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LOCAL AND GLOBAL INITIATIVES:
HOW SCIENCE SUPPORTS MANAGEMENT ACTIONS ON DIADROMOUS FISH

Diadromous fish stocking: weaknesses, strengths and future challenges
Bordeaux 7-8 July 2022

Lessons learned from *Acipenser sturio* and *Acipenser oxyrinchus* restoration programs

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Lessons learned from *Acipenser sturio* and *Acipenser oxyrinchus* restoration programs

Acipenseridae overview

A. sturio & *A. oxyrinchus* Action plans

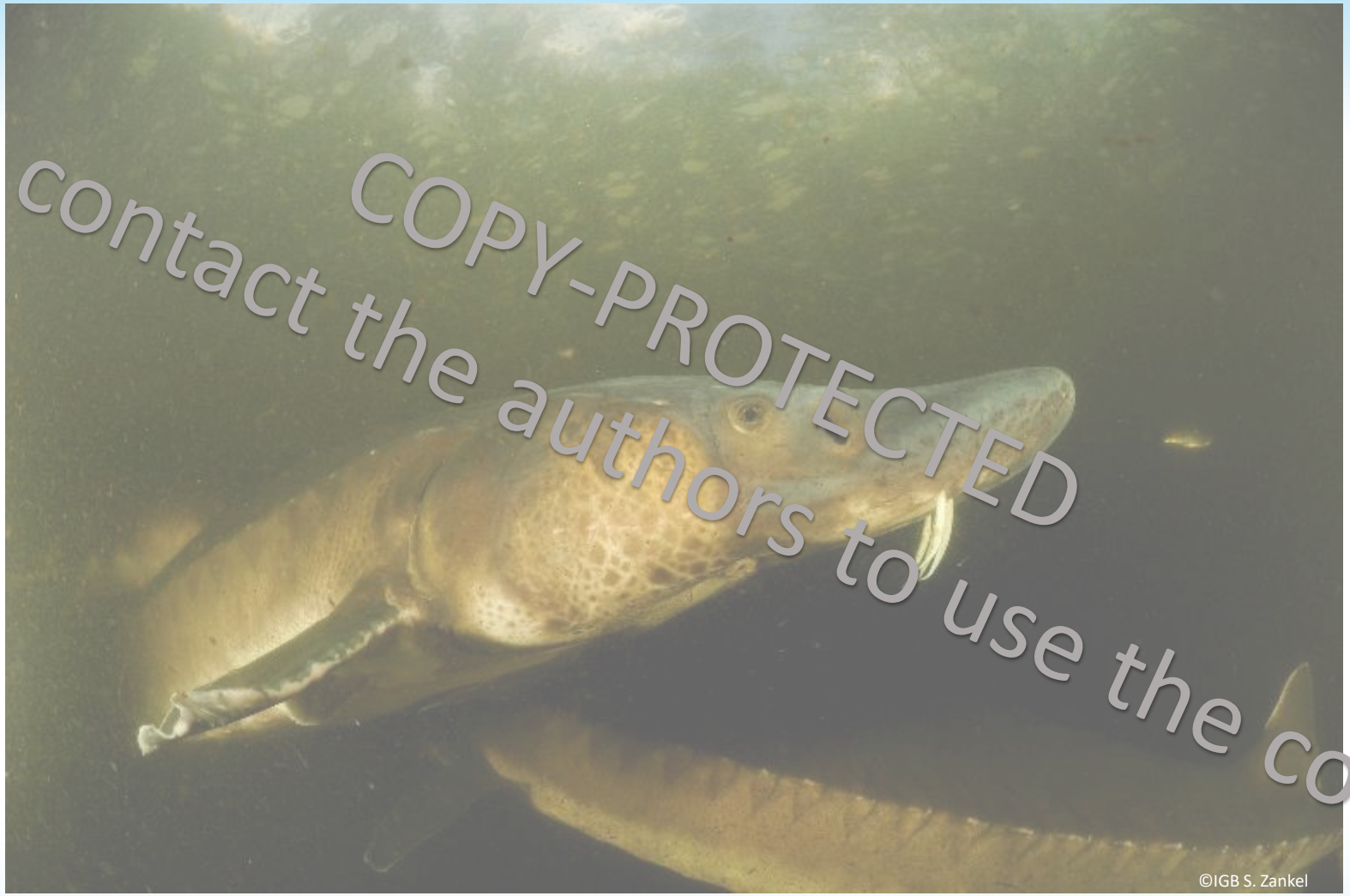
Why chose stocking to restore those populations?

How was stocking implemented?

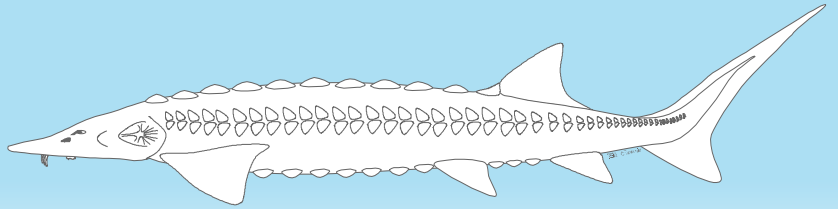
First results of the recovery programs

Lessons learned

Acipenseridae overview



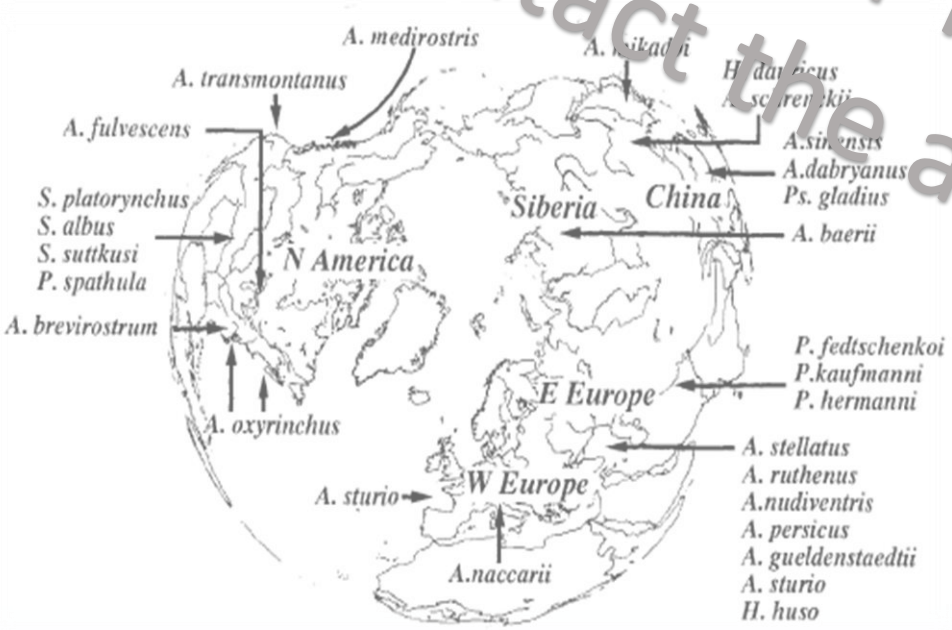
Acipenseridae



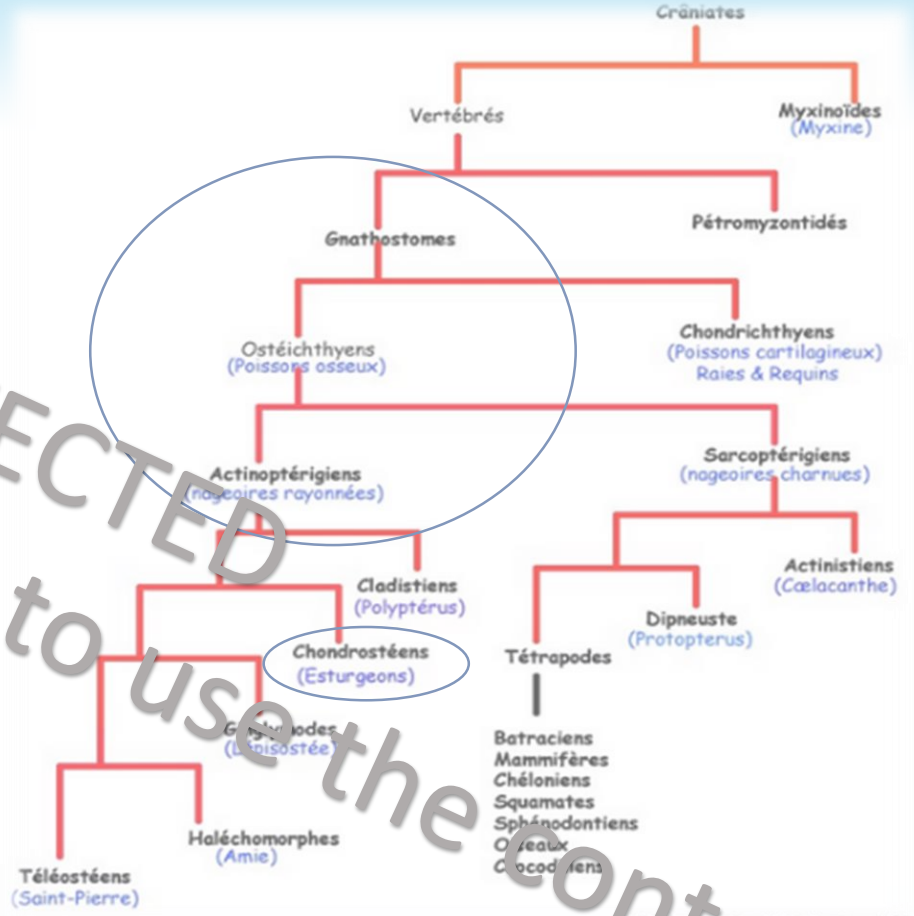
- Circumpolar distribution in the northern hemisphere

