

# When tourism and recreational fishing have contaminated rivers and high mountain lakes : Examples from Patagonia and Pyrenees



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### **Rivers of Patagonia :**

- Pristine environment
- Low productivity of rivers
- Presence of various native fishes (Galaxiidae,...)



### **Pyrenean mountain lakes :**

- Oligotrophic or very low productivity
- Sensitive ecosystems
- Naturally fishless due to topographic barriers

**Two ecosystems concerned by human-induced Introduction of non-natives salmonids species during the last 150 yrs**

- Increase the productive capacity of nations through acclimatation of new species
- Promote the development of small-scale fisheries
- To enable the development of recreational fishing and tourism

# Non-natives salmonids introduced for fish-stocking since the late 19th c.

## Pyrenees



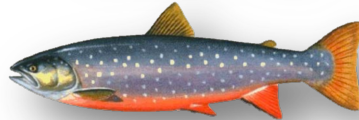
*Brown trout*



*Brook trout*



*Rainbow trout*



*Arctic char*



*Lake trout*

## Patagonia



*Brown trout*



*Rainbow trout*



*Chinook salmon*



*Atlantic salmon*



*Coho salmon*

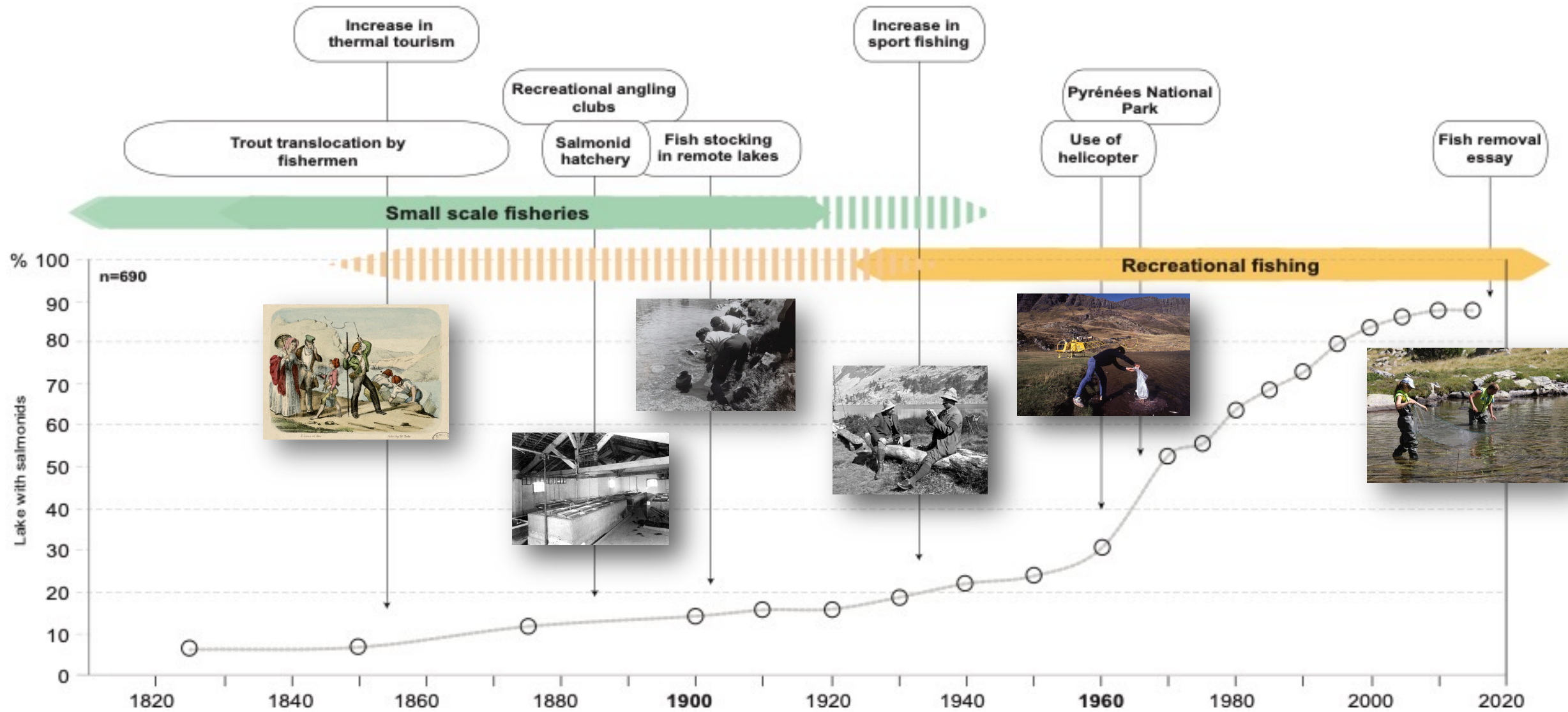


*Masu salmon*

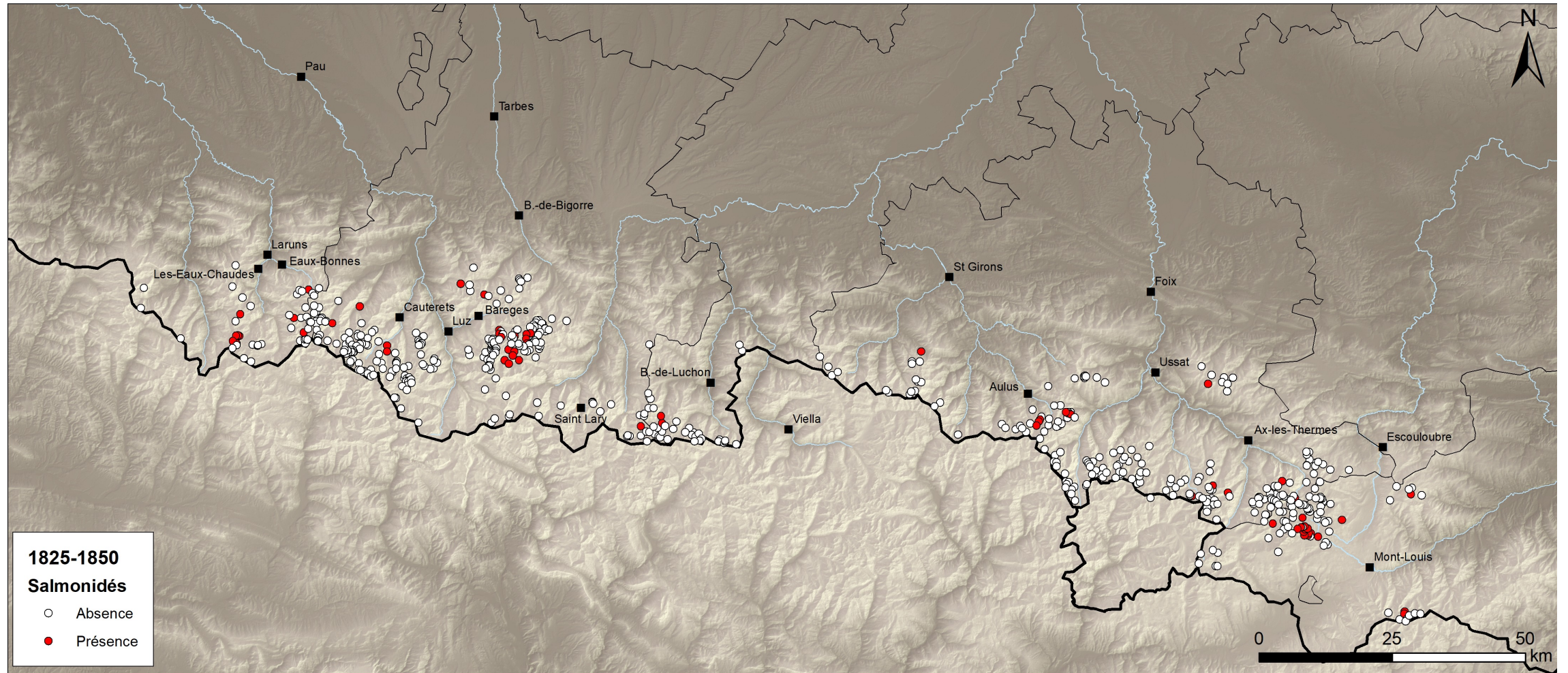


*Sockeye salmon*

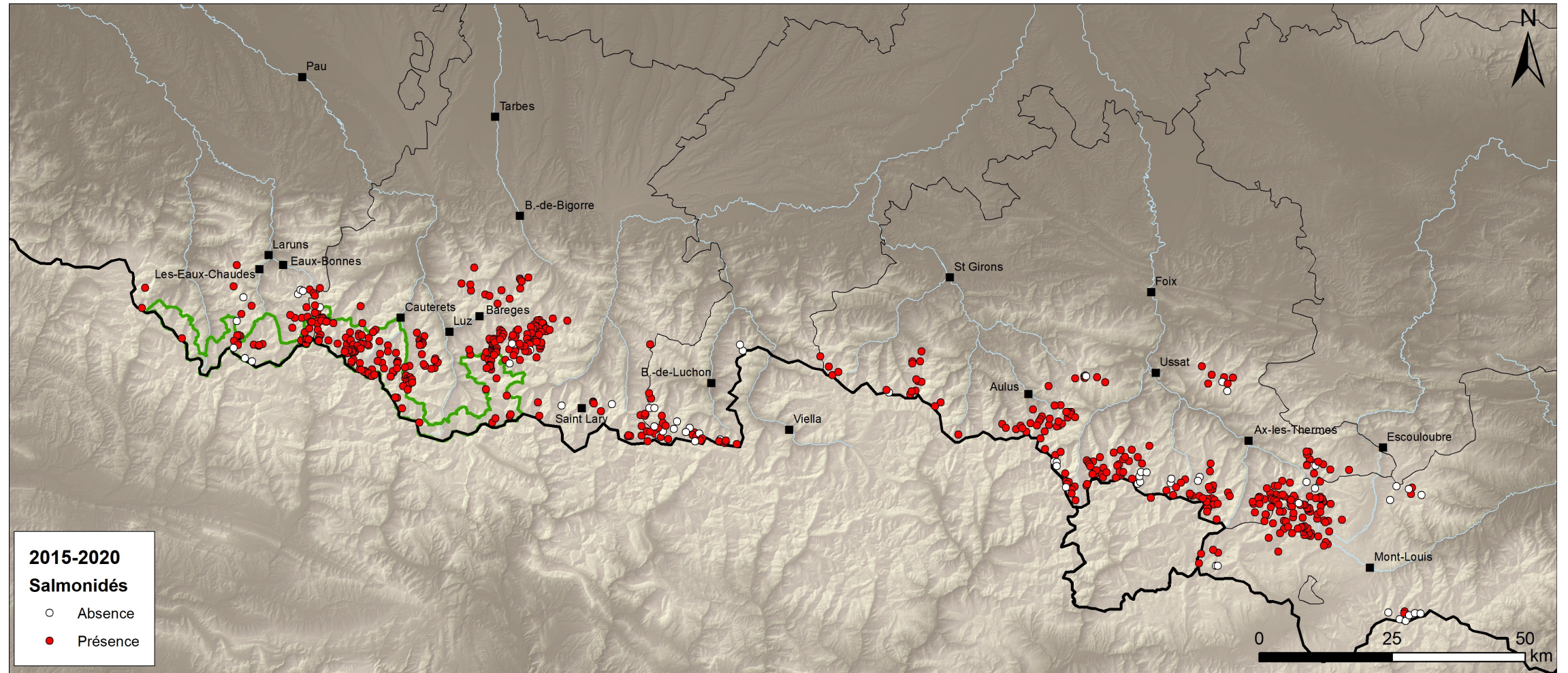
# Historical process of salmonids introduction in the pyrenean mountain lakes



