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sub-Action 11.1:
Consequences of human
disturbances on the
common sole population

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1. Introduction

Marine fish populations face various natural and anthropogenic pressures occurring at all stages of their life cycle. These pressures determine survival rates of individuals and populations size. Accounting for the consequences of these different pressures remains a fundamental ecological question and a requirement for sound management in the context of the Ecosystem Approach to Fisheries. The complex underlying ecological mechanisms and the difficulty to observe all life stages of populations require the use of models to address these challenges.

Through the example of the common sole (*Solea solea*) population in the eastern Channel, this project planned to combine different modelling approaches to quantify natural and human induced mortalities at different stages of the life cycle and to evaluate their combined consequences at the population scale.

2. Building quantitative nursery habitat mapping for the common sole in the Eastern Channel and estimating the effect of historical habitat degradation in the Seine estuary on population renewal

Estuaries and coastal waters are essential nursery habitats for many marine species, and especially for flatfishes. Thus, investigating how anthropogenic disturbances affect the quality of these habitats is of major importance to understand their consequences on the population renewal of marine species. For flatfishes, and especially for the common sole (Riou et al., 2001), the size and the quality of juvenile habitats determine the amount of recruits. The aim of the first part of present project was to analyse the effects of estuarine habitat degradation on the population of the common sole in the Eastern Channel, a key species in the fish community and fisheries in this area. The consequences of habitat degradation in the Seine estuary, the main river of the Eastern Channel, during the last 150 years were especially focused on (i.e. the drastic drop in the surface area and on the low water quality of the Seine estuary; Le Pape et al., 2007).

This part of the project first aimed at building average quantitative maps of coastal and estuarine sole nurseries in the Eastern Channel during the last decades by coupling a habitat suitability model to a geographical information system. An statistical model was first developed from scientific survey data (5300 beam trawl hauls realized since the early 1980s on both the French and English coasts of the Eastern channel) to describe young of the year sole densities with relation to bathymetry and sediment structure and to a stratification of the coast in 7 geographical sectors. This approach confirmed previous conclusions (Riou et al., 2001) about the interest of shallow muddy areas for juvenile sole. A Geographic Information System (GIS) was then used to develop quantitative maps of sole nursery habitats in the Eastern Channel by using this model to predict juvenile sole densities from maps of bathymetry and sediment structure (Figure 1). The contribution of each coastal and estuarine sector to the overall recruitment of the common sole at the population scale was calculated from these quantitative maps and indicated that juvenile densities are low in the Seine estuary with regards to other nursery sectors. This estuary, the single large one and potentially the most important nursery sector in the Eastern Channel, hosts only 14 % of the juvenile sole at the population scale.

