Conservation of anadromous sea lamprey: habitat, metamorphosis and aquaculture

Dr Ningping Gong, Senior Researcher
Dept of BioEnv, University of Gothenburg, Sweden
Dept of Biol Sci, Texas Tech University, TX, USA

Workshop on conservation of sea lamprey
2023-10-17, Falkenberg, Sweden

24 sea lamprey recorded at the Herting station

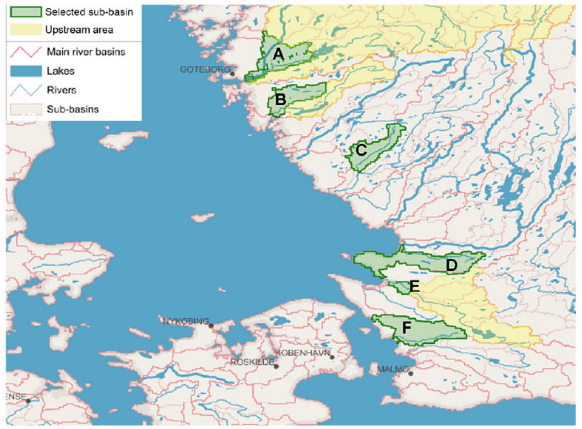
- Sea lamprey adults started to show in the middle of May, water temperature at 14.8 °C, river discharge 24.5 m^3/s).
- A special event on May 23, eight adults were recorded in a single day; water temperature 18.9 °C, discharge 22.5 m^3/s, the only rainy day in May.

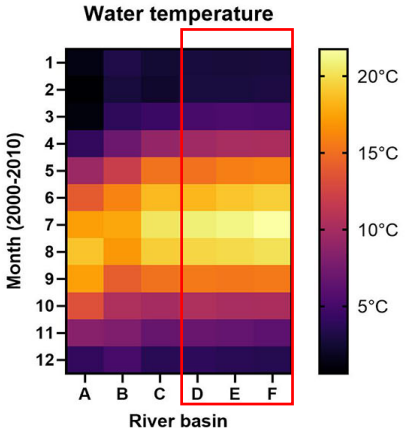
Art	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt
Ål	-	0	0	0	-2	-2	-4	-11	-6	0
Braxen	-	0	0	0	0	1	0	0	0	0
Fågel-Däggdjur	-	0	0	-6	1	1	-2	0	-2	-2
Gädda	-	0	0	0	2	1	0	0	0	0
Havsnejonöga	-	0	0	0	21	3	0	0	0	0
Id	-	0	0	0	1	1	0	0	1	0
Lax	-	0	0	40	305	292	914	235	176	35
Mört	-	0	0	1	2	1	0	5	7	0
Öring	-	0	0	1	1	17	125	92	165	33
Puckellax	-	0	0	0	0	1	8	0	0	0
Regnbåge	-	0	0	0	2	3	1	0	2	0
Summa	**0**	**0**	**0**	**36**	**333**	**319**	**1042**	**321**	**343**	**66**

Data from https://fiskdata.se/

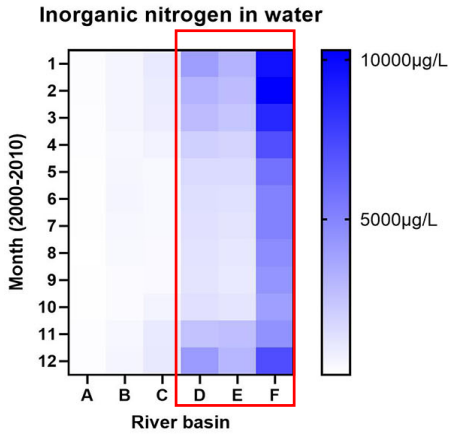
Historical data on water temperature and nutrients in the northern and the southern rivers

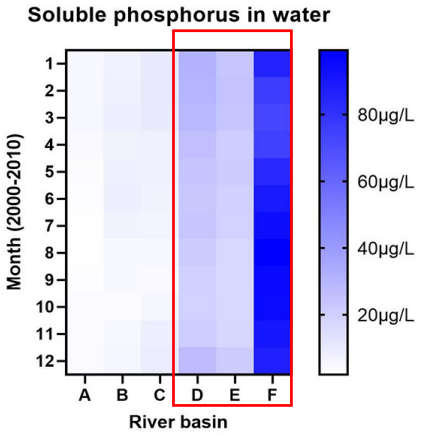
Data from the County Board in Halland.





- Stations A, B, and C are within Göta älv & Säveån, Kungsbackaån and Rolfsån, and Ätran, with annual spawning occurrence.





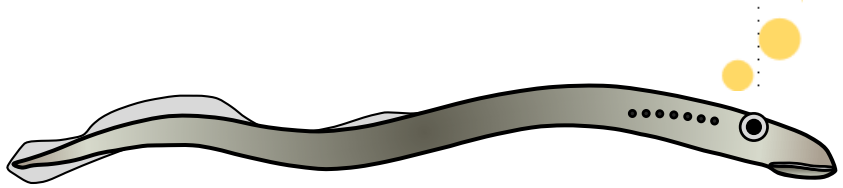
- Stations D, E, and F are within Stensån, Rönne å and Råån, with rare spawning occurrence.