# Historical process of salmonids introduction in the pyrenean mountain lakes



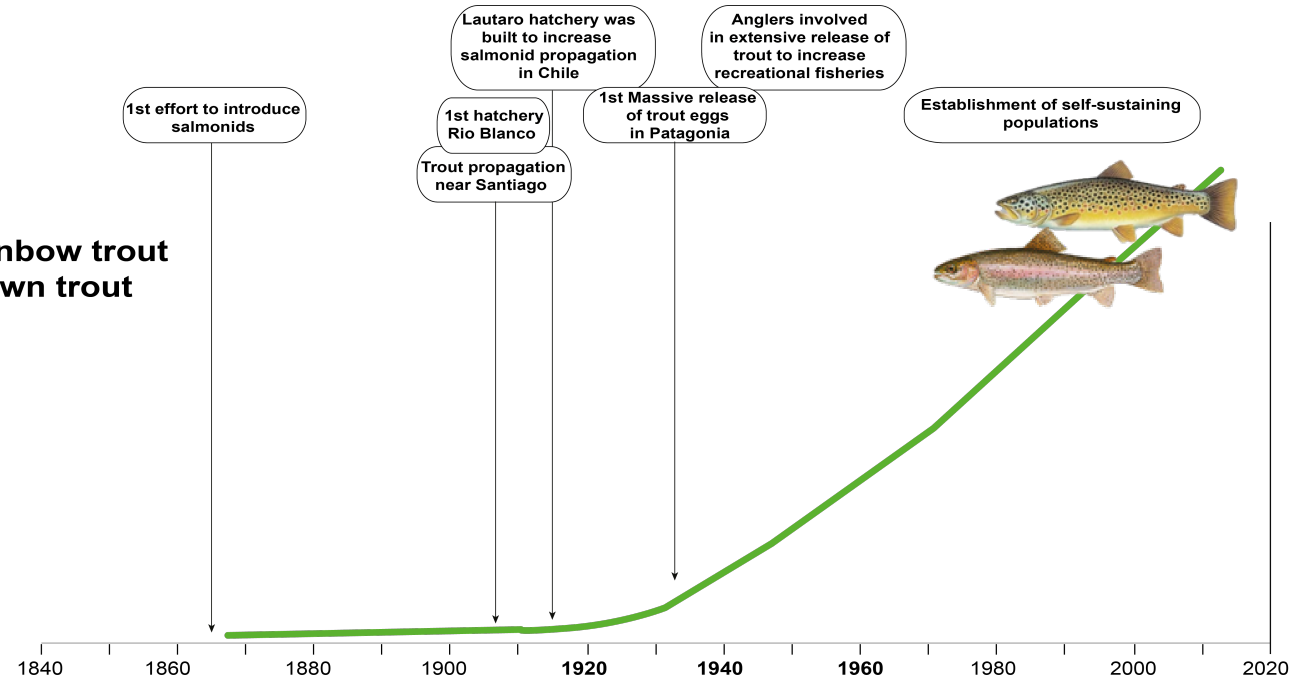
# Historical process of salmonids introduction in the pyrenean mountain lakes



