Ecological-economic impacts of ecosystem restoration in the Seine estuary: an application of a regional integrated Input-Output model

Cordier M., Pérez Agúndez J. A., O'Connor M., Hecq W.

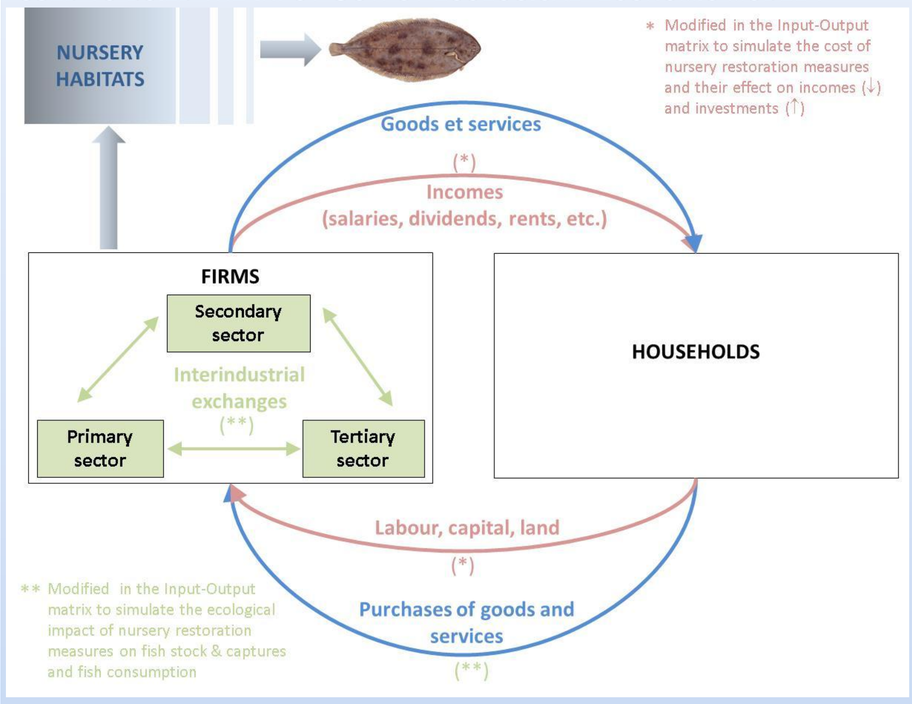
OBJECTIVE

An integrated Input-Output model is developed to assess environmental and economic impacts of the restoration of 25% of sand-flat nurseries (fish habitats) with high sole density lost in the Seine estuary between 1834 and 2004. Two scenarios are tested: i) one with restoration costs taken in charge by direct responsibles of nursery destruction (harbors) and ii) a second one with costs shared between sectors prorated to the amount of goods transported by boat (given that water transport infrastructures are one of the main causes of nursery destructions).

Two ecosystem services have been considered : 1) life support service ensured by nursery habitats for juveniles of *Solea solea* (common sole) ; 2) halieutic resources available for human consumption (*Solea solea*).

METHOD: MODELING OF ECOSYSTEM – ECONOMY INTERACTIONS

FIGURE 1. SCHEME OF THE INTERACTIONS BETWEEN THE ECOSYSTEM AND THE ECONOMIC SYSTEM USED TO BUILD THE INPUT-OUTPUT ECOLOGICAL–ECONOMIC MODEL :



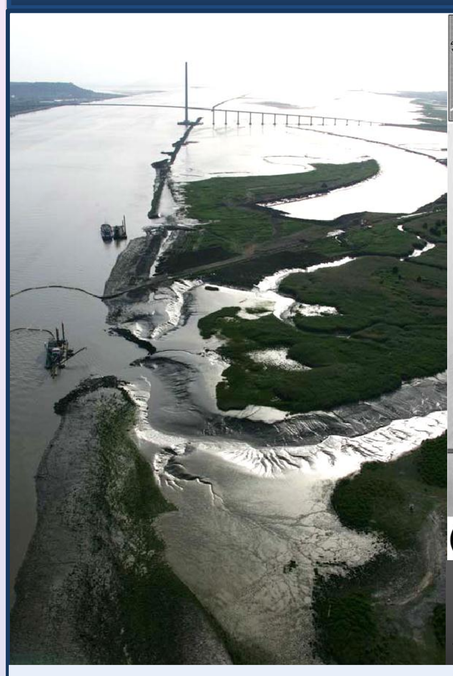
In Figure 1, exchanges between firms as well as between firms and households are simulated with an Input-Output model based on Supply and Use tables. These tables are a representation of the economy that records the way industries both trade with one another and produce for final consumption and investments.