Asia (China, Japan), Europe, North America, Russia (Magnin 1959)

- Eastern Asia origin of the group (Koshelev & Ruban 2022)

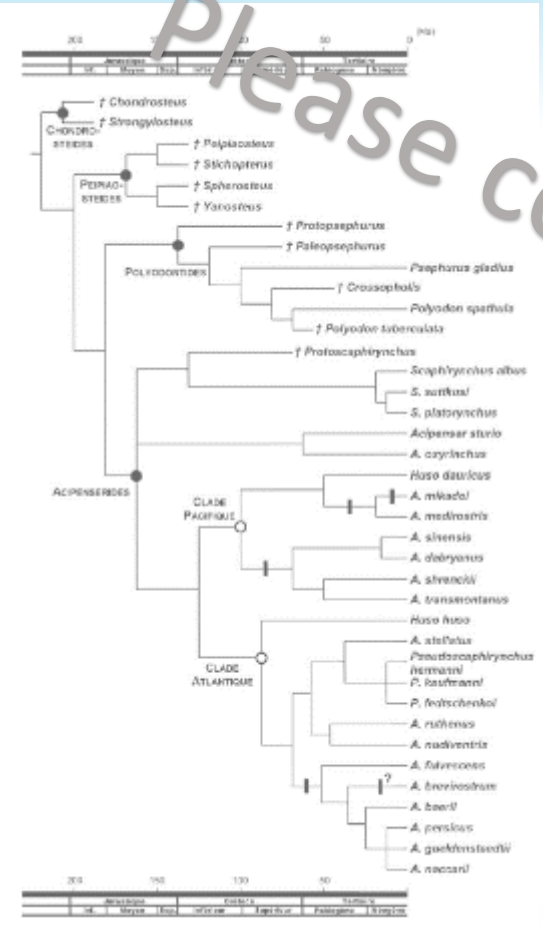


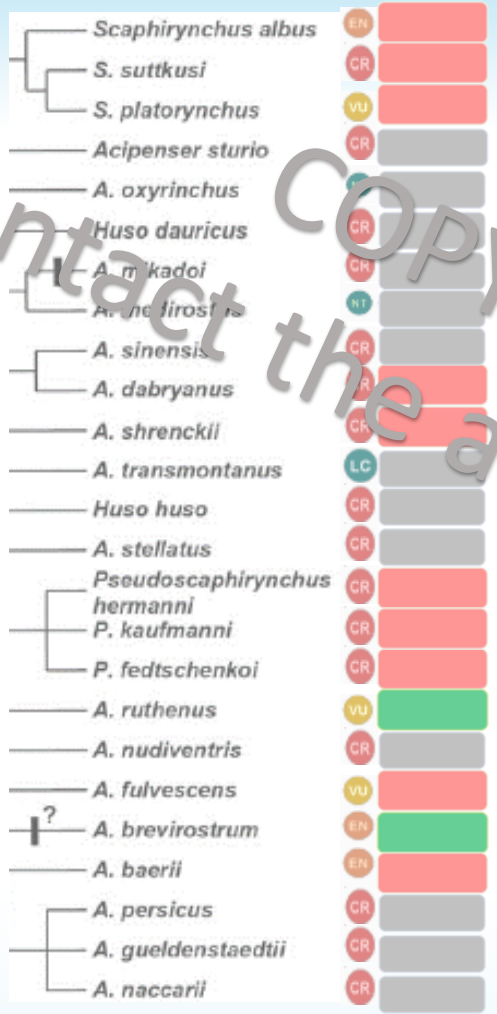
(Billard & Lecointre, 2001)



Acipenseridae

- 25/27 species, 4 genus (Birstein 1993, Birstein & Bemis 1997)



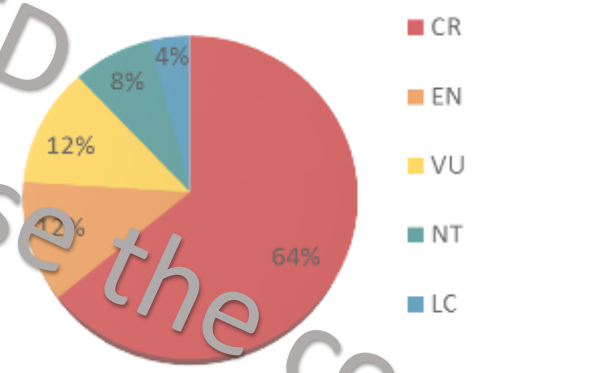


(adapted from Chassaing, 2010)

Freshwater species Potamodromous (40%)

Euryhaline species (8%)

Anadromous species (52%)



➢ **88% under threatened status**

Acipenseridae

Main characteristics

Five rows of large bony scutes, pentagonal shape of the body, heterocercal caudal fin, protractile ventral mouth, four barbels

Adult sizes from 0,5m (e.g. *Pseudoscaphyrhinchus spp*) to 8m (e.g. *Huso huso*) total length

Late maturity, iteroparous long living species (>= 50 years), average spawning interval = 4.2 years (Jäger et al. 2008)

Pseudoscaphirhynchus sp. (3 species)

0,5m Total length (life span ≈ 6 years)

Acipenser, Huso, Scaphirhynchus sp.

1 to 8 m Total length (life span >= 20 years)

Behavior

Freshwater spawning in large rivers in spring or fall, sticky eggs, downstream movements of juveniles to feeding habitats, in freshwater, estuary and at sea for diadromous species, seasonal movements, winter in deeper areas

Mainly bottom feeders, few piscivorous species

Umbrella species concept (Carrizo et al., 2017)

"These **large diadromous representatives of the megafauna** use freshwater, estuarine and marine habitats and they need functional connectivity between the diverse habitats they utilize. Most of them are classified endangered due to several anthropogenic threats (Rochard et al., 1990). **Their protection of the species and their habitats also protects other species of the same ecosystems**."

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Sturgeon species in Europe

Russian Sturgeon complex

CR, FFH A-V, CITES A-II

Adriatic Sturgeon

CR, FFH A-II, IV, CITES A-II

Ship Sturgeon

CR, FFH A-V, CITES A-II

Atlantic or **Baltic Sturgeon**

VU/EX, FFH A-V, CITES A-II

Sterlet

VU, FFH A-V, CITES A-II

Stellate Sturgeon

CR, FFH A-V, CITES A-II

European/Common Sturgeon

CR (EXW), FFH A-II, IV, CITES A-I

Beluga

CR, FFH A-V, CITES A-I

© M. Roggo f. *A. sturio*; © Thomas Friedrich

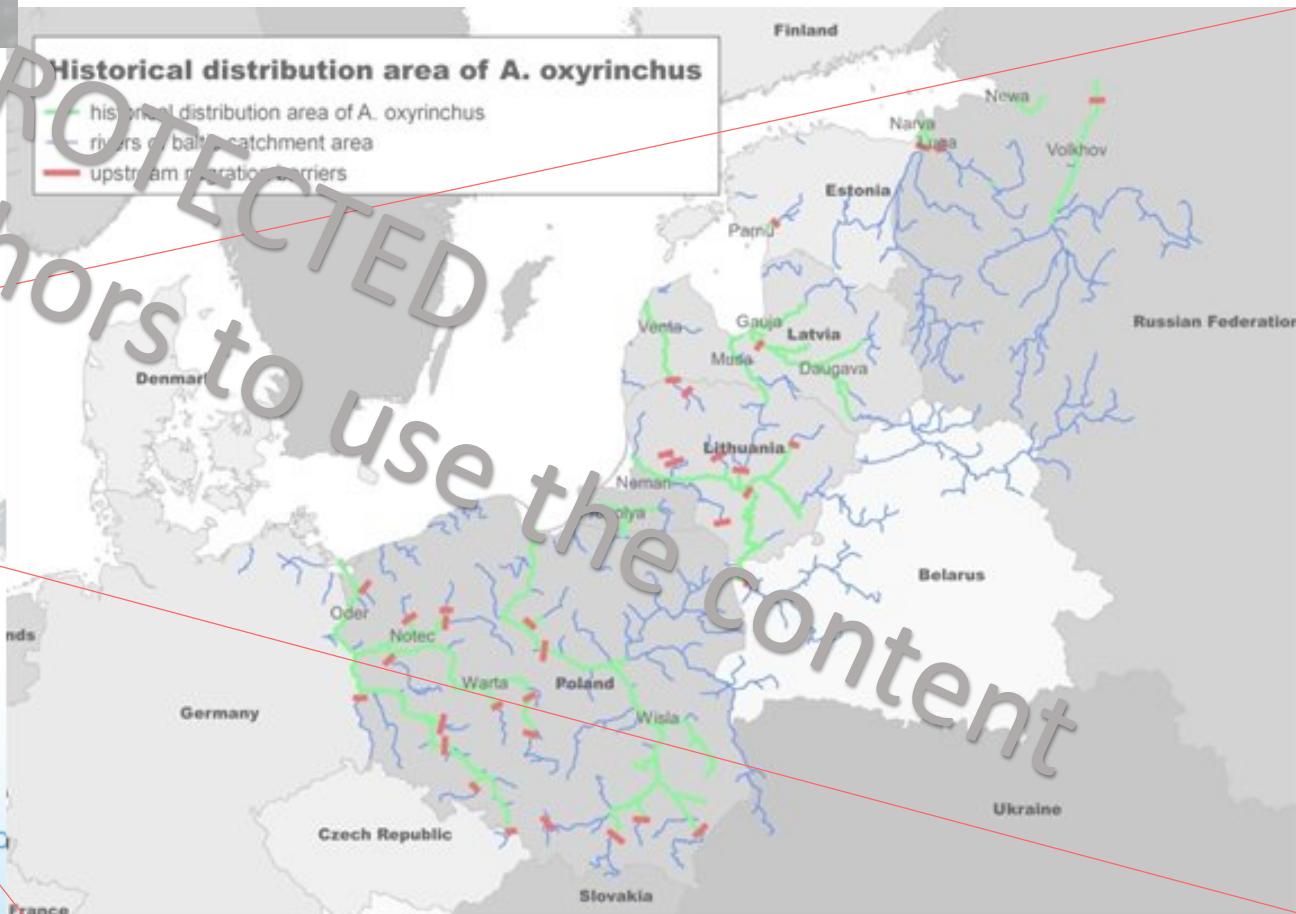
Acipenser oxyrinchus

Mainly distributed along North America East coast

In Europe distribution mainly in the Baltic Sea since 3500b.p.