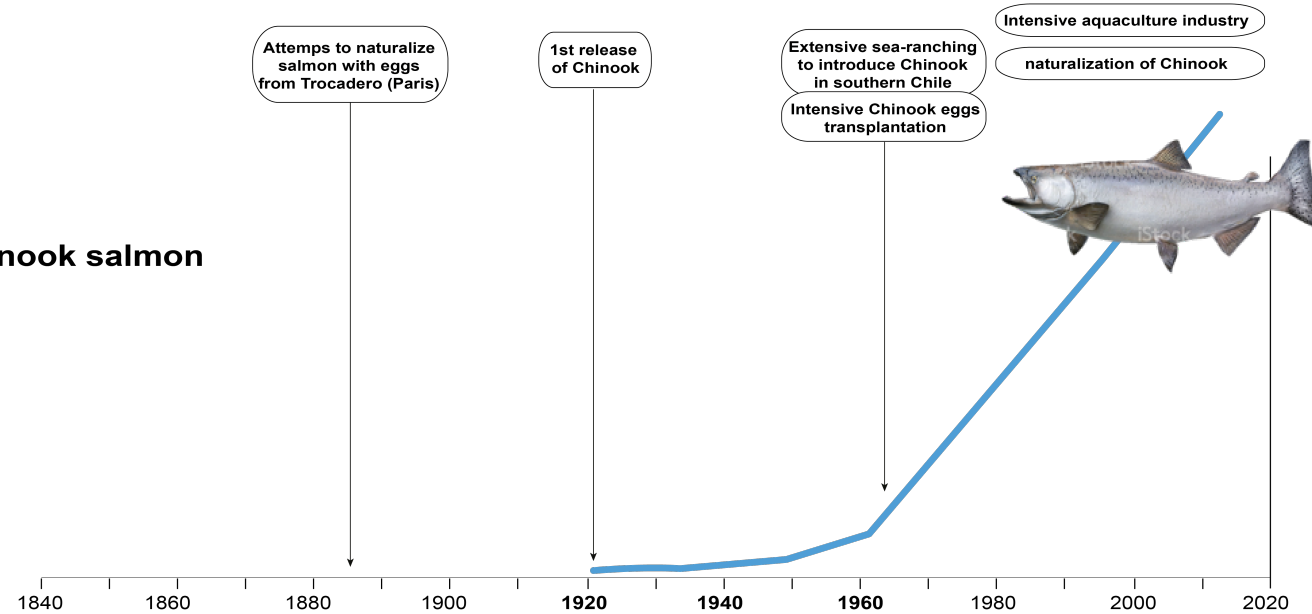
# Historical process in Chile



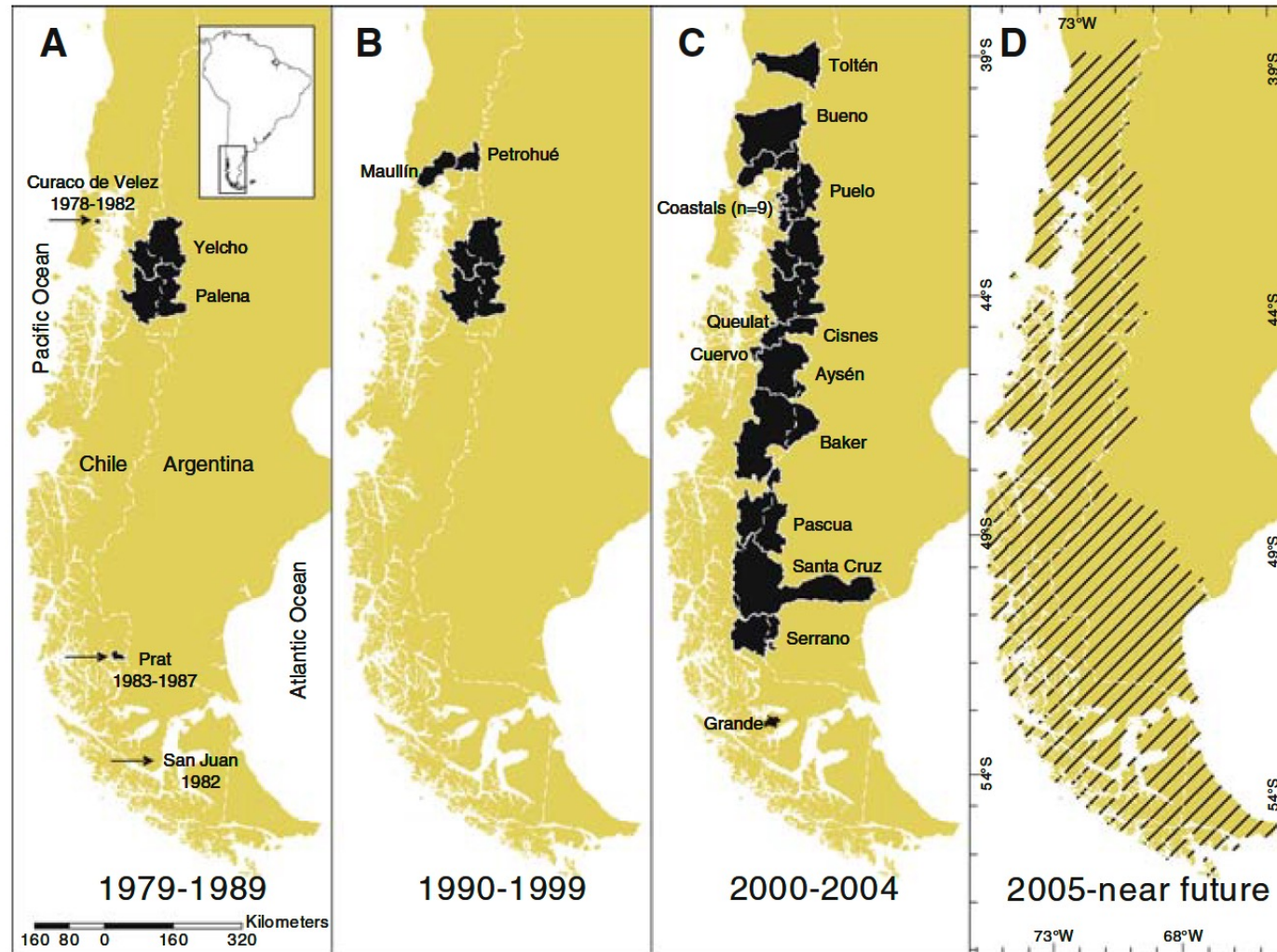
**Rainbow trout  
Brown trout**



**Chinook salmon**



# Historical process of chinook invasion in Chile

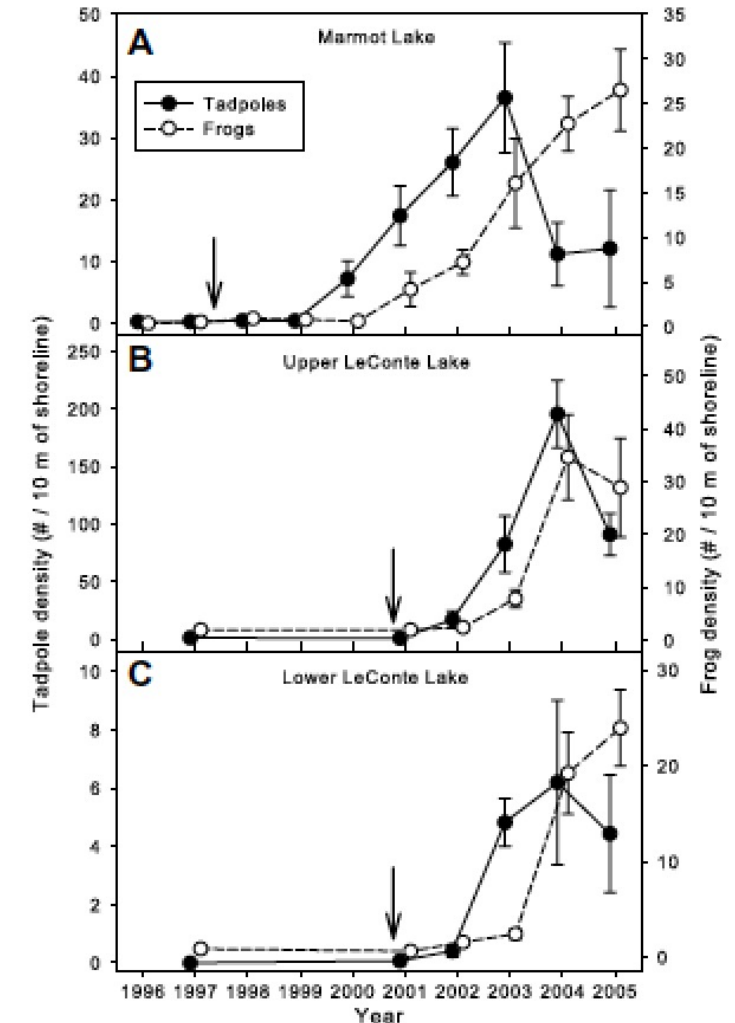




# Ecological consequences of the introduction of non-native salmonids

- **Introduction of top-predator has an impact on biodiversity**

- Drastic reduction or elimination of autochthonous species (zooplankton, macroinvertebrate, amphibians and native fishes present)
- Indirect impact on terrestrial predators (birds, bats, reptiles, amphibians,..)
- Vector of disease and pathogen transfert