Data from SMHI public database

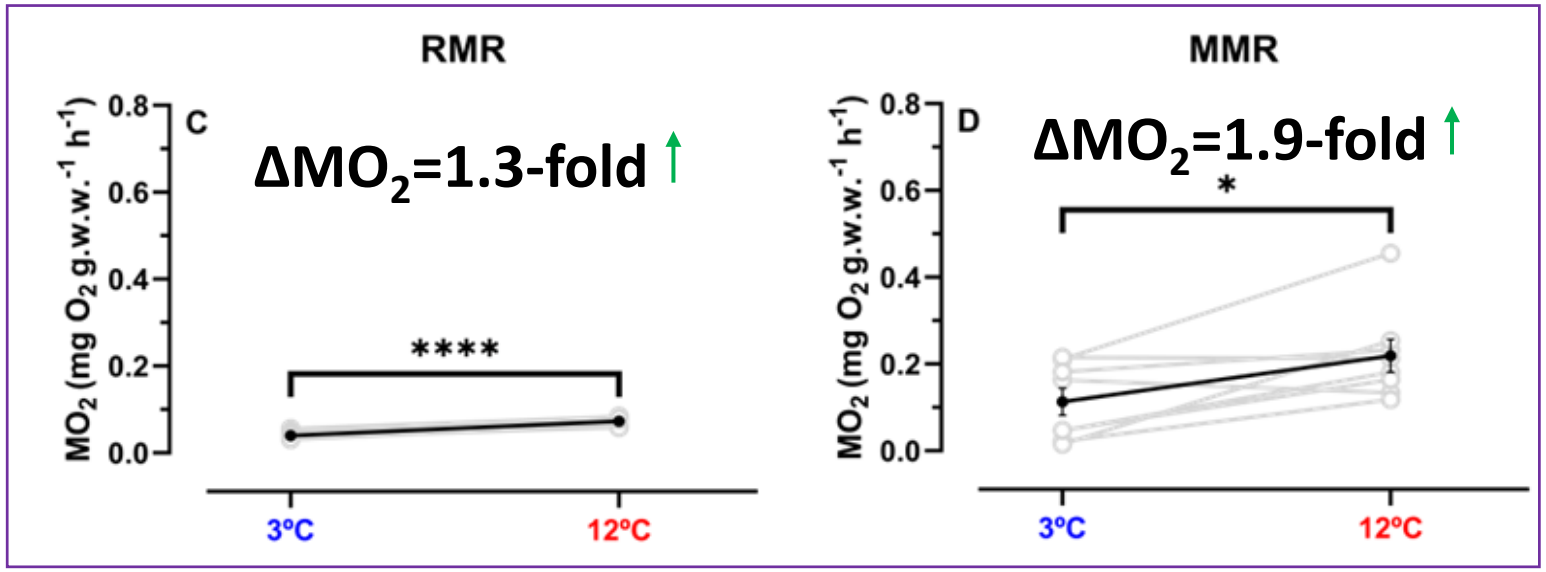
Environmental factors

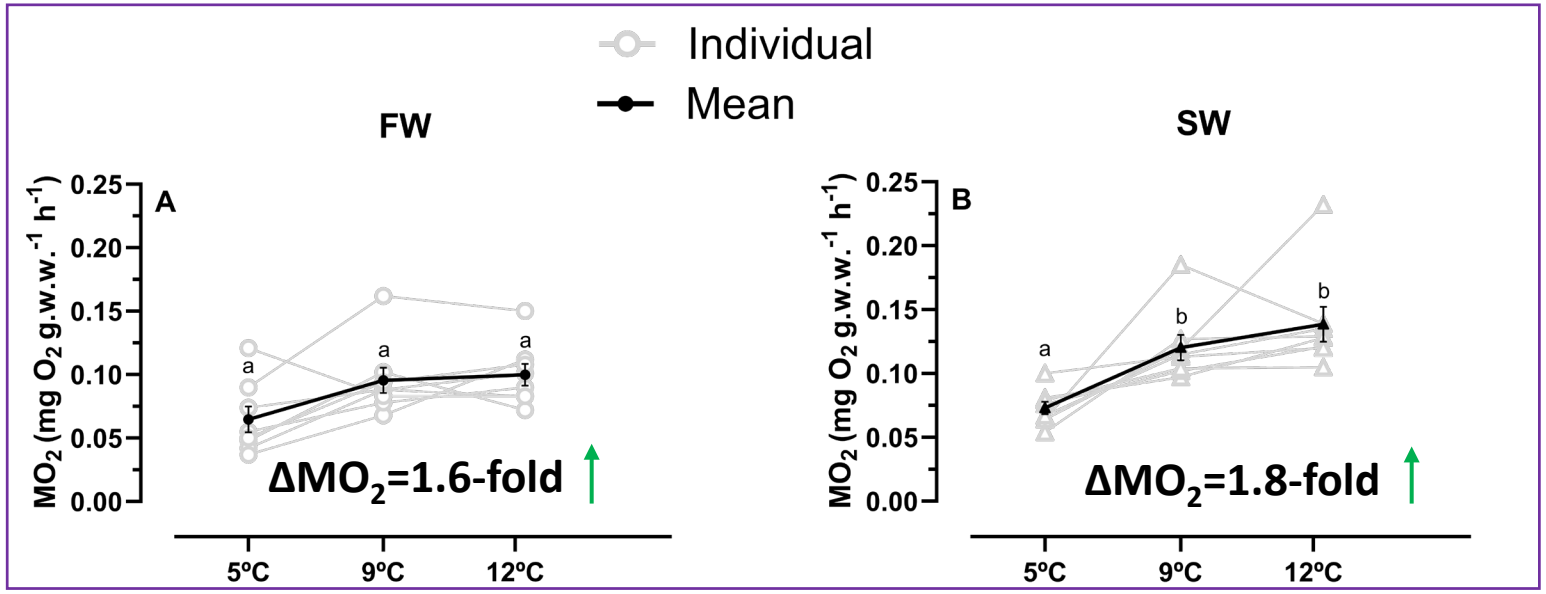
Characterize **metabolic rates** in the **sea lamprey** associated with:

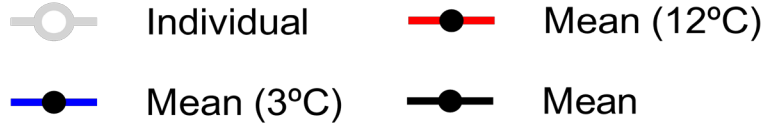
- Temperature
- Oxygen saturations



Effect of Temperature on Metabolic Rates





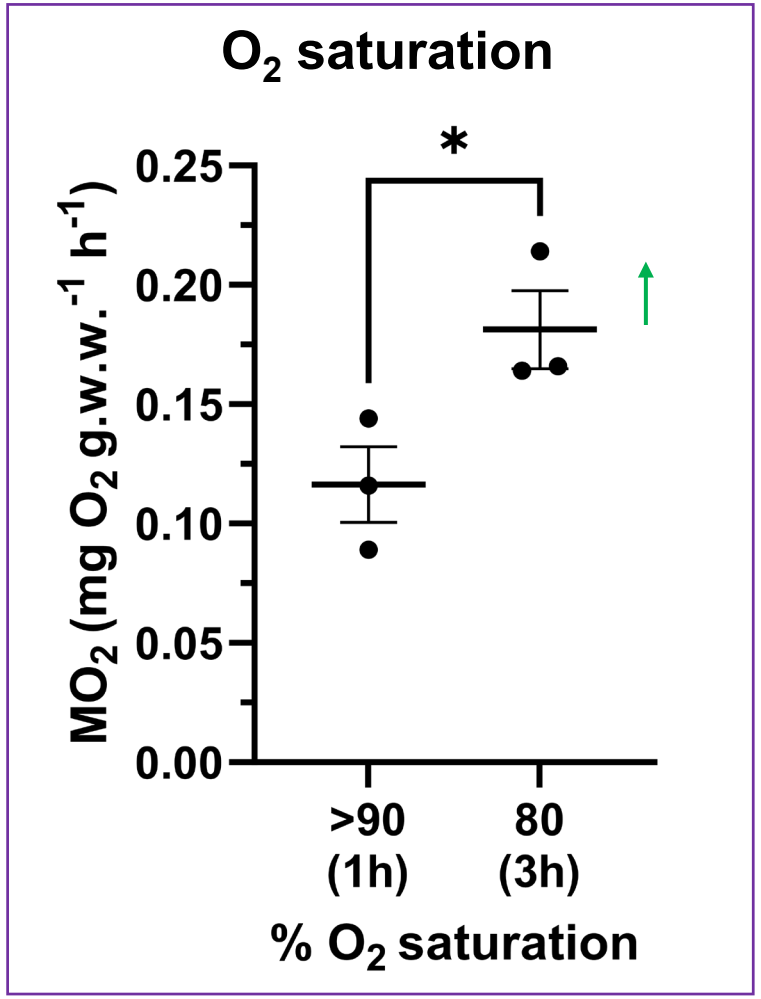


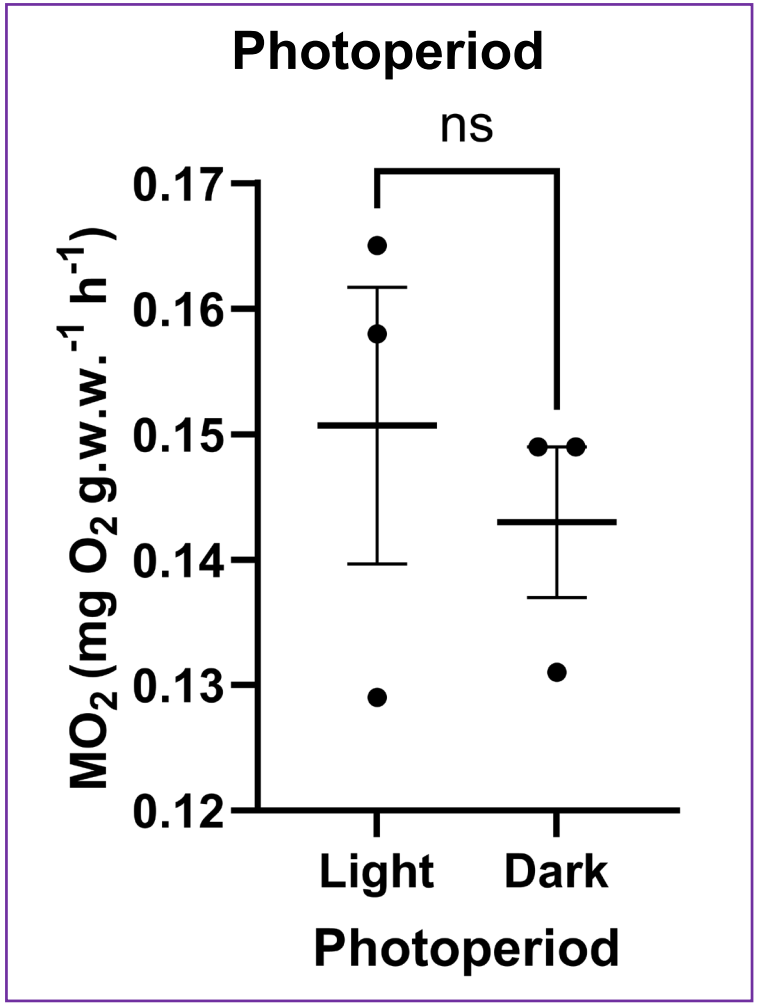
FW ammocoetes acclimated at 3 and 12 °C.
RMR: Rest Metabolic Rates
MMR: Maximal Metabolic Rates