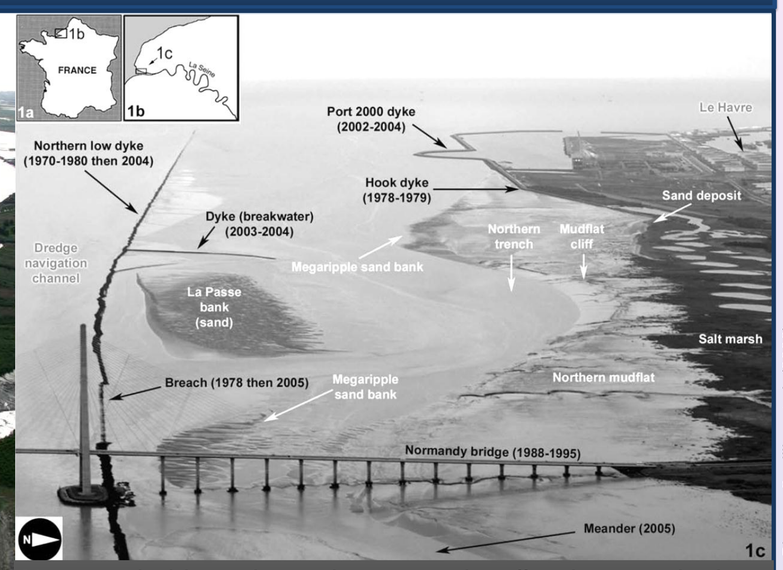
TABLE 1. ABUNDANCE INDEX OF SOLE JUVENILES AT AGE 0 (< 1 YEAR) IN NURSERY AREAS IN THE SEINE ESTUARY IN 2004 (ROCHETTE ET AL., 2010)

Bathymetry (m)	Sediments	Nursery surface (km^2)	Juvenile density index at age 0 (individuals/km^2)	A_{t_0} Juvenile abundance index (number of individuals)
a	b	c	d	column *c* x *d*
<-3[;8[	Gravels	6.40	31.06	198.78
[8;20]	Gravels	2.70	4.42	11.95
<-3[;8[	Sand	108.24	50.62	5478.44
[8;20]	Sand	34.33	7.31	251.02
<-3[;8[	Silt	41.66	68.82	2866.89
[8;20]	Silt	3.06	11.41	34.96
Total		**196.38**	**45.02 (mean)**	**8842.03**

Table 1 shows the data base (aggregated version) used to simulate the interaction between nursery areas and the stock of sole in the estuary (equations exogenous to the Input-Output matrices).