Functionally extinct since 1960s

Red/white = *A. oxyrinchus*
Blue = *A. sturio*
n. Ludwig et al. 2002



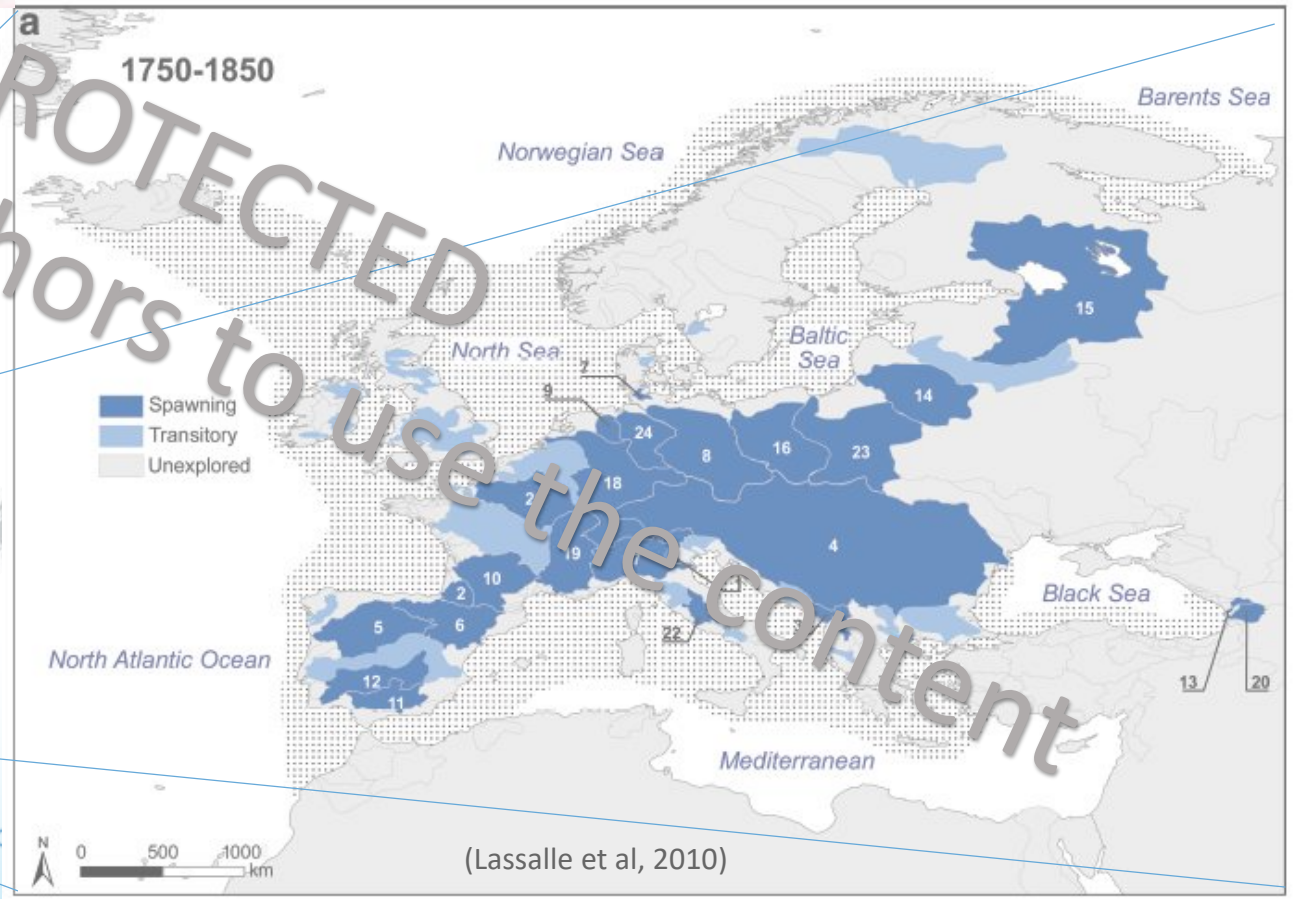
Acipenser sturio

In 1850 Distribution from Black Sea to North Sea, several populations in large rivers basins

In 2000 Distribution Bay of Biscay to North Sea, only one population left in the Gironde-Garonne-Dordogne basin

Red/white = *A. oxyrinchus*
Blue = *A. sturio*

n. Ludwig et al. 2002

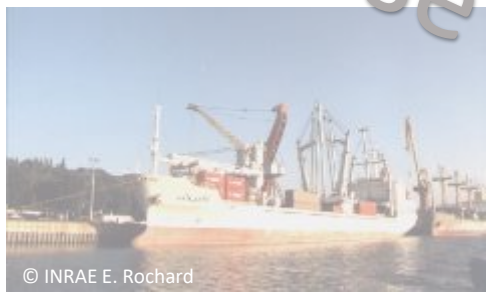


(Lassalle et al, 2010)

A. sturio & A. oxyrinchus

Sensitivity due to their life history traits

Late age at maturity depending upon latitude and sex Range 10-16 years old
Long life span 40, 60 & up to 100 years old
Anadromy: homing / habitat shift / osmoregulation / migration


© INRAE E. Rochard

Threats

Habitat loss (navigation, damming, substrate extraction), Fisheries, ship strikes, pollution?, climate change?


© Enfoque

Threats removal tentative


© Vattenfall 2011

Acipenser sturio

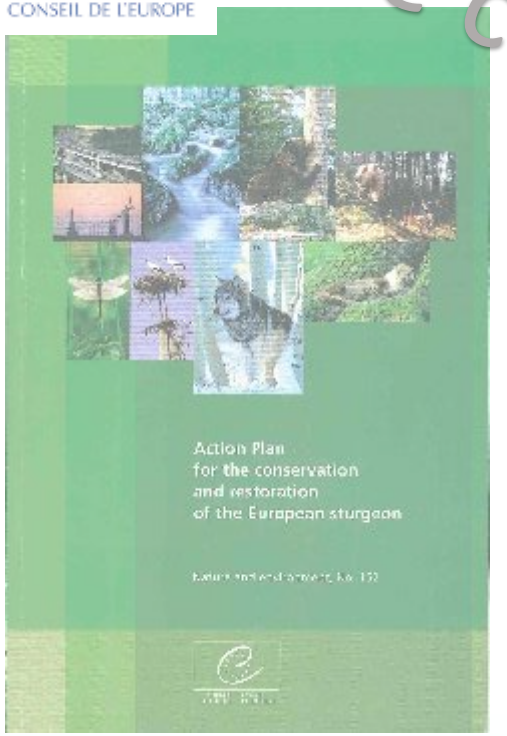
Protection in fisheries successful ? (D, F)
Habitat protection effective (F)
Habitat restoration not attempted yet
Connectivity improvement (Fish ladder on Elbe River)

Acipenser oxyrinchus (EU)

Protection in fisheries with little success (D, PL, LV, LT, RUS)
Habitat protection largely non-existent or ineffective
Habitat restoration: dam removal successful in the US (Kennebec) but no attempt in EU

A. Sturio Action Plans for its Conservation and restoration

European level

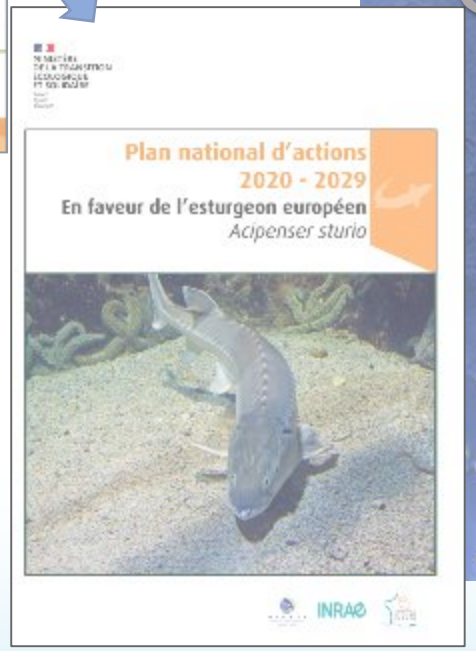


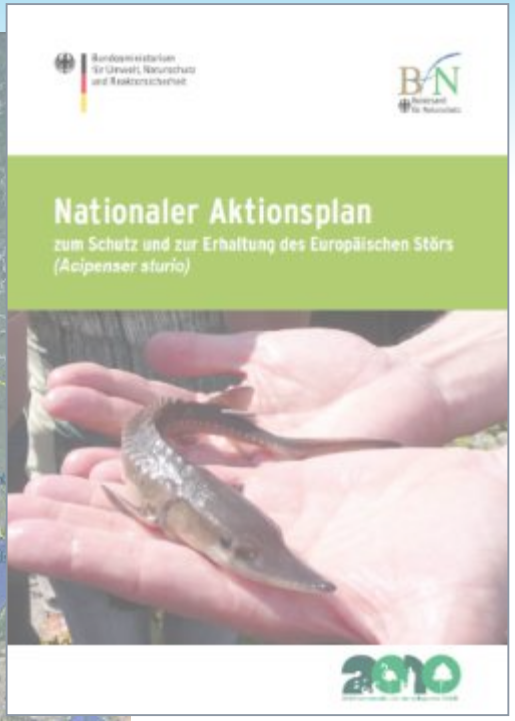
- **1 *In situ* conservation of *A. sturio***
  - Significant reduction of fishing mortality
  - Effective control of allochtonous species
- **2 Protection and restoration of essential sturgeons habitats**
  - Protecting and improving the quality and continuity of essential riverine and estuarine sturgeon habitats
- **3 *Ex situ* conservation and re-introduction of *A. sturio***
  - *Ex situ* conservation of *A. sturio*
  - Release of *A. sturio* for re-establishment or enhancement
- **4 International cooperation**
  - Facilitation of international co-operation