Temperature increase transition over 20 hours

Barany et al., in preparation

Effect of O_2 Saturation and Photoperiod on Metabolic Rates



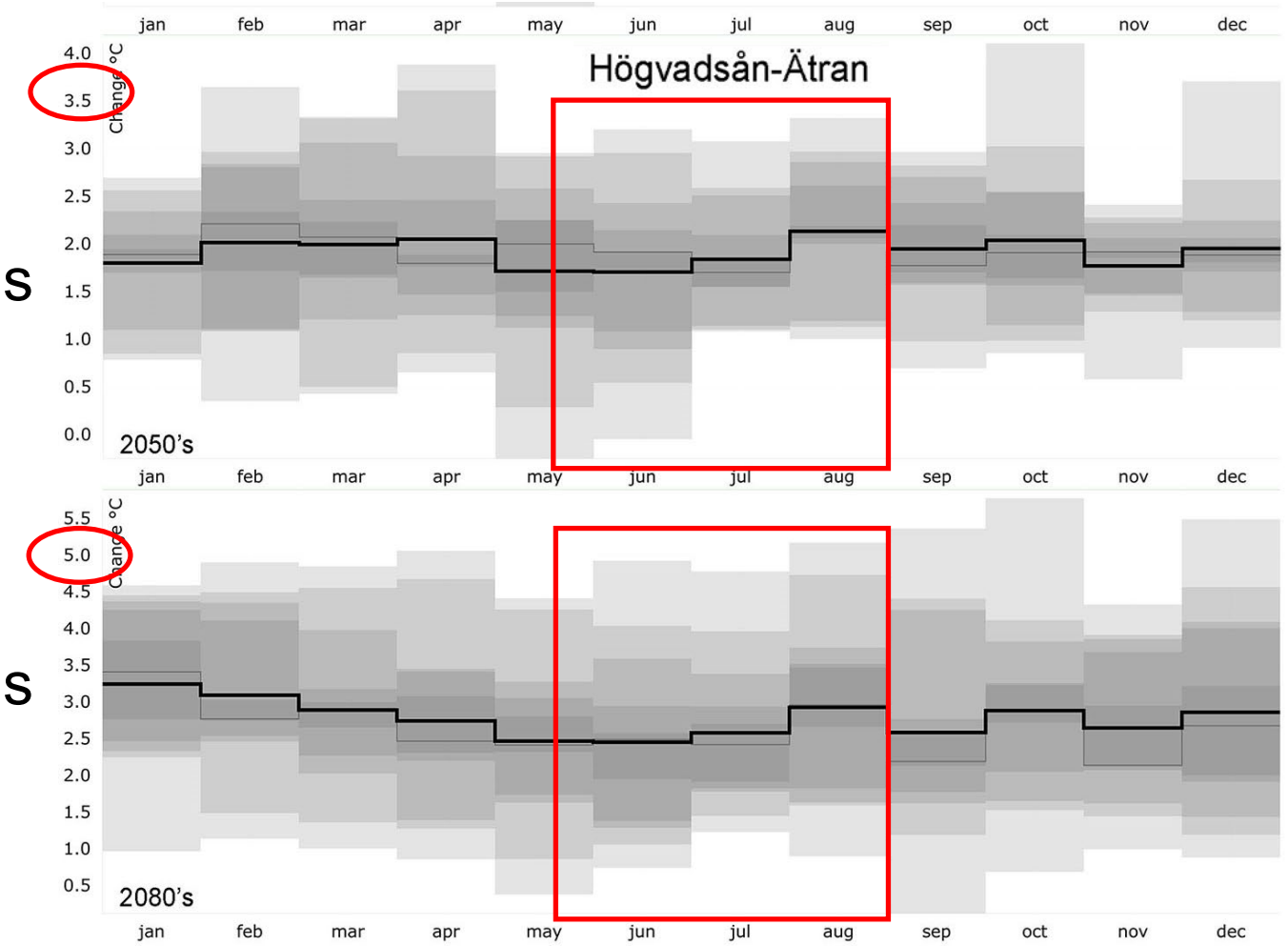


Barany et al., in preparation

Prediction of increasing water temperature with high deviations in the Högvadsån

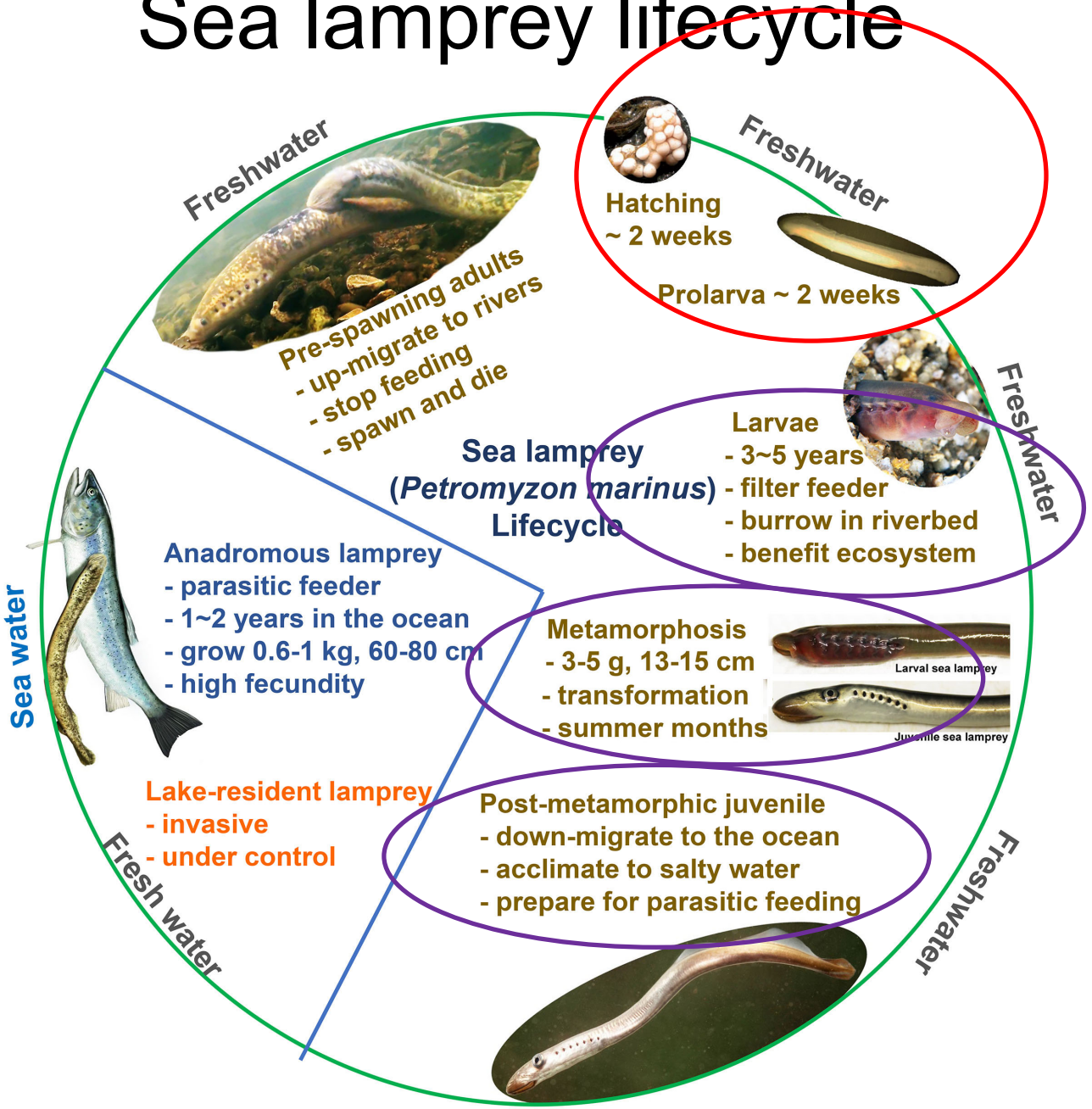
2050's

2080's



Data from SMHI, Hypeweb on Europe Climate Change

Sea lamprey lifecycle



Field survey of sea lamprey ammocoetes

A historical habitat of ammocoetes in Lärjeån, Angered, Gothenburg.

Field collection of sea lamprey ammocoetes in the Saw Mill River, a tributary of the CT River, MA, USA, in 2023.

~10 sea lamprey ammocoetes were found at this site with fine sand.

No sea lamprey was found in the electrofishing survey in 2020
(Park- och naturförvaltningen i Göteborg 2020. Rapport 2020:2.)

Photo credit to Gong

Study of sea lamprey metamorphosis

- In collaboration with the S.O. Conte Anadromous Fish Research Laboratory, USGS, MA.