# Ecological consequences of the introduction of non-native salmonids

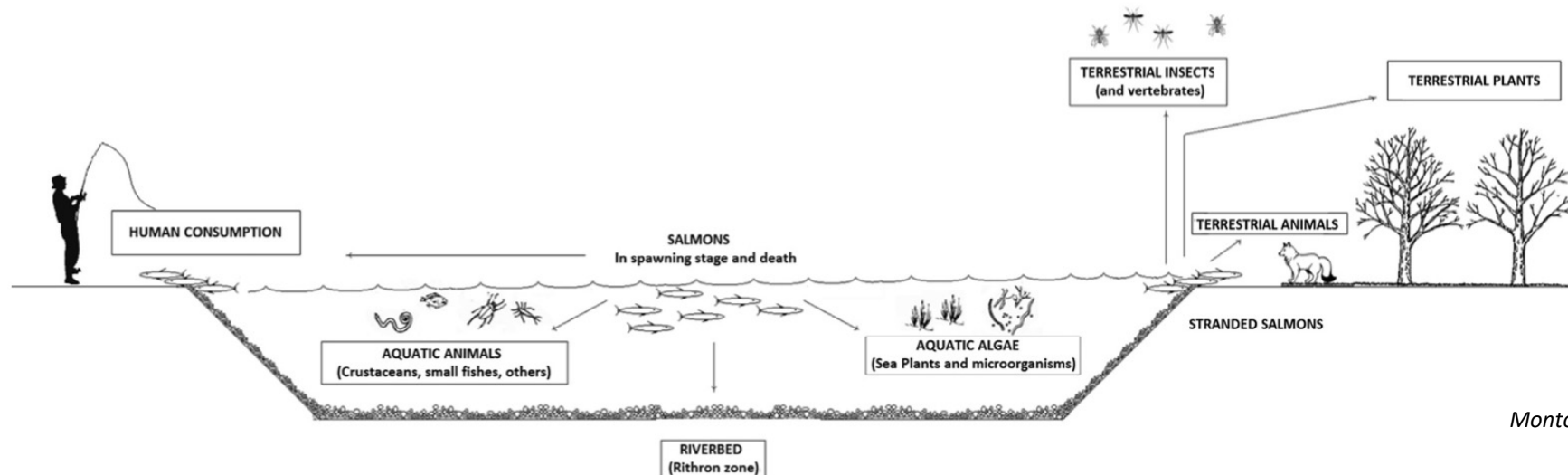
- **Transfert of nutrients**

→ Chinook introduce marine-derived nutrients in stream and rivers foods webs (impact on river productivity and on terrestrial ecosystems)



- **Source of biotransport of pollutants (ETM and POPs)**

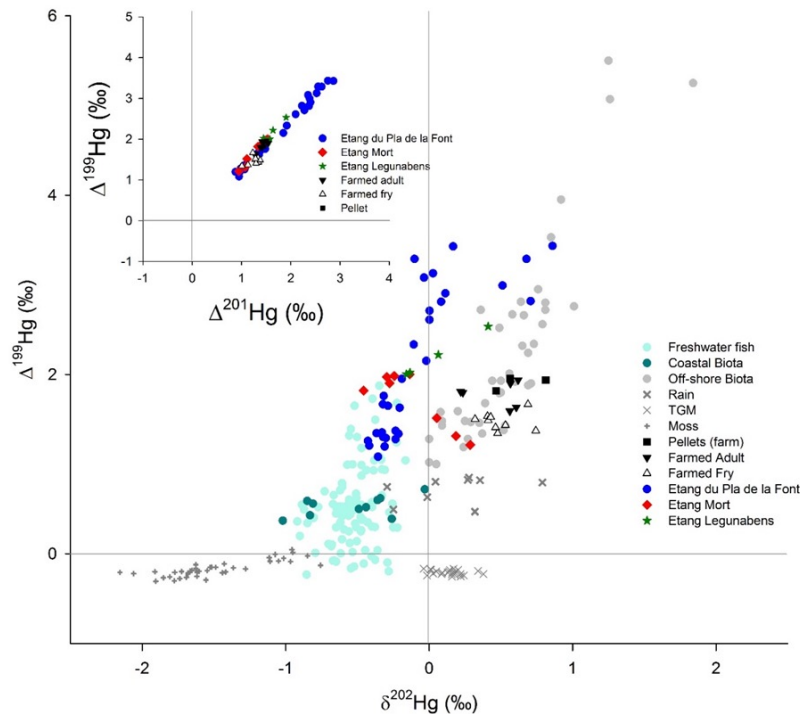
→ Chinook introduce POPs which are then redirected in the ecosystem



# Ecological consequences of the introduction of non-native salmonids

- Source of biotransport of pollutants

→ Introduction of marine mercury in mountain lake through fry feeding in hatchery (marine fishmeal)



## Transfer of marine mercury to mountain lakes

Sophia V. Hansson<sup>1,5</sup>, Jeroen Sonke<sup>2</sup>, Didier Galop<sup>3</sup>, Gilles Bareille<sup>4</sup>, Séverine Jean<sup>1</sup> & Gaël Le Roux<sup>1</sup>