→ **Implemented in France (Gironde basin) and in Germany (Elbe basin)**

A. Sturio Action Plans for its Conservation and restoration

Updated





A. oxyrinchus HELCOM Protection and Recovery Plan

- 1 **Actively support the recovery** of the target populations to **initiate a positive population trend**
- 2 **Protect the populations under recovery from accidental and directed removal of individuals**
- 3 **Protect and restore the sturgeon habitats where available/necessary**
- 4 Secure or facilitate **sturgeon migration** in all target rivers
- 5 **Increase** public, administrative and political **awareness** on sturgeon conservation
- 6 **Set proper financial and legal prerequisites for sturgeon restoration**
- 7 **Monitor and evaluate Action Plan implementation** to allow **adaptive management**

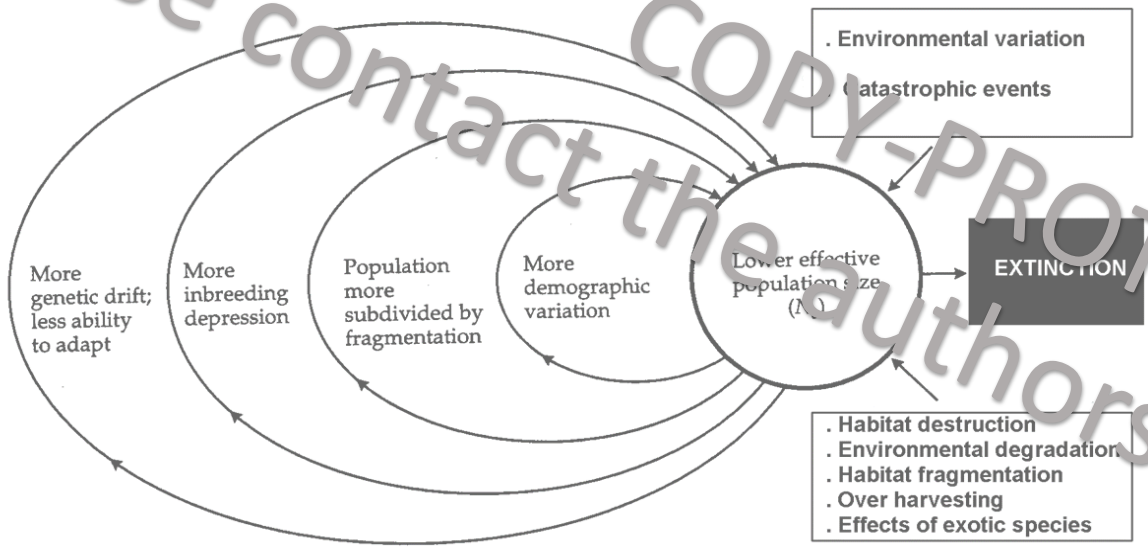
Active implementation
Germany / Poland / Lithuania / Latvia / Estonia / Russia / Sweden
3 main rivers **Odra**, **Vistula** & **Nemunas**

& support through fisheries awareness campaigns by Finland & Denmark

Actions plans differences in coordination

Criterion	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
Action Plan implementation	5-10 year plan	National plan (not restricted in time)	10 years plan Basin wide and national
Administration	Coordinated by a joint committee including stakeholders	No coordination body for implementation	Coordinated by a scientific body on Helcom level (EG STUR)
	Supervision by Environmental Ministry	Cooperation with Environmental Ministry	Cooperation with Environmental Ministries

Why chose stocking to restore those populations ?



Primack, 1998

©Conservation bytes

Why chose stocking to restore populations ?

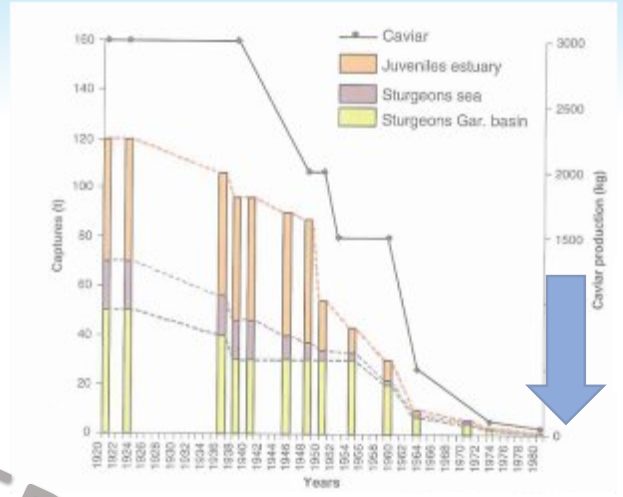
Protection measures

Recovery options	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
Last observation of natural reproduction	1994	1964	Pre 1960
Closed season for recovery of population	July-December (1950) Gironde estuary (1952) **Full protection** **1982**	Fisheries protection 1954 **Full protection** **1976**	**Full protection** **1932** (Poland)
Closed areas for reproduction protection	-	1896 (Oste River)	-
Gear restrictions for juvenile protection	**Minimum fish size** (1890, 1923…1935, 1950) **Mesh size** (1928)	**Minimum size** and **mesh size** in Elbe River (1892, 1894, 1915, 1918) Baited hooklines Eider River (1914)	-
Habitat protection of essential habitats	Spawning habitats (ZNIEFF 1985-2008)	Feeding habitats (marine 2006)	Feeding habitats (marine 2006)

Why chose stocking to restore populations ?

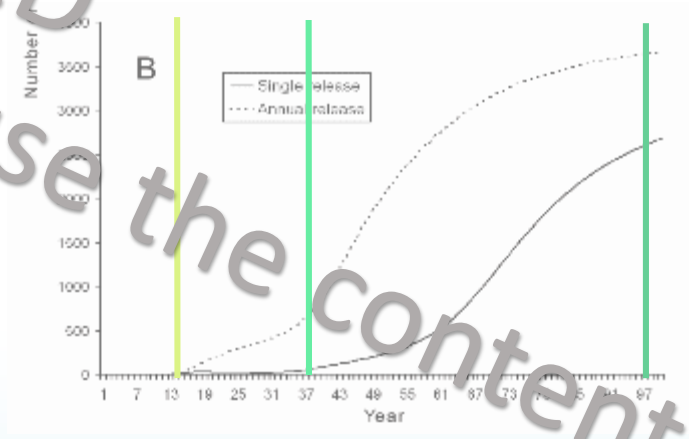
- Protection measures too late after the decline
  - Habitat protection insufficient or too late ?
  - Protection in fisheries did not revert the decline, at the beginning of the measures bycatch continued to remove last individuals
- Reproduction at low population sizes too rare (extinction vortex) and mortality of early life stages too high (Boreman 1997)
- Without releases the recovery time at least twice as long thus increasing the risk of fatal effects of adverse impact
  (>25 years considering population growth curve (Jaric & Gessner 2014))

Catches of *A. sturio* in the Gironde from 1920 to 1980



Fishing ban 1982

Castelnaud 2011



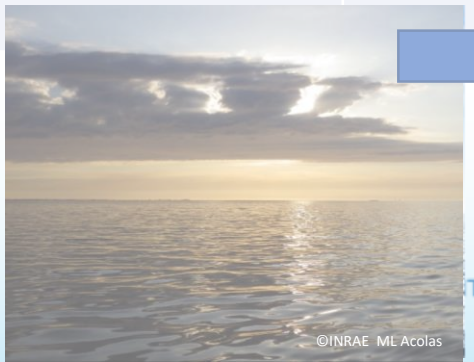
Jaric & Gessner 2014

How was stocking implemented ?

How was stocking implemented ?

Ex-situ conservation: broodstock development

	A. sturio F	*A. sturio* D	*A. oxyrinchus*
Last observation of reproduction	1994	1964	Pre 1960
Population size at onset of restoration efforts	500-2000 (Rochard, 1992)	0	0
Onset of *ex situ* measures	1994	1996	2004
Collection of spawners in the wild to safeguard remaining genetic heterogeneity	Wild spawners collected at sea and in the GGD	Worked only at population levels pre 1900 Backup population from F1	Did not work after 1900 Mature fish imported from Canadian population, captive stock based on them and imported eggs



How was stocking implemented ?

