temperature

Portugal’s Climate

Average number of expected days with a minimum temperature below or equal to 0 ºC in the Iberian Peninsula and the Balearic Islands (1971 – 2000)

From: Iberian Climate Atlas
Portugal’s Climate

Temperatures - January 27th 2017 at 6:00 (Portugal)

Average winter expected conditions:
Wind flow from west, with strong ocean influence. Cloudy and rainy weather with quite “smooth” temperatures in the Atlantic coastline.

On the fish site location the typical range of air temperature at 6:00. Under such winter conditions, as illustrated on this image, usually fluctuate from 7ºC to 12ºC (under cloudy/rainy circumstances) and 4ºC to 10ºC (on clear sky conditions). The “cold strikes” will be explored ahead.

Source of image and forecast: Ventusky - https://www.ventusky.com

Miguel Andrade viviparos@viviparos.com
Cool Fish - Water temperature

Portugal’s Climate

Temperatures - January 27th 2017 at 15:00 (Portugal)

Average winter expected conditions:
Wind flow from west, with strong ocean influence. Cloudy and rainy weather with smooth temperatures in the Atlantic coast line.
On the fish site the typical range of air temperature at 15:00, during winter conditions like the illustrated ones, usually fluctuate from 14ºC to 16ºC (under cloudy/rainy circumstances) and 15ºC to 19ºC (on clear sky conditions).
Medium average January temperature is 10.9ºC.

Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate

Temperatures on January 27th 2017 at 6:00 (Europe)
Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate

Temperatures on January 27th 2017 at 15:00 (Europe)
Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

The Global Climate 2011-2015: HOT AND WILD

The World Meteorological Organization has published a detailed analysis of the global climate 2011-2015 – the hottest five-year period on record - and the increasingly visible human footprint on extreme weather and climate events with dangerous and costly impacts.

The record temperatures were accompanied by rising sea levels and declines in Arctic sea-ice extent, continental glaciers and northern hemisphere snow cover.

All these climate change indicators confirmed the long-term warming trend caused by greenhouse gases. Carbon dioxide reached the significant milestone of 400 parts per million in the atmosphere for the first time in 2015, according to the WMO report which was submitted to U.N. climate change conference.

DOC also examines whether human-induced climate change was directly linked to individual extreme events. Of 79 studies published by the Bulletin of the American Meteorological Society between 2011 and 2014, more than half found that human-induced climate change contributed to the extreme event in question. Some studies found that the probability of extreme heat increased by 10 times or more.

“The Paris Agreement aims at limiting the global temperature increase to well below 2 ° Celsius and pursuing efforts towards 1.5 ° Celsius above pre-industrial levels. This report confirms that the average temperature in 2015 had already reached the 1°C mark. We just had the hottest five-year period on record, with 2015 claiming the title of hottest individual year. Even that record is likely to be beaten in 2016,” said WMO Secretary-General Petteri Taalas.

“The effects of climate change have been consistently visible on the global scale since the 1980s: rising global temperature, both over land and in the ocean; sea-level rise; and the widespread melting of ice. It has increased the risks of extreme events such as heatwaves, drought, record rainfall and damaging floods,” said Mr. Taalas.

Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Cold strikes and heat waves are the major factor limiting the potential of local climate for most Goodeid species permanent outdoor pond culture (year round).

Post scriptum: Extremely cold weather in January 2017

A northern flow, determined by an anticyclone that stretched from Iceland to the Canaries and a cyclone extending from Scandinavia to the Mediterranean, earlier in the week, on the 15th and 16th, carried extremely cold air from the polar region to Central and South Europe.

On the 18th January with the change of flow to the northeast the mass of cold and dry air reached Portugal mainland, originating very low values of air temperature.

The central and southern regions, which are more exposed to the north-east flow, including those on the coast, recorded extremely low values of minimum temperature, which are absolute records, that is, they are now the lowest minimum temperature values ever recorded.


Miguel Andrade viviparos@viviparos.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

A northern flow, determined by an anticyclone that stretched from Iceland to the Canaries and a cyclone extending from Scandinavia to the Mediterranean, on the 15th and 16th January, carried extremely cold air from the polar region to Central and South Europe.