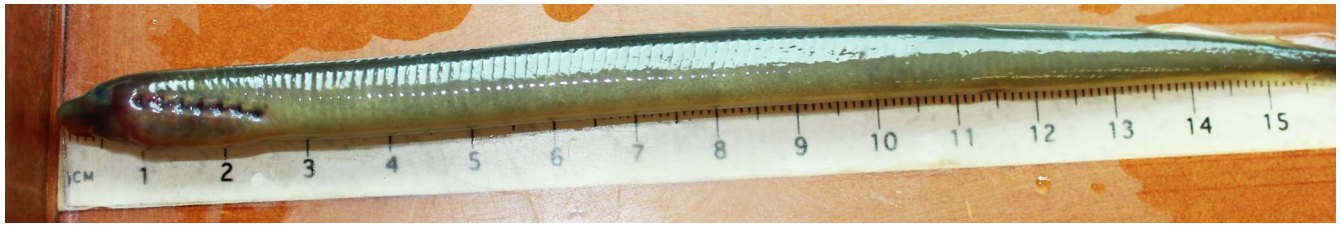
Dr Stephan McCormick
Scientist Emeritus at USGS
Adjunct Professor at Umass

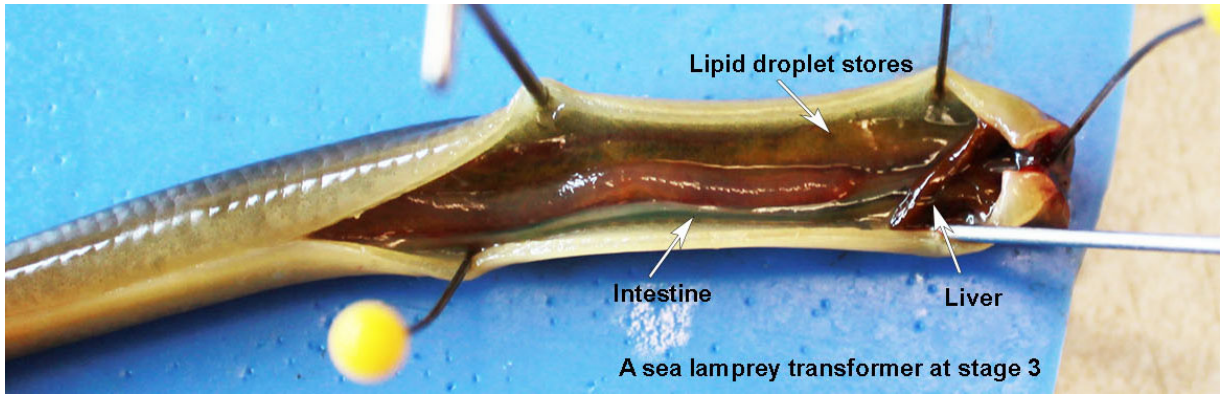
Amy Regish
Research physiologist
the Conte lab, USGS

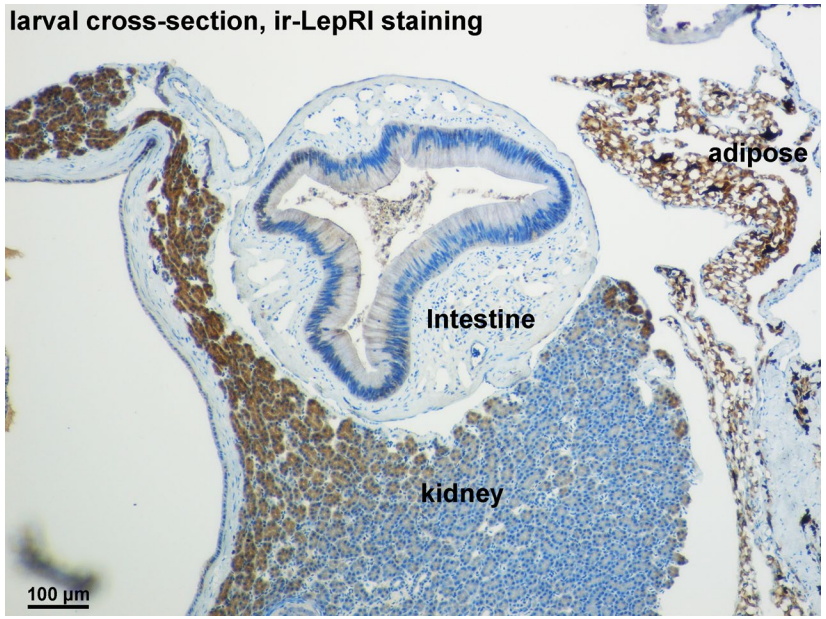
Dr André Barany
Assistant Professor
Complutense University
of Madrid, Spain

Biological preparation for metamorphosis

- Sea lamprey ammocoetes reach certain body size (≥ 13 cm)
- enter “arrested growth phase” and accumulate massive fat, up to 14% of body weight; pre-metamorphic larvae are ≥ 3.0-gram with condition factor ≥ 1.45.







Body adiposity to trigger metamorphosis

- Question: If the onset of metamorphosis is related to fat accumulation in the body, how does the brain receive the information and trigger the initiation of the process?

- A candidate hormone: **leptin**, the product of obese gene in mammals, an adiposity signal.

*Is **leptin** existing in the lampreys?*

› Comp Biochem Physiol B Biochem Mol Biol. 2001 Jul;129(4):777-85.
doi: 10.1016/s1096-4959(01)00388-8.

Maybe

Proteins immunoreactive with antibody against a human leptin fragment are found in serum and tissues of the sea lamprey, Petromyzon marinus L

S Yaghoubian [1], M F Filosa, J H Youson

Not found in the lamprey genome, unlikely existing.

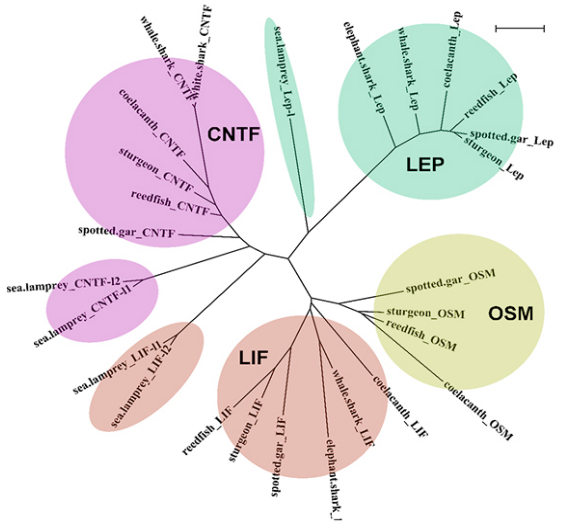
nature ecology & evolution
ARTICLES
https://doi.org/10.1038/s41559-018-0673-5
OPEN

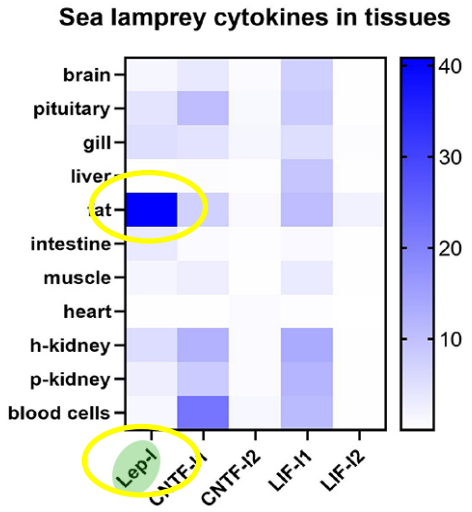
Shark genomes provide insights into elasmobranch evolution and the origin of vertebrates

An adipose-derived hormone in sea lamprey

We have obtained some key information, to support the "**Yes**" scenario:

- Identified 5 candidate genes that are evolutionarily related to leptin.
- One of them was predominantly produced by the visceral fat of sea lamprey adult, which we named leptin-like (Lep-l).





Gong, unpublished.

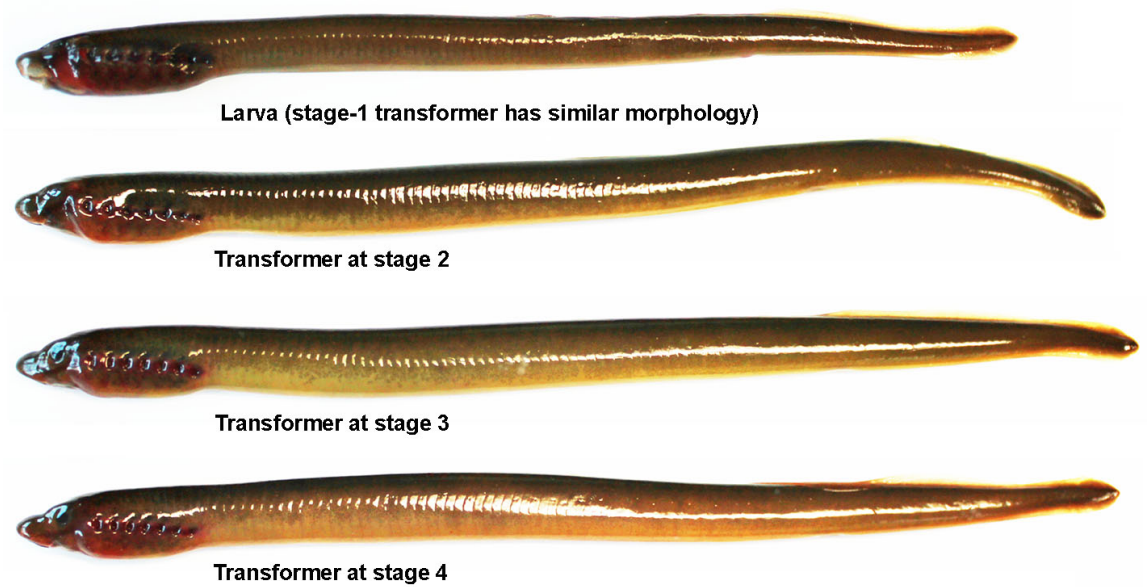
To establish a radioimmunoassay to measure Lep-l levels in relation with body adiposity

Early stages of lamprey metamorphosis

- Based on the morphological and physiological changes, sea lamprey metamorphosis is divided to seven stages.