Ex-situ conservation: broodstock development

☺

-Save the species from extinction

-Safeguard remaining genetic heterogeneity

-Increase the number of individual for stocking

-Increase knowledge about the species

-Citizen education

☹

-Impact on the original population by taking specimen

-Adaptation to captivity conditions: genetic and behavior losses

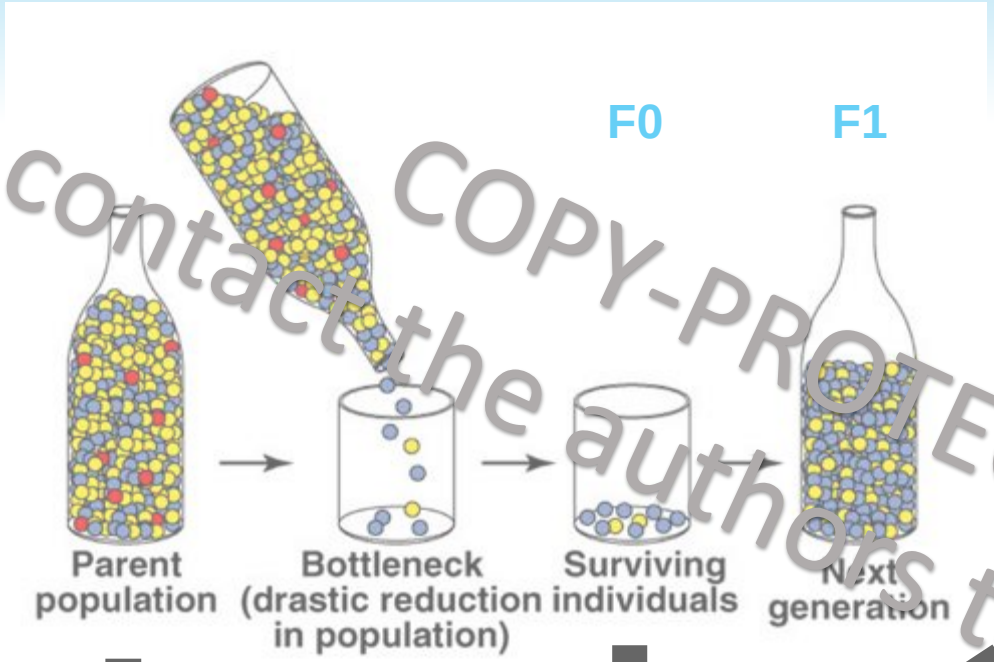
- Acclimation in a captive environment & difficulty for reproduction

-Constraint to manage the stock (perennial funding, qualified staff)

➔**A challenge to overcome reproduction (best conditions, best food) and to maintain diversity**

How was stocking implemented ?

Ex-situ conservation: broodstock development



Roques et al. 2017

ORIGINAL DIVERSITY

A. sturio

BROODSTOCK (N=42)

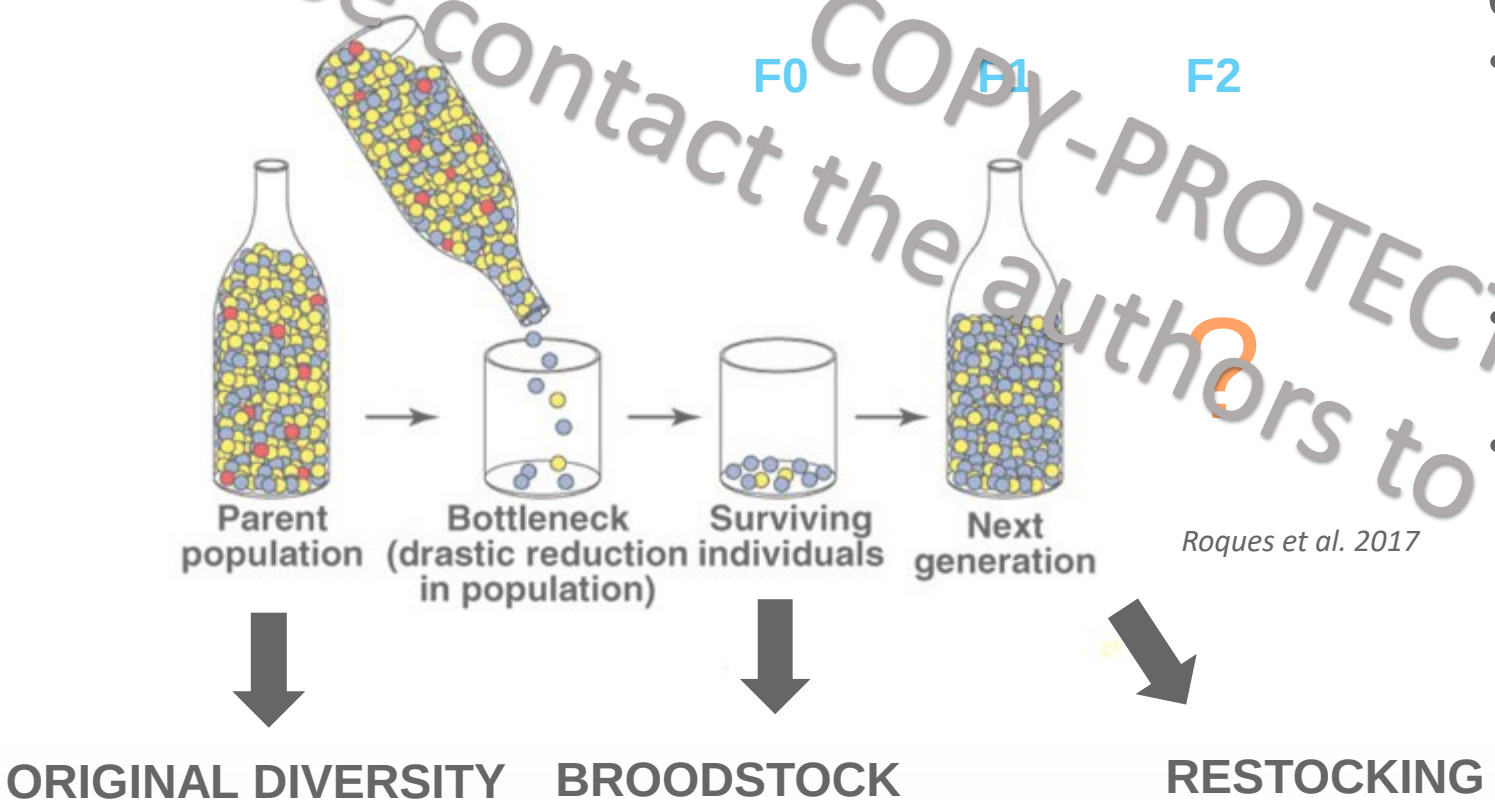
Genetic bottleneck
Low eff. pop. size (Ne≈10)
Low diversity (N=3-4 all/loc)
Structured in 3 groups
Some breeders=related

RESTOCKING (≈200 juveniles)

Diversity is maintained (95%)
70% families represented
3 genetic groups
Some level of inbreeding

How was stocking implemented ?

Ex-situ conservation: broodstock development



Roques et al. 2017

Countermeasures:

- **Start early** with collection of broodstock from the wild - don‘t miss the chance. **But when to start** to limit impact on the wild population?
- Include **wild fish** whenever possible to enhance genetic diversity
- Implement **genetic breeding plans** to minimize inbreeding and outbreeding
  - Studbook implementation (Roques 2018)

How was stocking implemented ?

Stocking strategy

Measures taken	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
Stage at release „Bet hedging strategy“	Larvae, 3 month old, 1 year old, 2 year and older	3 month old, 1 year old, 2 year and older	Larvae, 3 month old, 1 year old, 2 year and older
Location of stocking	Historical spawning grounds mainly and feeding grounds for larger fish		
Tagging	Genetic tagging and pit tag for bigger fish (>6months)	Floy tags > 12 cm	Floy tags > 12 cm

How was stocking implemented ?

Stocking strategy

☺

-Increase the number of individuals in the wild

-Avoid the high mortality rate of the early stage that occur in the wild (effective use of resources)

-Helps to reduce risk of extinction through diversification

☹

- Requires genetic broodstock management to minimize inbreeding

- Domestication risk

-Hatchery practice may have impact on individual fitness related traits: hatchery reared fish less adapted to the wild

➔**A challenge to adapt hatchery practice to optimize fitness related traits of juvenile produced**

➔**A challenge to choose the best ontogenetic age for stocking efficiency**

How was stocking implemented ?

Stocking strategy: conventional hatchery environment vs natural environment

Johnsson et al. 2014

Spatial & temporal variability
Unpredictable events
→Structural complexity
→Water flow and level
→Species diversity (predators)

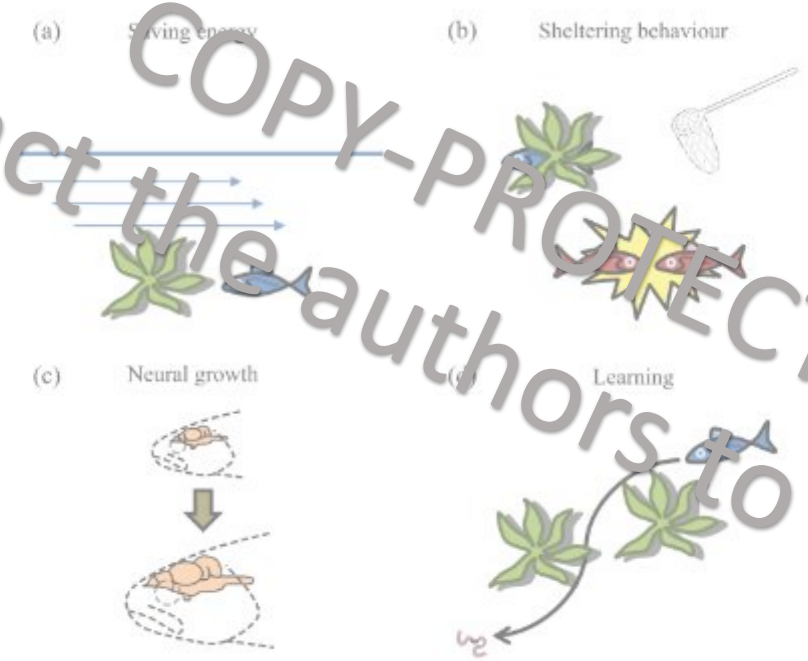
Spatial & temporal Homogeneity
→Regular food supply
→Higher density

➔**Key environmental differences likely to affect phenotypic development**
(Giller & Malmqvist 1998, Huntingford et al. 2012)

How was stocking implemented ?