On the 18th January with the change of flow to the northeast the mass of cold and dry air reached Portugal mainland (please see red circle), originating very low values of air temperature.
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Temperatures on January 19th 2017 at 6:00 (Europe)
Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Temperatures on January 19th 2017 at 6:00 (Iberia)

Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Temperatures on January 19th 2017 at 15:00 (Europe)
Source of image and forecast: Ventusky - https://www.ventusky.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Temperatures on January 19th 2017 at 15:00 (Iberia)
Source of image and forecast: Ventusky - https://www.ventusky.com
Portugal’s Climate – The cold strikes and heat waves

Minimum air temperatures in January 18th and 19th, 2017

Cool Fish - Water temperature

Miguel Andrade
viviparos@viviparos.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Data logging results for January 2017:
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Data logging results for January 2017:

Miguel Andrade viviparos@viviparos.com
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Data logging results for January 2017:
Cool Fish - Water temperature

Portugal’s Climate – The cold strikes and heat waves

Data logging results for the *deathly week* cold strike of January 2017:
Cool Fish - Water temperature

The 2016 July event – A case of upper incipient lethal temperature?

Along July 2016 I was reported, by telephone, of regular episodes of fish mortality... but only on the children’s swimming pool fish community(!?!)

Some lost fish were preserved in a freezer, for future analysis and the corps had no signs of injuries or illnesses. Most of all the demise fish were Goodea atripinnis.

What was suddenly went so wrong?...
Was it a consequence of high water temperatures?
Could it be a classical case of low tolerance to warmness from this unfamiliar species to me?

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The setup – filling the pool (March 20th 2016).
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The setup – The pool is ready!! (March 20\textsuperscript{th} 2016).
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The setup – The fish arrival (April 1\textsuperscript{st} 2016).
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The setup – The fish species: *Goodea atripinnis* and *Skiffia multipunctata.*
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The scenario in July 29th 2016 (note that the fish are out of sight and inactive).
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

After the first partial water change (the solution to pollution is dilution).

The fish start to become active and feeding was evidenced once more.
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

After the third partial water change (increasing dissolved oxygen).
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

After the third partial water change (yes... we can finally spot active fish and fry).
The 1 million Euro question…
Could such fish sudden casualties have been directly related to high temperatures?
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

Miguel Andrade
viviparos@viviparos.com
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

*Squalius pyrenaicus* - Iberian Chub (Escalo-do-Sul)

Another sudden case of fish mortality, but this time on the 6m x 4m x 1.10m pond (26,000 litre) in August 8th 2016 (under my presence)... during the heat peak.

Miguel Andrade  viviparos@viviparos.com
The 2016 July event – a case of upper incipient lethal temperature?

Maximum air temperatures in August 4th and 8th 2016

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The air temperature at the fish pond location: (comparison between July and August)
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The air temperature at the fish pond location: (July – 16/07/2017 at 15:00)
The 2016 July event – a case of upper incipient lethal temperature?
The air temperature at the fish pond location: (August – 08/08/2017 at 15:00)
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature? The air temperature at the fish pond location: (July – 15/07/2017 at 15:00)
The 2016 July event – a case of upper incipient lethal temperature?
The air temperature at the fish pond location: (August – 08/08/2017 at 15:00)
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?

The water temperature at the 26,000 litres fish pond: (comparison between July and August)
Cool Fish - Water temperature

The 2016 July event – a case of upper incipient lethal temperature?
The water temperature at the 4.000 litres fish pond: (comparison between July and August)
The 2016 July event – a case of upper incipient lethal temperature?

Some facts related with the 1 million Euro question:
Are unquestionably the Goodeid casualties occurred in July in the children’s swimming pool directly related to high temperatures?

First conclusion:
Water and air temperatures did not differ significantly from July to August. August was somehow hotter in several occasions.

Second conclusion:
On the children’s swimming pool, water quality did showed remarkable opposing quality parameters between July (poor quality) and August (improved quality after several urgent partial water changes).

Third conclusion:
Fish mortality in August (*Squalius pyrenaicus*) took place on the 26.000 litre pond, where the water quality had no significant variability regarding July. There were no registered fatalities on the children’s swimming pool in August (populated exclusively with *Goodea atripinnis* and *Skiffia multipunctata*).
✓ **Lesson n.º 1:** Evaluating the species adaptation to local climate, assuring a good care (daily feeding with a balanced diet, field observation, pond management, etc.), or even assist the fish in case of an required thermal compensation... at a distance of 153 Km (door to door by road) and with quite infrequent visits - it’s unmanageable!

✓ **Lesson n.º 2:** Assessing species temperature tolerance is more effective with observation in aquaria (controlled environment). This method is quite precise and temperature can be controlled whenever the fish start to show any signs of (cold) stress (physiological cascade of responses).

✓ **Lesson n.º 3:** In order to avoid temperature stress and pain on fish, the outdoor culture of most Goodeid species **in mainland Portugal** is only possible during some months (distinct calendars according to the region). In some regions however, a few species (depending on original population) can survive in outdoor fish ponds all year round, with episodes of cold/heat physiological shock, in some locations.
Lesson n.º 4: High temperatures in summertime are the key factor of physiological stress in indoor Goodeid custody in Portugal. The tank’s placement must be chosen according the location’s thermal performance or be provided with a way of controlling the water temperature (cooling system).