## Ecological consequences of the introduction of non-native salmonids

- **Collateral introduction by anglers of invasive fishes used as live bait**

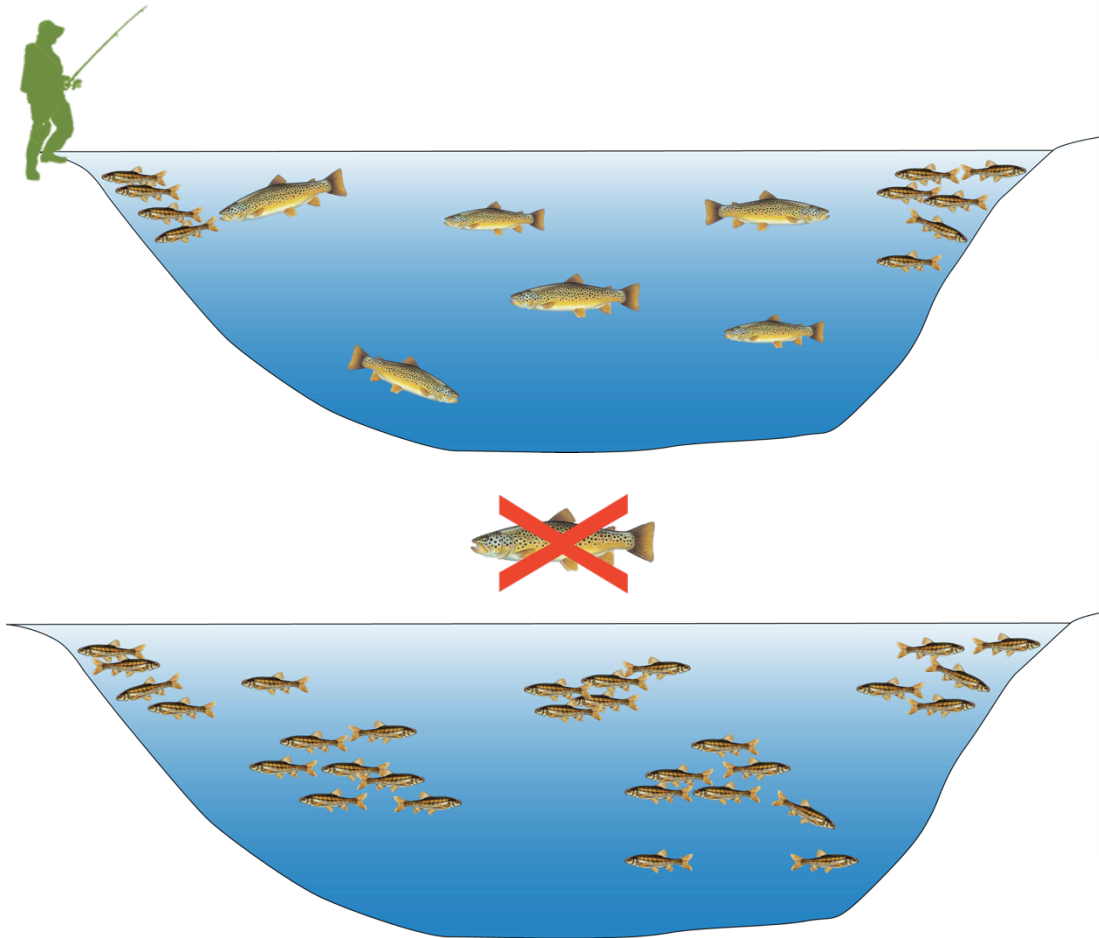
→ Pyrenean lakes are subject to an invasion by minnows whose impact is worst than that of the trout alone



# Ecological consequences of the introduction of non-native salmonids

- Collateral introduction by anglers of invasive fishes used as live bait

→ Lake eutrophication



## Beyond the observation a complex situation

- **Introduction and invasion by salmonids is a real ecological and conservation problem :**

- Biological invasion
- Reducing biodiversity
- Nutrients inputs
- Biotransport of pollutant

- **But recreational fishing is an economical resource that generates significant profits :**

- Chili = ca. 15 M \$ /year ( ca. 6 M \$ in Cohayque district)  
(Canada : 2 billions \$)
- France = 1 billion € (ca. 2 M d'€ in Pyr.-Atlantique district)

- **For anglers, these salmonids are now considered as common good that needs to be protected**

- New fishing practises (No kill, Catch and release )