CONTEXT



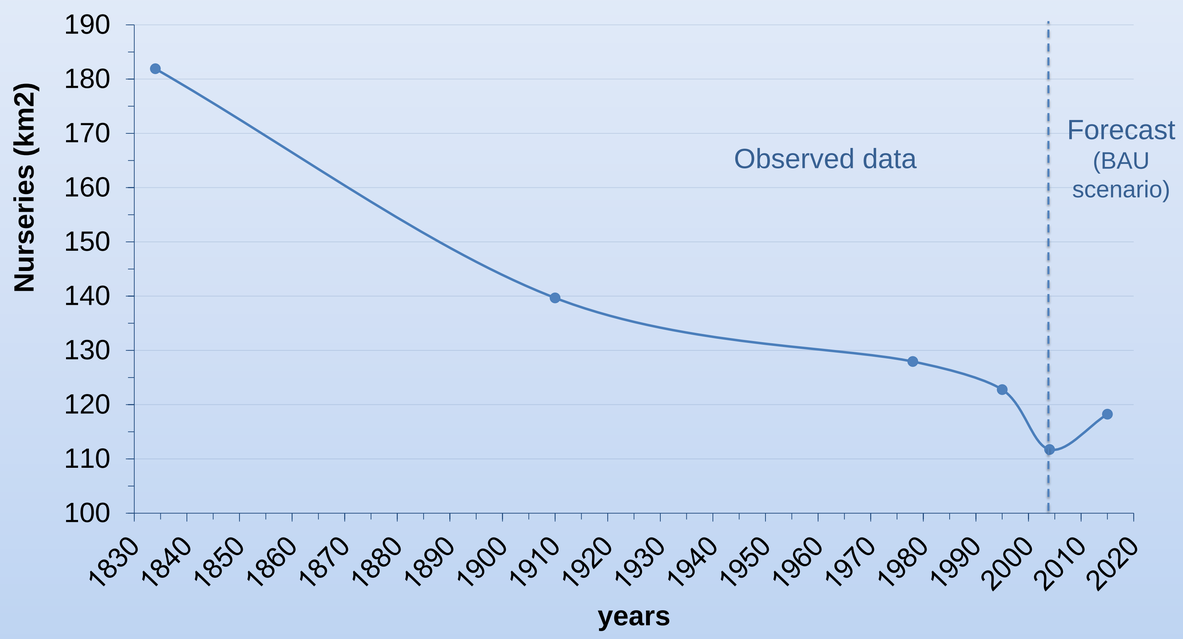


Nursery habitats have been continually destroyed since 1834 by the construction of dykes and harbour extensions for maritime transport, and by the Normandy bridge.

Picture: Christophe Bessineton, Maison de l'estuaire (2007)

Picture: Cuvilliez et al. (2008)

FIGURE 2. EVOLUTION OF THE TOTAL NURSERY * AREA IN THE SEINE ESTUARY BETWEEN 1834 AND 2004



* Have been considered in Figure 2 only high density nurseries, i.e. estuarine areas with a density of sole juveniles (< 1 year) higher than the estuary average (i.e. > 45 juveniles/km2).

RESULTS : IMPACTS OF THE RESTORATION OF 24.38 km^2 OF SHALLOW SUBTIDAL NURSERIES (1m depth; 174 million $€_{2007}/km^2$)