Lesson n.º 5: Without a decent information regarding the original biotope temperatures, there is an high risk of submitting fish, outside their natural habitat, to preventable stress. Different populations from the same species can show distinct responses to temperature (depending on life-history, thermal history and shaped by an unimaginable period of natural selection).

Lesson n.º 6: The stress caused on fish with temperatures outside the preference zone rarely become lethal. The consequences depend on the rate and magnitude of exposure to the adverse temperature and how far we approach the critical limits.
✓ Lesson n.º 7: Exposition to temperatures outside the tolerance zone (thermal tolerance limits) inhibits the fish’s ability to survive, particularly when it approaches critical thermal limits (maximum or minimum), and can result in sub-lethal disturbances (as i.e. cellular damage) and reduction of life span.

✓ Lesson n.º 8: Mortality during cold strikes can result from indirect causes other from a simple straight relation with temperature tolerance. Starvation, loss of the ability to react to external stimuli (inhibiting predator evasion) and water quality (when low temperature affects specific immune responses) are indirect causes of mortality.

✓ Lesson n.º 9: Health and fitness recovery from sub lethal temperature exposure effects, depends also on the rate and magnitude of the adverse situation and on the general condition of the specimens before the insult.

Miguel Andrade  viviparos@viviparos.com
Cool Fish - Lessons and plans for the future

Actual circumstances...

✓ Lowest water management since 1993 > between 31.950 and 33.732 litres (4.395 waiting):
  1 Fishpond - 2m x 2m x 1m (4m² and around 4.000 litres) at father’s garden
  1 Fishpond - 6m x 4m x 1,10m (24m² and around 26.000 litres) at father’s garden
  1 Tank with 150 litre water volume at home
  1 Children swimming pool - 2m x 2m x 0,40m (2m² and around 1.600 litres) at father’s garden
  2 Tanks with 51 litre water volume at home
  4 Tanks with 20 litre water volume at home
  1 Adult portable swimming pool 3m x 2m x 0,75m (5m² and around 3.900 litres) at home.
  1 Tank with 25 litre water volume at father’s garage
  1 Tank with 70 litre water volume at father’s garage
  1 Tank with 100 litre water volume at father’s garage
  1 Tank with 300 litre water volume at father’s garage.

Right now, I am still keeping 7 Goodeid species, but breeding only 4 with success (however in rather small number of individuals - very low recruitment).
Reducing, from this year on, to only 3 breeding Goodeid species for a long-term!

Miguel Andrade viviparos@viviparos.com
Cool Fish - Lessons and plans for the future

Plans for the near future I

✓ Increasing water management between 36.550 litre and 38.376 litres:
1 Fishpond - 2m x 2m x 1m (4m² and around 4.000 litres) at father’s garden
1 Fishpond - 6m x 4m x 1,10m (24m² and around 26.000 litres) at father’s garden
1 Adult portable swimming pool 3m x 2m x 0,75m (5m² and around 3.900 litres) planned fish room
4 Tanks with 100 litre water volume planned fish room
1 Tank with 300 litre water volume planned fish room
1 Tank with 150 litre water volume at home
1 Children swimming pool - 2m x 2m x 0,40m (2m² and around 1.600 litres) at father’s garden
4 Tanks with 20 litre water volume planned fish room
1 Tank with 25 litre water volume planned fish room
1 Tank with 70 litre water volume planned fish room
4 Tanks with 51 litre water volume planned fish room

Colour code legend:
Active (permanently on use) resources
Partially active resources (only in use when needed - at least once a year)
Backup, standing by or inactive resources

Keeping and breeding 5 Goodeid species in adequate numbers (minimum viable population) for the long-term!
Cool Fish - Lessons and plans for the future

Plans for the near future II

✓ Increasing data logging with input devices (sensors) for:

- Air temperature (temperature sensor)
- Water temperature near surface (waterproof temperature sensor)
- Water temperature bottom (waterproof temperature sensor)
- Air pressure (barometer sensor)
- Light (photoconductive cell)

This wireless outdoor Arduino based “weather station”, with PC logging and graphs is intended to register environment data from the children’s swimming pool at each 60 minutes. No external power required (solar powered).

This will be a full logging and reporting information system. It can even be accessed at any moment via wireless communication.

This project will later be duplicate for each outdoor fish pond, in particular with every future technological enhancement of the original design.

Image source: [http://2xod.com/articles/Arduino_Wifi_Weather_Station_Data_Logger_HF-LPT100/](http://2xod.com/articles/Arduino_Wifi_Weather_Station_Data_Logger_HF-LPT100/)
Thank you very much for your attention!
I am open for your questions.