  Stages 1-2: early-mid July in MA

  Stages 3-4: early-mid August in MA



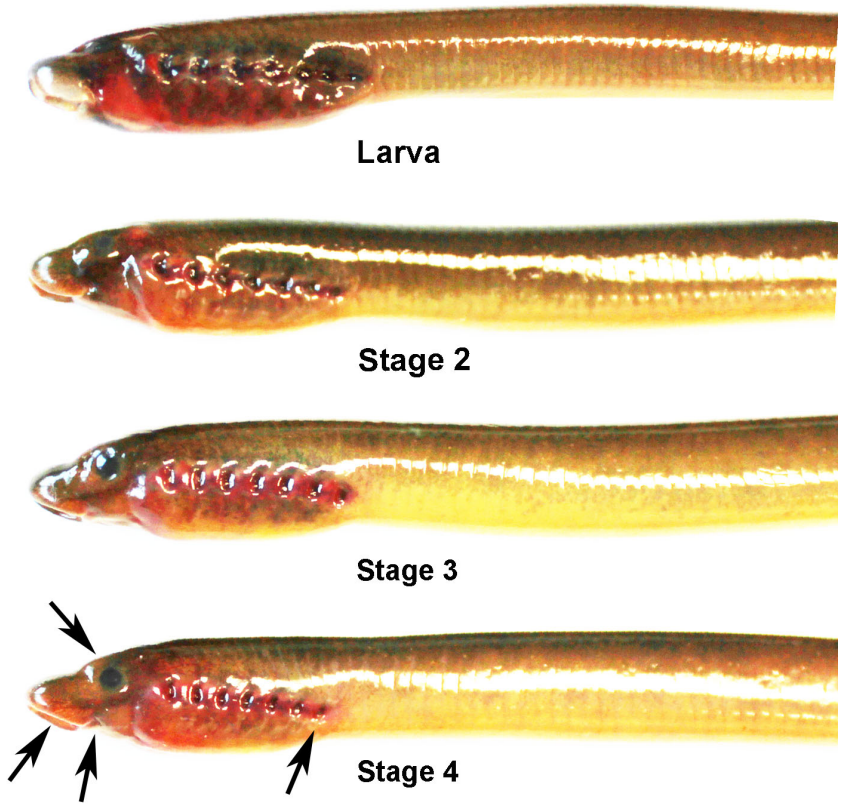
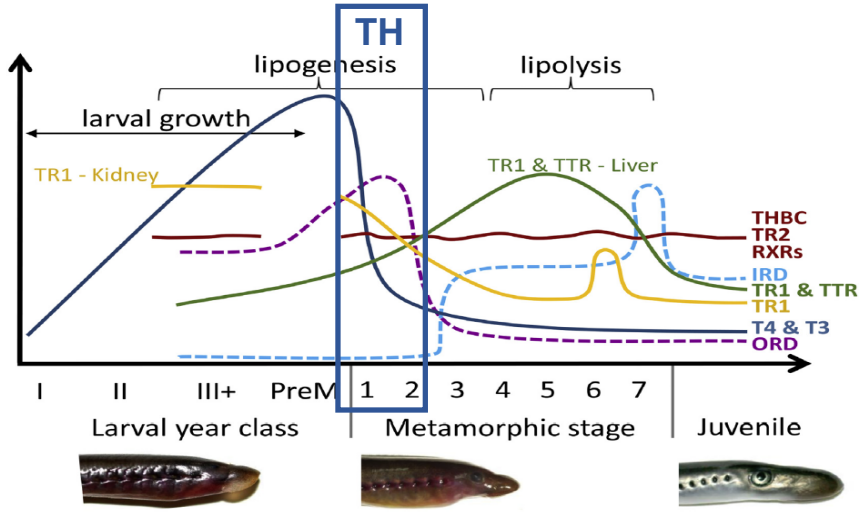


Photo credit to Gong

Two key endocrine factors at the early stages

- **Thyroid hormone:**

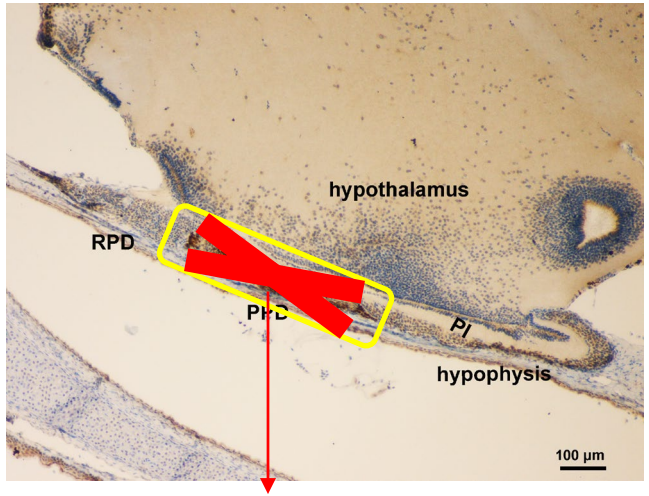
  A sharp ***decline*** of levels at the onset of metamorphosis (Wright and Youson, 1977);



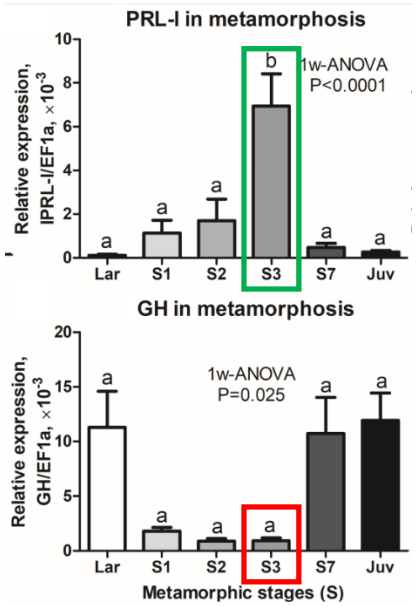
Manzon & Manzon, 2021

Prolactin:

- We identified a novel hormone in the pituitary gland, predominantly produced by cells in the proximal region;
- Its production reaches climax at stage 3, compared to its related growth hormone (Gong et al, *PNAS*, 2022).



Metamorphosis only proceeded to stage 3 (Joss, 1985).



Late stages of metamorphosis

- Stages 5-6: early-mid September in MA.
- Completion of larval metamorphosis in early November in the Conte lab (USGS).