Stocking strategy: conventional hatchery environment vs natural environment

Enhancing phenotypic flexibility by introducing physical structure (Johnsson et al. 2014)



➔**Increasing stimuli in the rearing environment would improve behavioral capacity and post release survival « training to natural conditions »**

(Boysen and Hoover 2009; Brown and Laland 2001; Chebanov et al. 2011; Olson et al. 2012

How was stocking implemented ?

Stocking strategy: conventional hatchery environment vs alternative

IMITATING NATURE: DOES IT WORK?

'Fish aimed for stocking in the wild [...] should be prepared for life in the wild, which requires well-developed learning skills in, for example, foraging and avoiding predators. These fish should have the species-specific behavioural repertoire of a wild fish'

Brännäs & Johnsson, 2000

Does it produce more adapted fish ?

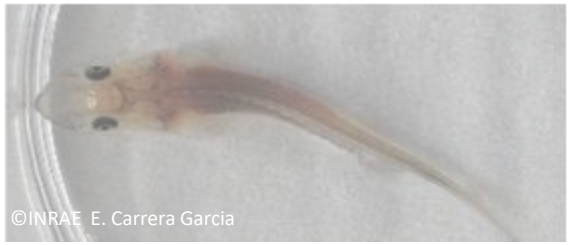
?

How was stocking implemented ?

Stocking strategy: conventional hatchery environment vs alternative

Enriched (1-month-old)

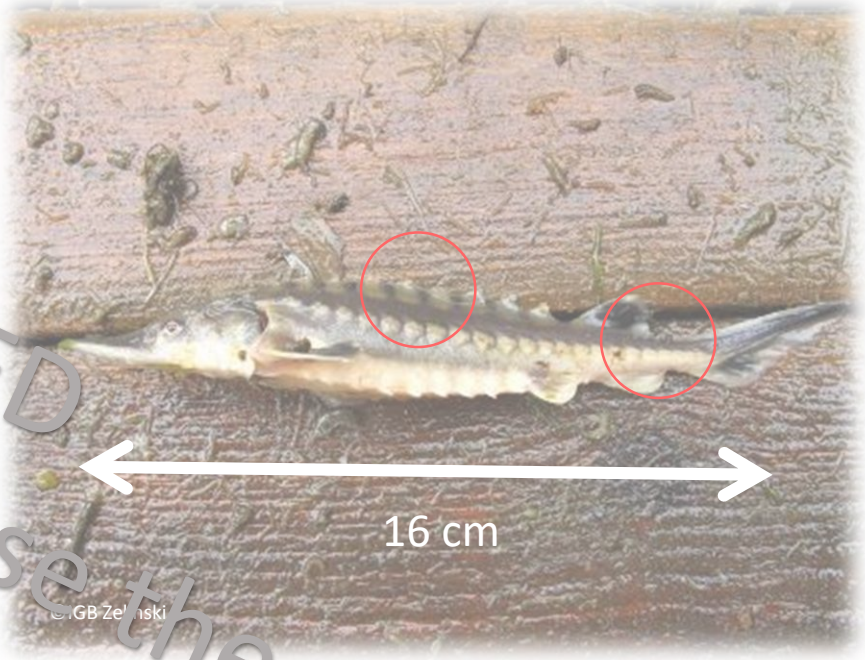
Traditional (1-month-old)



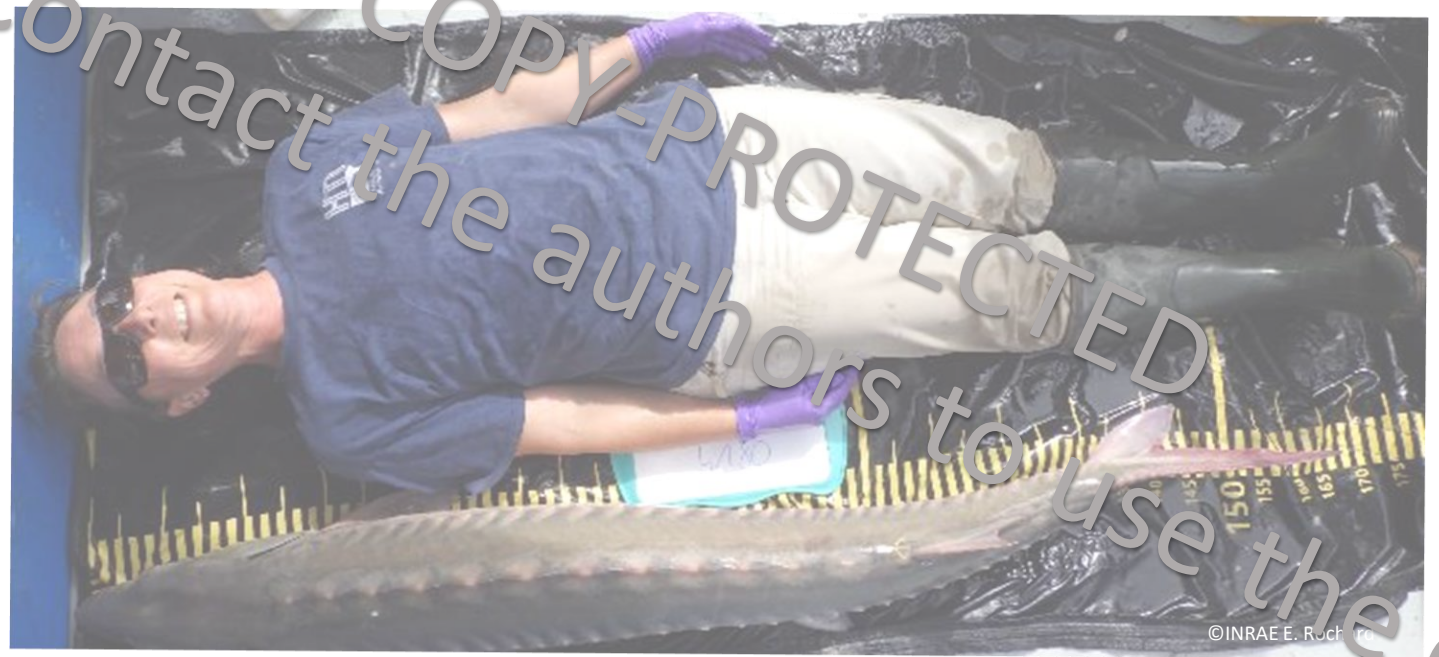
Enriched environment advantages:
early imprinting and exposure to pathogens, predator odors and environmental fluctuation

Difference in behavior: "enriched" slower to initiate a risky behavior and more explorative than "traditional"
A genotype environment interaction
(Carrera et al. 2017)

More pigmented fish and more spiny scutes
Caudal peduncle thicker enabling a faster swimming motion (Vcrit 20% higher than control) (Gessner, pers. com.)



First results of the recovery programs



First results of the recovery programs

Juveniles stocked and adult observation in the wild

Criterion	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
Stocking period	1995 and 2007-2015	2008-2015	2006-ongoing
Fish released	Abt. 1.700.000	Abt. 19.600	Abt. 4.600.000
Returning adults (observed)	8 observations of adults in freshwater since 2020	8 adults in freshwater since 2020	1 adult in freshwater in 2017
Reproduction in the wild	No	No	No
Natural recruitment	No	No	No

First results of the recovery programs

Ex-situ stock actual composition

Criterion	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
2022 Ex situ stock size	146 Ind (N♀, N♂)	398 Ind. (194♀, 204♂)	860 (410♀, 450♂)
2022 Number of potential spawners	5♀, 15♂	0♀, 12♂	12♀, 26♂
Assisted reproduction from **F1**	About 800 larvae obtained in 2022	none	> 900 000 larvae from 3 females since 2018

First results of the recovery programs

Monitoring in the wild to follow stocking results

Criterion	*A. sturio* F	*A. sturio* D	*A. oxyrinchus*
Monitoring	6 sampling / year in the Gironde Estuary Bycatch reports Telemetry	Only through telemetry and accidental bycatch	Only through telemetry and accidental bycatch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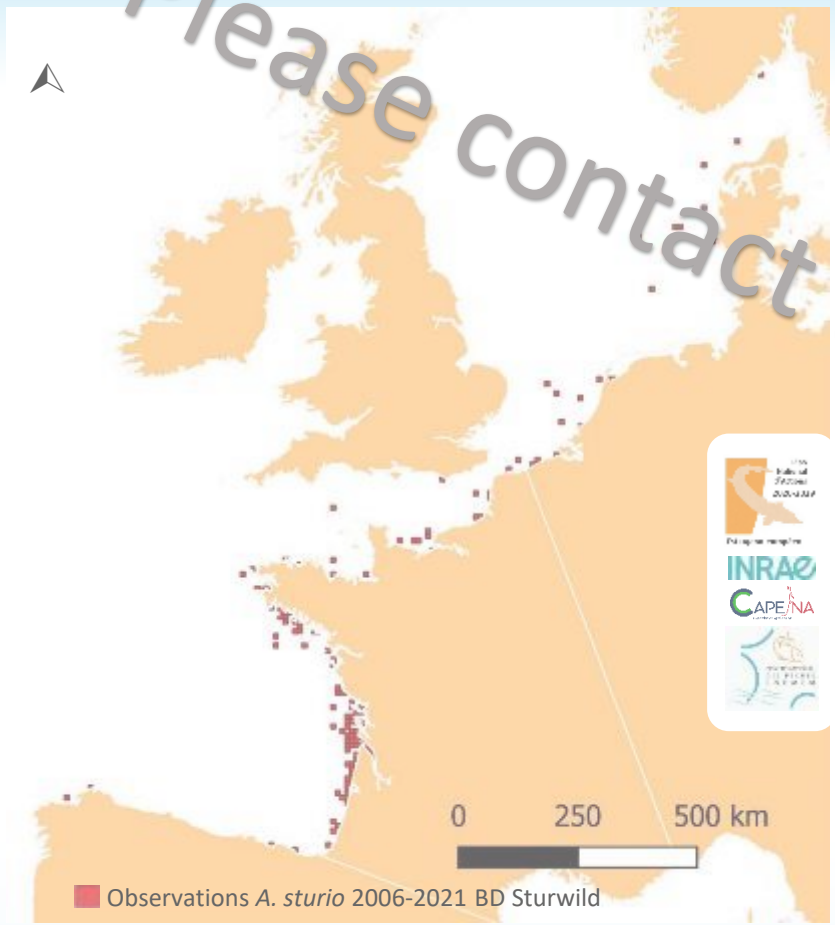
© Anonymous