FIGURE 3. ENVIRONMENTAL IMPACT

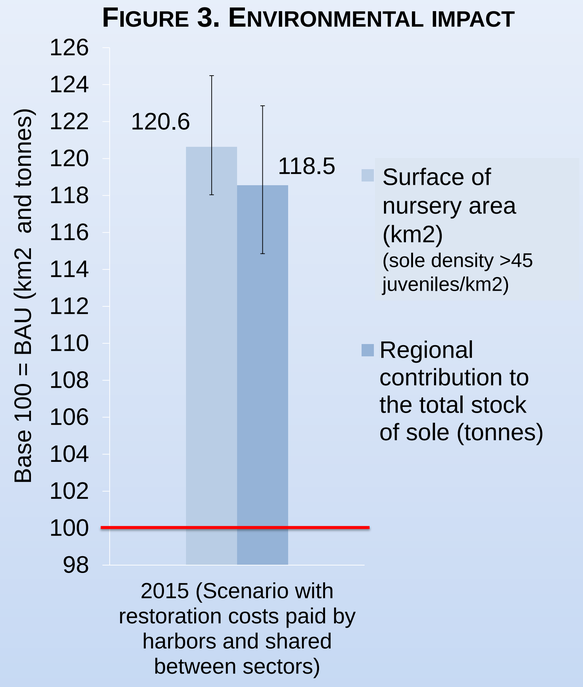


FIGURE 4. MACROECONOMIC IMPACT

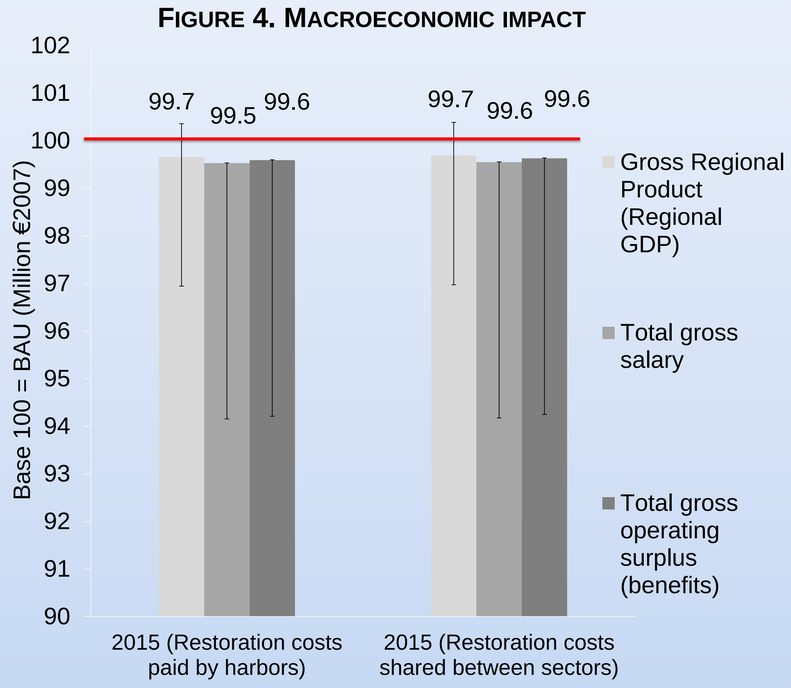
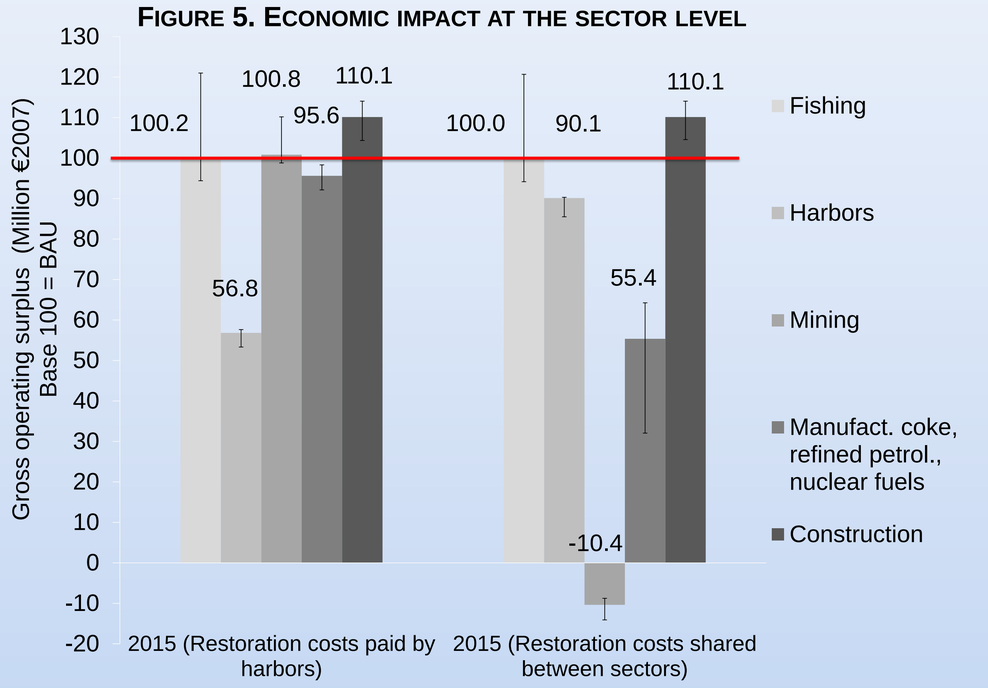


FIGURE 5. ECONOMIC IMPACT AT THE SECTOR LEVEL



Our results show that the restoration of a total of 24.38 km^2 of subtidal nursery areas over the period 2004-2015 would result in a stock of sole in 2015 that exceeds the "Business As Usual" scenario (without restoration measures) by 18.5% (Figure 3). In spite of high restoration costs, the negative macro-economic impacts are very low (Figure 4). For instance, the Gross Regional Product reaches for both restoration scenarios 99.7% of the level that would be achieved in the BAU scenario. However, at the sector level (Figure 5), three economic sectors appear to be particularly sensitive to the nursery restoration measure that fulfils the polluter-pay principle. Indeed, when only direct responsible sectors of nursery destructions (harbors) take in charge restoration costs, their gross operating surplus (benefits) reaches 56.8% of the BAU value. In a more fair allocation, in which costs are shared between direct and indirect responsible sectors (harbors but also primary and secondary sectors that transport goods by boat), the gross operating surplus (GOS) of harbors rises to 90.1% of the BAU value. However, in return, the mining sector GOS falls to -10.4% and the GOS of the sector of manufactures of coke, refined petroleum… falls to 55.4% of the BAU value.

CONCLUSIONS

The results show that a large nursery restoration programme generates significant negative economic impacts at the sector level but only a slight negative impact at the macro-economic one. This suggests that the restoration costs can be seen more as a problem of cost allocation than as a problem *per se*. In addition only 2 ecosystem services have been quantified. Yet, it is likely that the model would have given a positive macroeconomic impact if the 5 other ecosystem services related to nurseries had also been quantified : 1) provisionning of 8 commercial fish species other than sole; 2) supporting services for these species (formation of nursery habitats); 3) regulation of flood impact; 4) recreational fishing; 5) regulation of water quality.