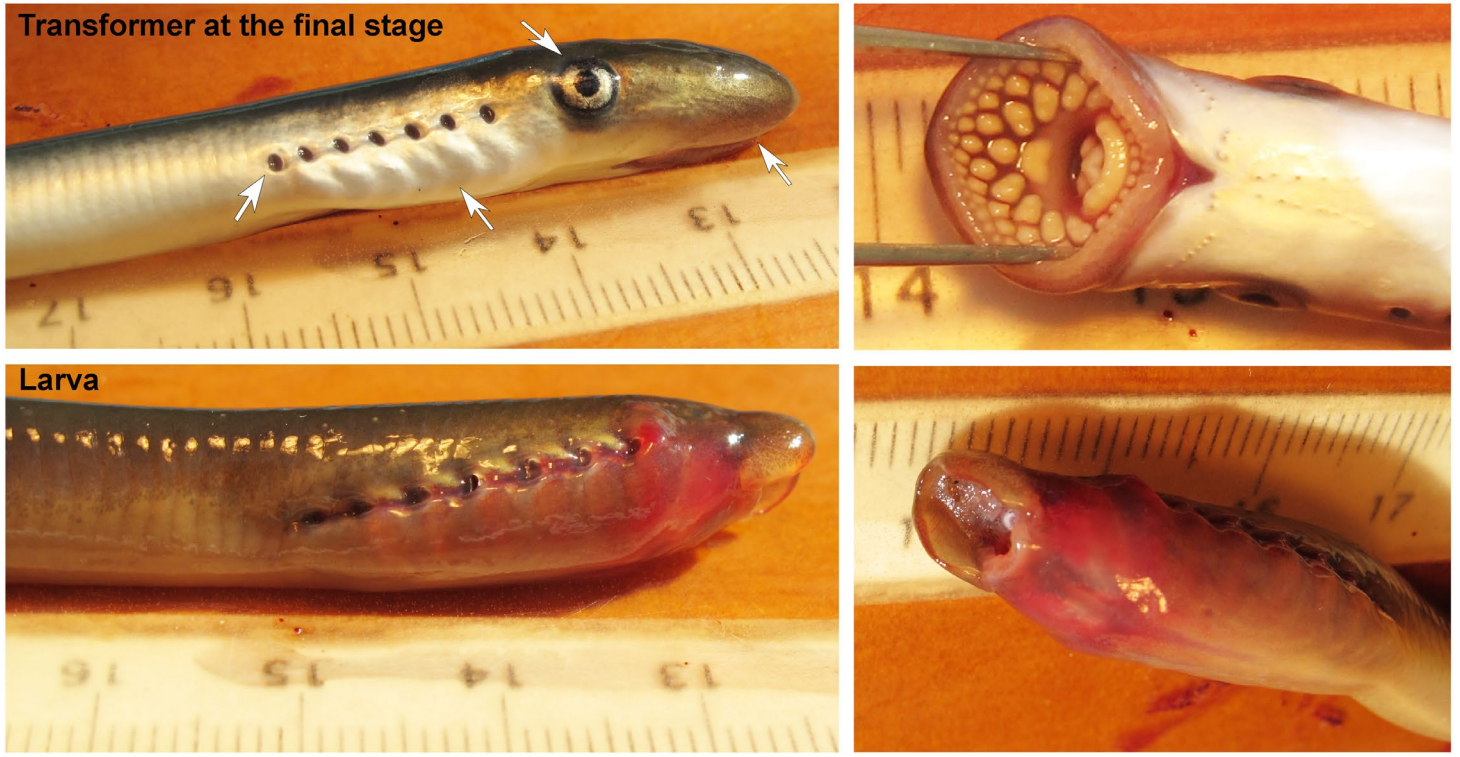
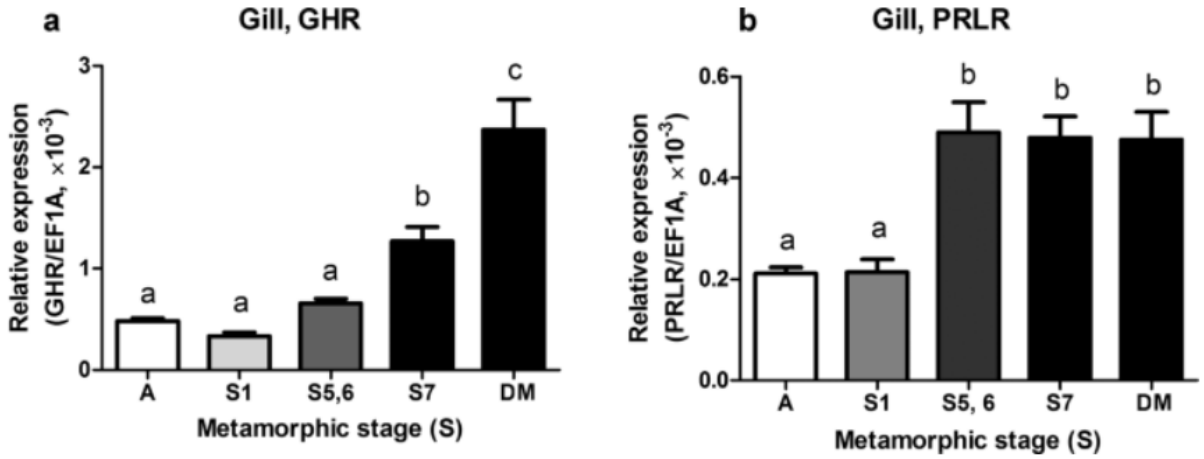


Photo credit to Gong

Acquiring SW tolerance at the late stages

Salinity effects (Reis-Santos et al., 2008):

- Ammocoetes only survived up to 10‰.
- Transformers (stages ≥6) can survive in full-strength sea water (35‰).

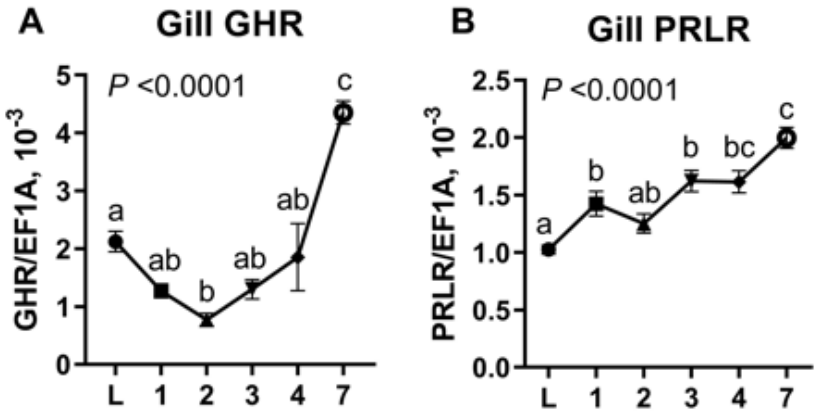


Gong et al., 2020

Two key hormones in the gill development:

- Growth hormone
- Prolactin

Both of hormone signaling systems are involved in the late stages of metamorphosis



Gong et al., in preparation.

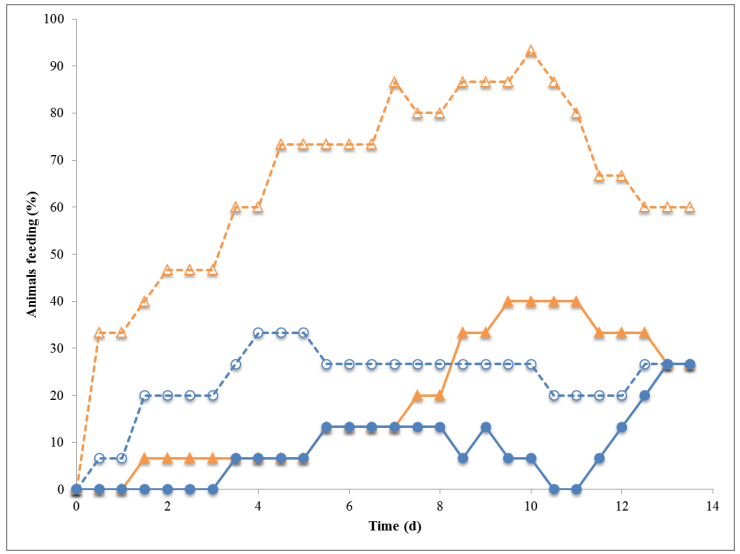
Feeding of post-metamorphic juveniles: Challenges

- Studies of Norstog (2017-2021) showed:

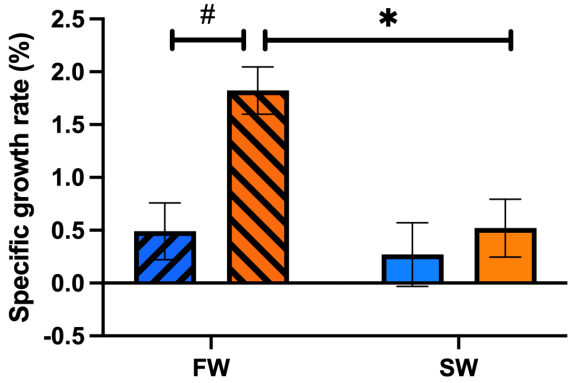
  low attachment of anadromous sea lamprey juvenile on the host fish (<30%)

  low specific growth rates (<1% in 2 weeks)

Feeding behaviours differentiated between anadromous and lake-resident sea lamprey.



Attachments of brook trout over time by CT (anadromous sea lamprey from CT River blue) and LC (Lake Champlain; orange) lamprey in ***FW (dashed)*** and **SW (solid).**

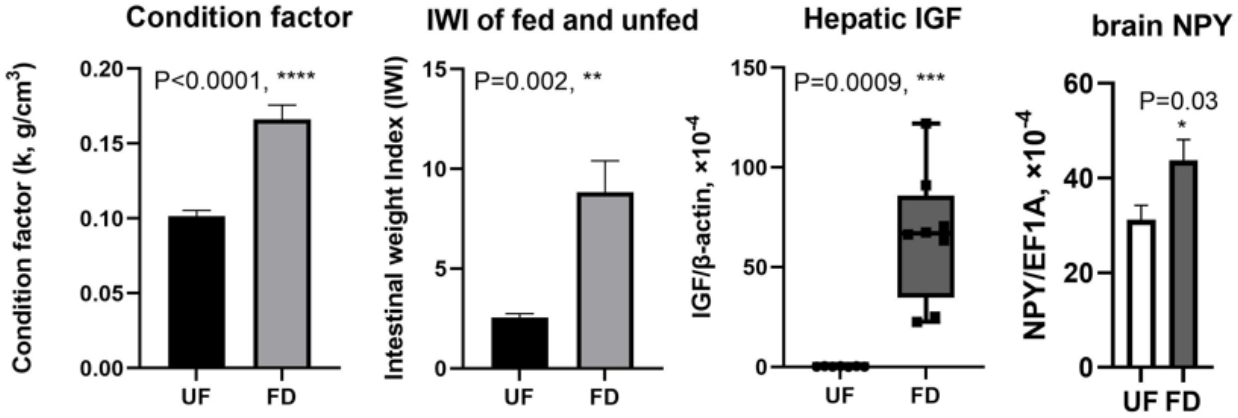


CT (blue) and LC (orange) lamprey over a two-week period. (Norstog et al., unpublished)