First results of the recovery programs

Monitoring in the wild: incidental observations

A. sturio incidental observations 2006-2021



Charbonnel & Acolas 2022

External tagging

A. oxyrinchus incidental observations 2010-2017

Habitat at sea

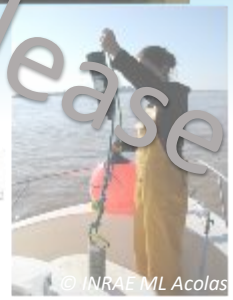
Size & location (sea, estuary, river)

First results of the recovery programs

Monitoring in the wild: telemetry

➢ **Gironde:** Passive acoustic tracking

© INRAE E Rochard

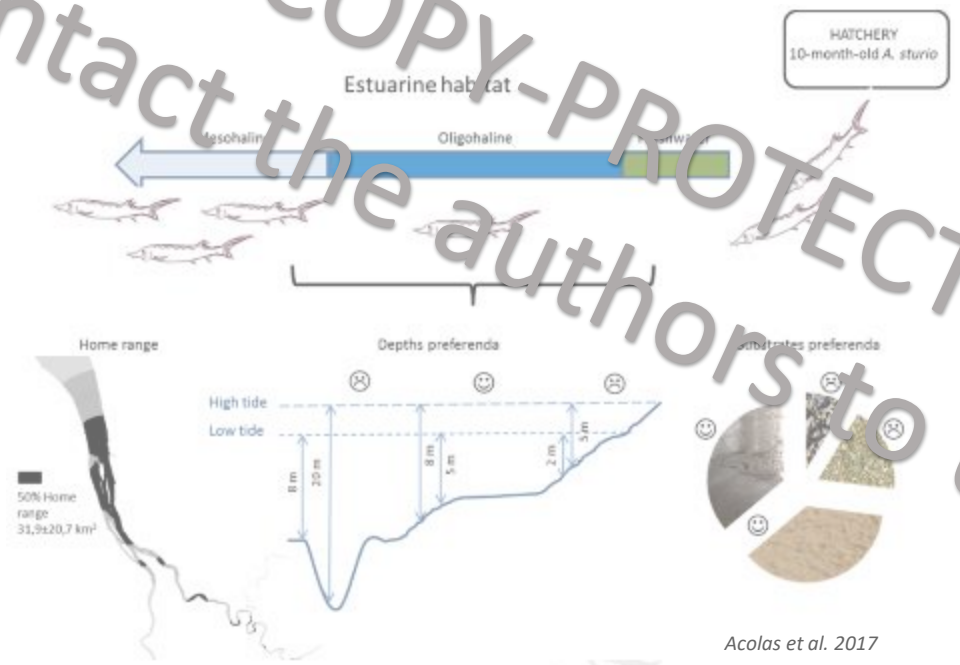


© INRAE ML Acolas

➢ **Elbe:** Active tracking

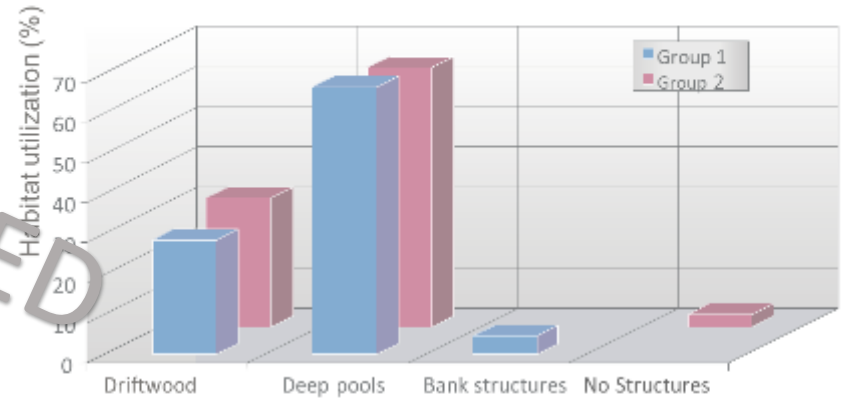
© IGB J. Gessner

A. sturio juveniles 10 month-old upstream estuary habitat preferences



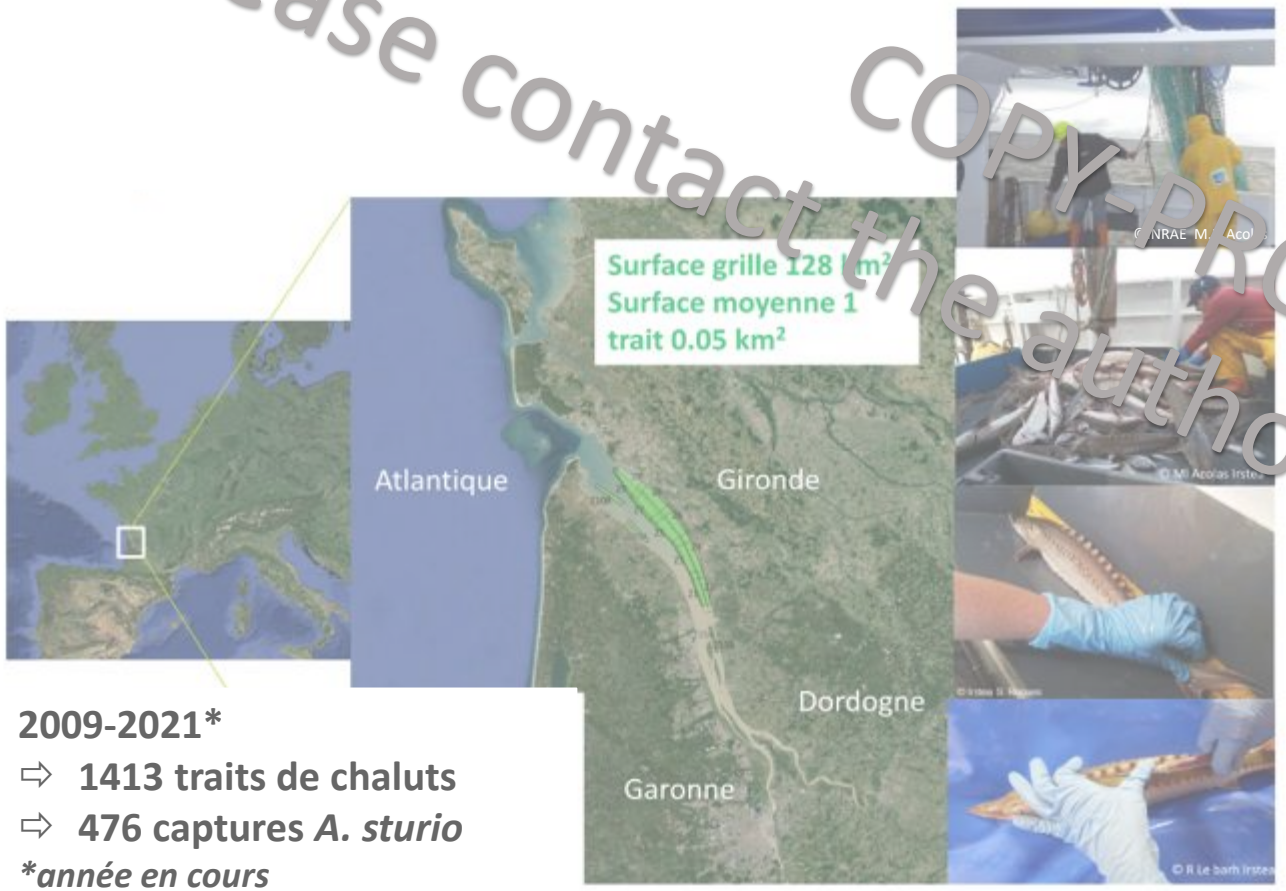
Acolas et al. 2017

A. oxyrinchus juveniles 35-50 cm
Staging habitat freshwater



First results of the recovery programs

Monitoring in the wild: estuarine fraction of *A. sturio* Gironde population



2009-2021*

⇨ **1413 traits de chaluts**

⇨ **476 captures *A. sturio***

année en cours

Fish size & weight & location

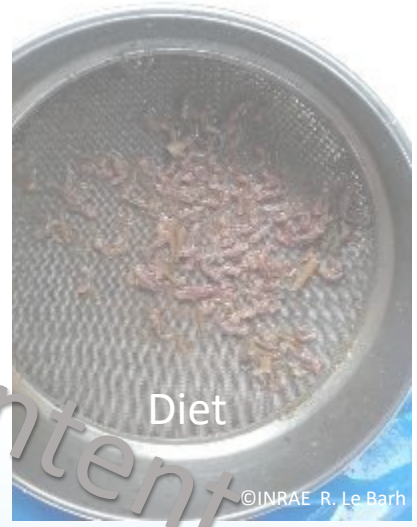
Sampling of tissue for further analysis (i.e. genetic)

Age estimation

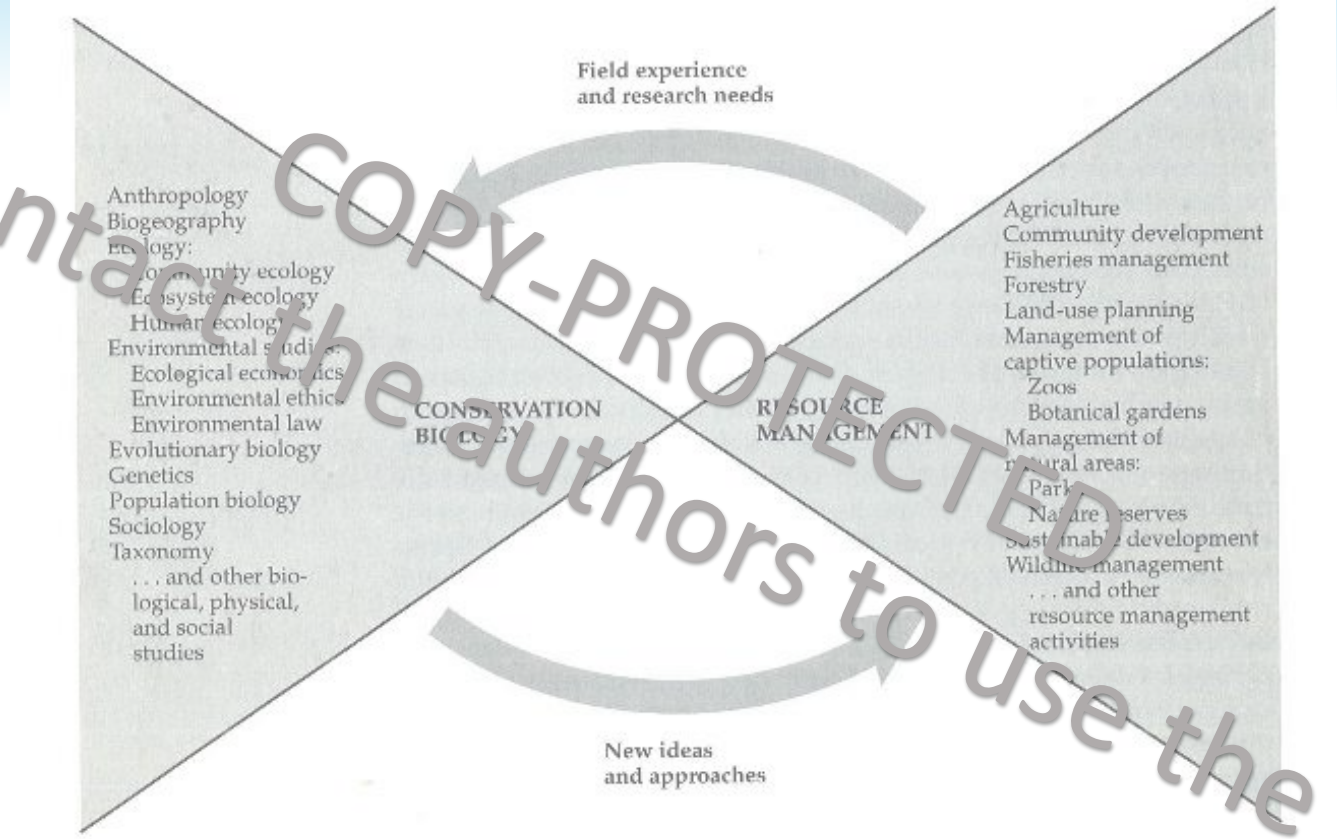
Tagging

Diet assessment

Contaminant analysis (Sturtop ANR)



Lessons learned



Primack, 1998 adapté de Temple, 1991

Lessons learned - practical

- **In the absence of reproductive population**, **recovery of populations need active support** in order to
  - Limit impacts upon essential habitats (spawning, early life phases)
  - Limit mortality linked to fisheries & navigation
  - Enhance awareness
  - Acquire knowledge to improve information on potential critical impacts
- It is important to start with ***ex situ* measures before the species becomes rare** to preserve sufficient genetic heterogeneity
- Old broodstock from the wild better success than F1 ? From *A. oxyrinchus* experiences the productivity of the broodstock, the fertilization and the hatch was better in older broodstock of wild catch, comparison ongoing
- **Conservation aquaculture** practice, not only aquaculture
- Differences between *A. sturio* and *A. oxyrinchus*
  - level of risk of extirpation
  - potential to increase genetic variability through imports

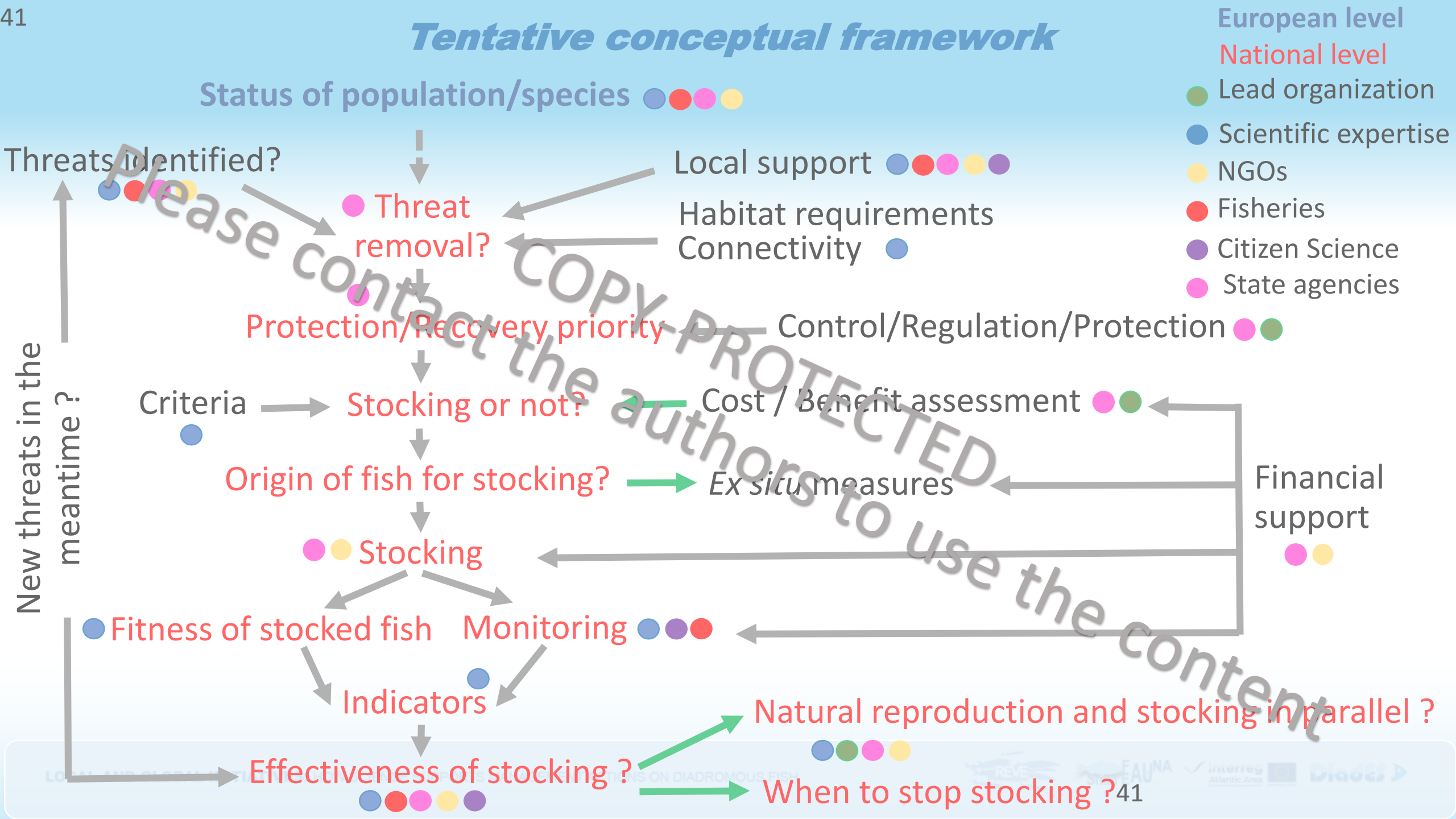
Lessons learned - administrative

- Recovery requires **national coordination with sufficient authority**
- **Challenges** in habitat protection and restoration needs a **multitude of stakeholders to be involved**
- **Clear prioritization** of recovery over other uses necessary
- **Funding** must be institutional and must be provided in accordance with Action Plan targets to avoid friction in implementation
- **International collaboration** can help to
  - Overcome national obstacles
  - Share methods and knowledge
  - Increase survival at sea
- **Coordination of the 2 *A. sturio* plan important** / sharing methods and knowledge

Lessons learned – issues to be solved

- Future challenges comprise:
  - **Conflict between supported and self-sustaining populations**
    - **when to stop releasing ?**
    - **when to stop *ex situ* stocks ?**
  - Long-term **maintenance of broodstock** (size adapted to needs)
  - **Cost split** between national and collaborating beneficiaries
  - **Ensuring long term monitoring** of performance of fish after release, during and after natural reproduction to determine impacts and countermeasures
  - Responsibility for and **extent of rehabilitation measures**
  - Addressing the challenges of **climate change**

Tentative conceptual framework



Many thanks to all people involved &
Thank you for your kind attention!

LOCAL AND GLOBAL INITIATIVES:

HOW SCIENCE SUPPORTS MANAGEMENT ACTIONS ON DIADROMOUS FISH