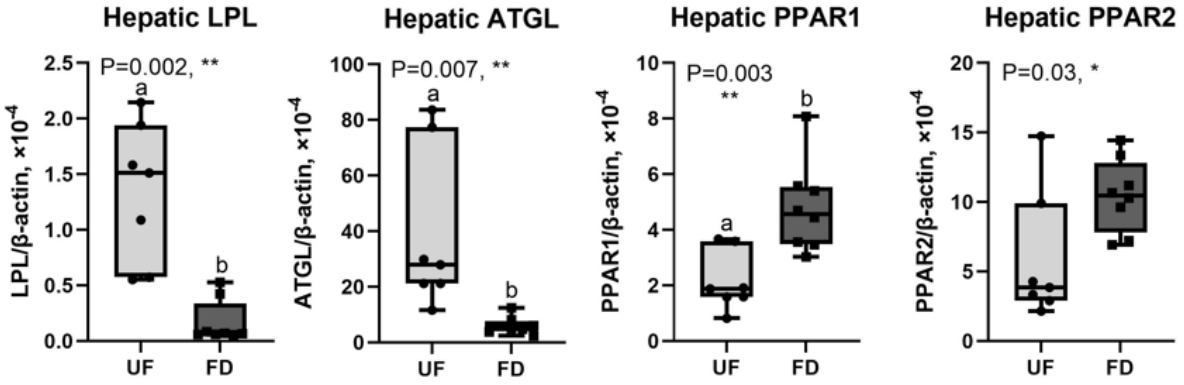
Dr Jessica Norstog
USGS, Umass.

An improved feeding trial of sea lamprey in 2022

- We modified the experiment procedure, and an improved feeding trial was performed by Dr Barany:



- Significant changes in fat metabolism were detected in the liver:



Dr André Barany
University of Madrid, Spain

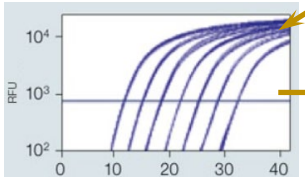
Barany and Gong, in preparation

Our project plans

- Our future studies: WP1 in field, WP2 analysis in lab, WP3 in fish rearing facility.

WP1

WP2



Images from Carim et al., USDA 2016, Qiagen, BioRad.

WP3

Our team in the ecological study in Sweden

- Our team at GU, SLU, and Swedish Anglers Association.
- Ecological study of sea lamprey ammocoetes and metamorphosis in the rivers :
  to understand habitat, distribution, abundance, population structure
  to map larval distribution by using environmental DNA (eDNA).

Prof Johan Höjesjö
SEG, BioEnv, GU
Ecological study
Coordinator

Dr Ningping Gong
FEL, BioEnv, GU
eDNA methodology
Data analysis

Dr Niklas Wengström
Sportfiskarna, Göteborg
Electrofishing survey

Dr Joacim Näslund
SLU-Aqua
Electrofishing, eDNA

A vital measure in the conservation and control: Artificial propagation of lampreys

- High demands of sea lamprey for various studies
- Obtain sea lamprey ammecoetes for releasing, to facilitate the restoration of wild population.
- Available technique supports from the international groups in the lamprey aquaculture:

  Propagation program of Pacific lamprey by Yakama Nation, WA, USA (2013-)

  Sea lamprey aquaculture and procurement (slap) initiative program, MI, USA (2022-)

A “Master Plan” shared by Lampman

Sources/Usage: Public Domain.

SLAP initiative members at Hammond Bay Biological Station, including John Hume (Michigan State University), Trisha Searcy (GLSC), Nick Johnson (GLSC), and Ralph Lampman (Yakima Nation). Photo credit: Tyler Bruning, USGS.

Picture From USGS website

Our team in **Anadromous Sea Lamprey Aquaculture (ASLA)** Initiative program:

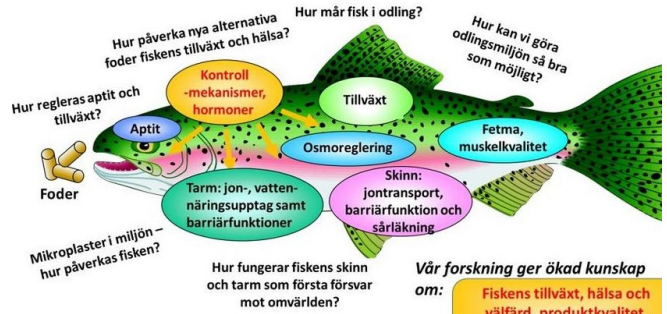
Fish Endocrinology Lab (FEL), Swedish Mariculture Research Center (SWEMARC), Salmonid Ecology Group (SEG)

Dr Gong, FEL, GU
Primary investigator
Cultivation and treatments

Prof Höjesjö, SEG, GU
Coordinator
Ecological studies

Dr Jonathan Roques
SWEMARC, GU
Aquaculture, RAS

Dr Barany, CUM, Spain
Gamete fertilization,
feeding, gut physiology



Research by FEL Group

SEG
Salmonid Ecology Group

In SEG we study dispersal patterns and ecology in salmonids. We also study interactions between salmonids and the freshwater pearl mussel.

Led by Johan Höjesjö the group consists of post-docs, PhD students and Masters students interested in a wide range of topics surrounding salmonids. We study the behaviour and ecology of salmonids in the field and the lab, and we address both basic and applied problems. Although the work is focused primarily in Sweden the group conducts studies across Europe and collaborates with several international groups. We are also involved in many restoration projects in collaboration with various stakeholders.

GÖTEBORGS UNIVERSITET

UNIVERSIDAD COMPLUTENSE MADRID

Natrium

Bild: Kanozi arkitekter

To establish international partnership

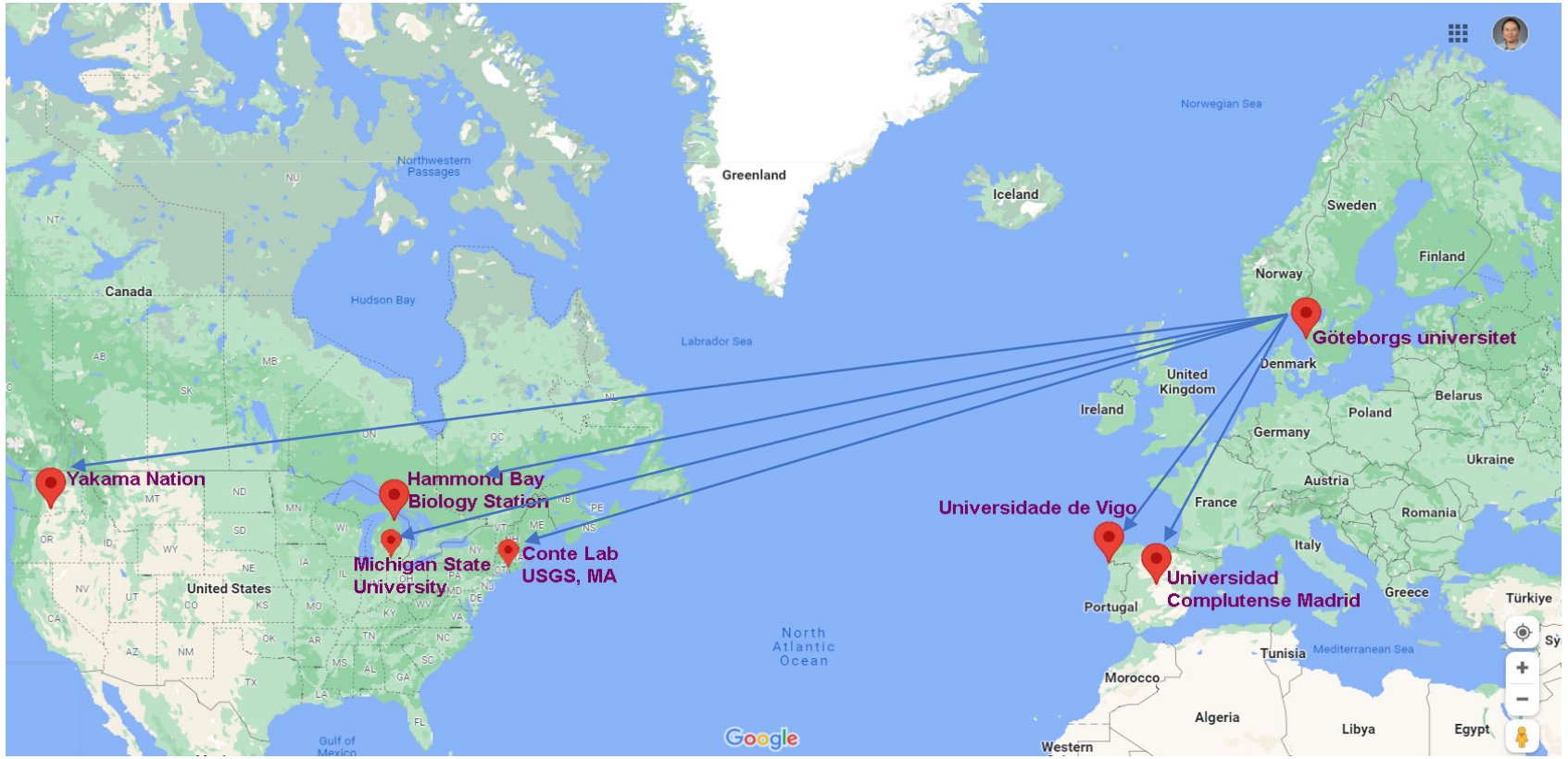
In Spain: Complutense University of Madrid and University of Vigo (Dr Barany's group)

In USA: Conte Anadromous Fish Research Laboratory, USGS, MA (McCormick, Regish)

Hammond Bay Biology Station, USGS, MI (Dr Nicholas Johnson, Trisha Searcy)

Michigan State University, MI (Dr John Hume, Prof Weiming Li)

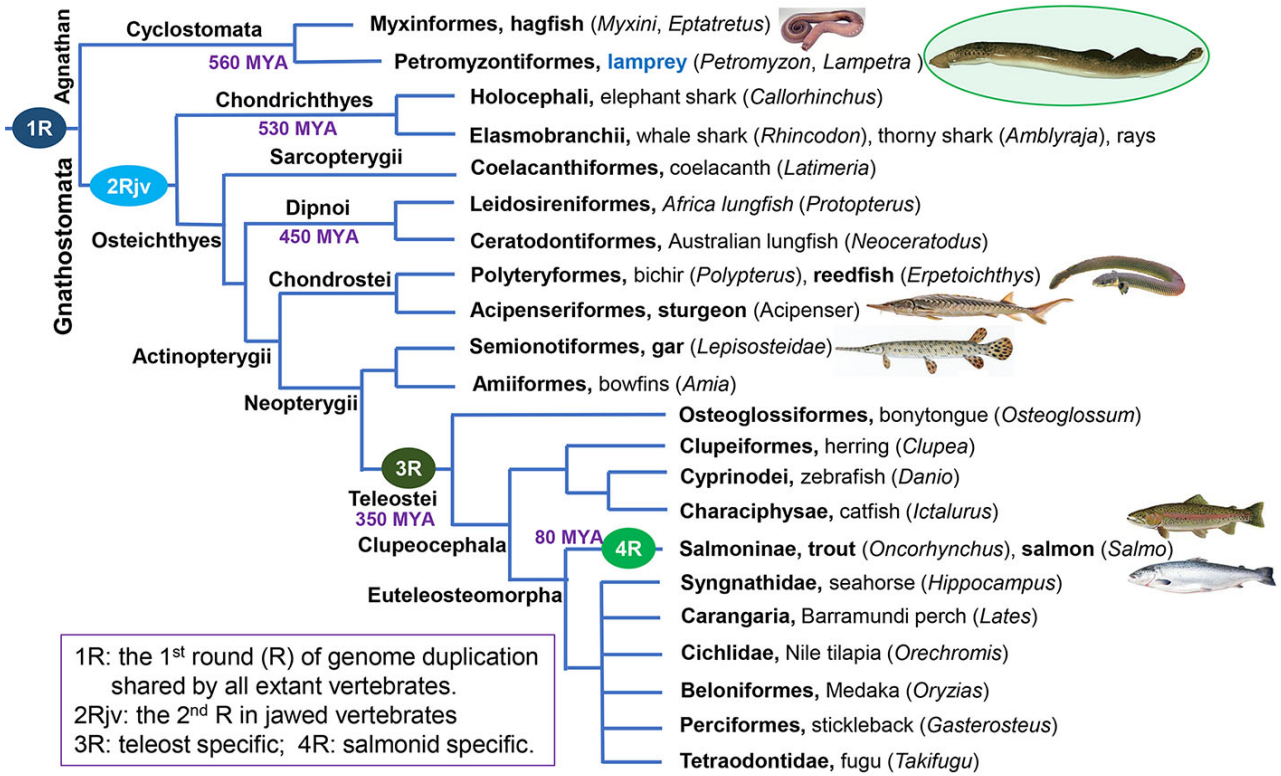
Yakama Nation, WA (Ralph Lampman)



Our aims in the ASLA initiative program

- To establish a **protocol** of artificial propagation of anadromous sea lamprey larvae
- to understand **optimal rearing conditions and diets** for larval growth and health
- to assess of **temperature impacts** on the early larvae (***age 0***) and ammoceotes (***age 1***)
- to perform **ecological study in the lab**, e.g., tag survival, behaviour, and habit requirements (choice experiment, sand and sediment, diet, and personality variation), with ammoceotes (***ages 1-2***).
- to perform **studies in a selected river segment**, through releasing pit-tagged ammocoetes and using tracking station, with ammocoetes (***ages 2-4***).
- to obtain **“eyed” juveniles** for restoration and aquaculture (***age 5~***).

The ASLA initiative program provides valuable experimental animals for our research in evolutionary endocrinology (GU, TTU) and in neurobiology (UU), stress physiology (OSU).



Scheme of an evolutionary tree in relation with genome duplication events, with the images of the fish species in my research on evolutionary biology.

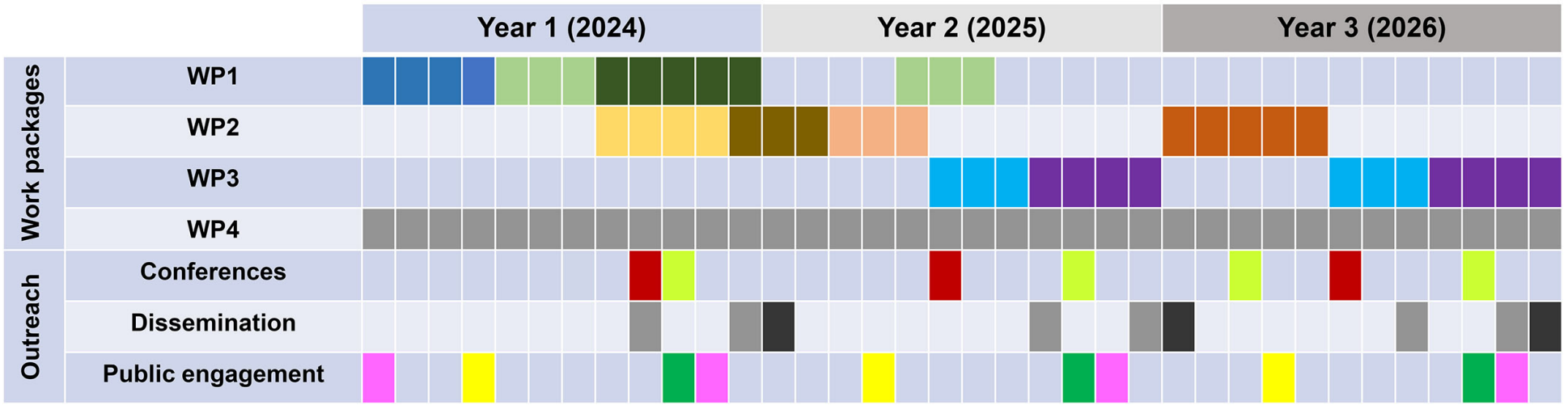
Prof Mark Sheridan
Texas Tech University, TX
Comparative Endocrinology

Prof Dan Larhammar
Uppsala University, SE
Neuroendocrinology
Molecular Biology

Dr Ciaran Shaughnessy
Oklahoma State University
Stress physiology

Dr David Lagman
Uppsala University
Memory and vision

Project outline and Gantt Chart



Establish specific qPCR method for eDNA survey (WP1), in the lab.

Water sampling in the rivers, eDNA extraction, qPCR (WP 1), during the seasons of juvenile down-migration and adult spawning.

Field study of larval and metamorphic sea lamprey in the river basins and data analysis (WP1), during metamorphic period.

Sampling of blood and tissues from metamorphic transformers in the Connecticut River (WP2), during metamorphic period.

Analysis of blood and tissues from metamorphic transformers by RIA, qPCR and IHC (WP2), in the lab.

Feeding study of post-metamorphic juveniles and sampling of blood and tissues (WP2), when the juveniles begin to feed.

Analysis of the samples from the feeding experiment by RIA, qPCR, IHC and WB (WP2), in the lab.

Establishing the protocol of artificial propagation of sea lamprey larvae (WP3), during adult spawning season.

Examining temperature effects on the early development of lamprey larvae, age 0-1 (WP3), in the lab.

Communication with stakeholders and dissemination (WP4) throughout the project period.

International national Peer-review article Report Meeting Science festival Workshop and study visit

Thank you!







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National Science Foundation