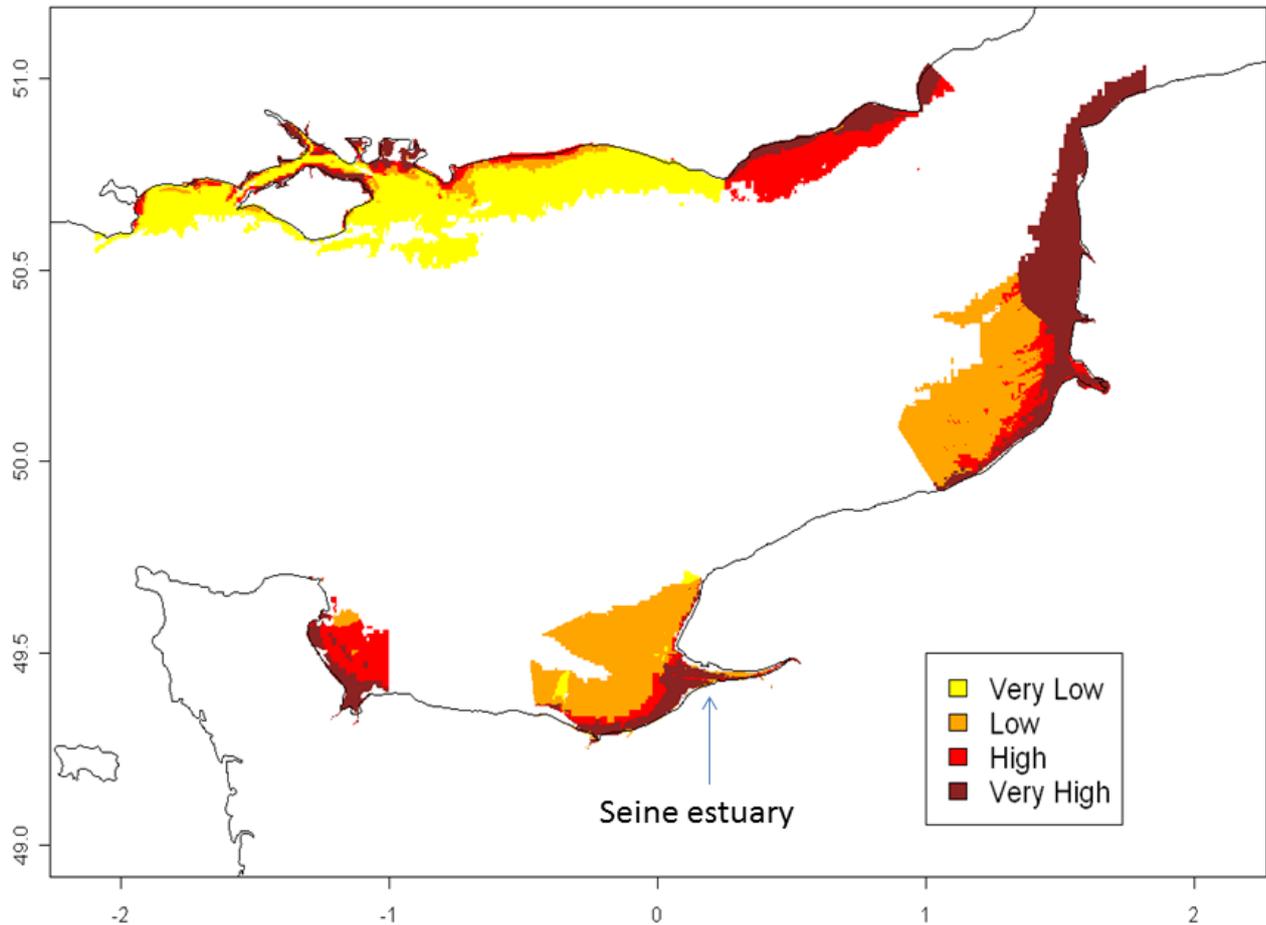


Figure 1: Quantitative map of the distribution of young of the year sole in the Eastern Channel (relative unit of catch per unit effort during scientific surveys using a beam trawl with a 20 mm stretched mesh)

A complementary modelling approach developed on another project (Vectors, EU, 7th Framework Program) focused on larval dispersal, from spawning to settlement over nurseries, thanks to a particle transport model simulating hydro-climatic conditions of the eastern Channel and including individual-based life history. This model showed that the amount of larvae reaching nursery grounds fluctuated mainly because of hydrodynamical conditions but that low juvenile densities observed in the Seine estuary may not be explained by a lower larval supply (Rochette et al., 2012). As the Seine estuary is the highest contaminated estuarine system in Western Europe (Courrat et al., 2009), the hypothesis of higher mortalities linked to lower habitat quality in this estuary (Gilliers et al., 2006; Le Pape et al., 2007) was underlined.

Thanks to historical maps of the Seine estuary, habitat suitability maps were built for key dates in the modifications of this estuary since 1850. This backward predictive approach suggests that habitat loss in the Seine estuary has led to a 42 % decrease of its nursery capacity (Figure 2a). As the density of juvenile sole in the Seine estuary is low in comparison to other sectors, this represents only a 4% loss at the sole population scale, in the Eastern Channel. However, when we assumed that prior to anthropogenic disturbance the juvenile density in the Seine estuary might have been equivalent to the current density of adjacent sectors with higher quality, and receiving the same amount of larvae, the loss in abundance could be nearly 17% (15-32%) (Figure 2bc).

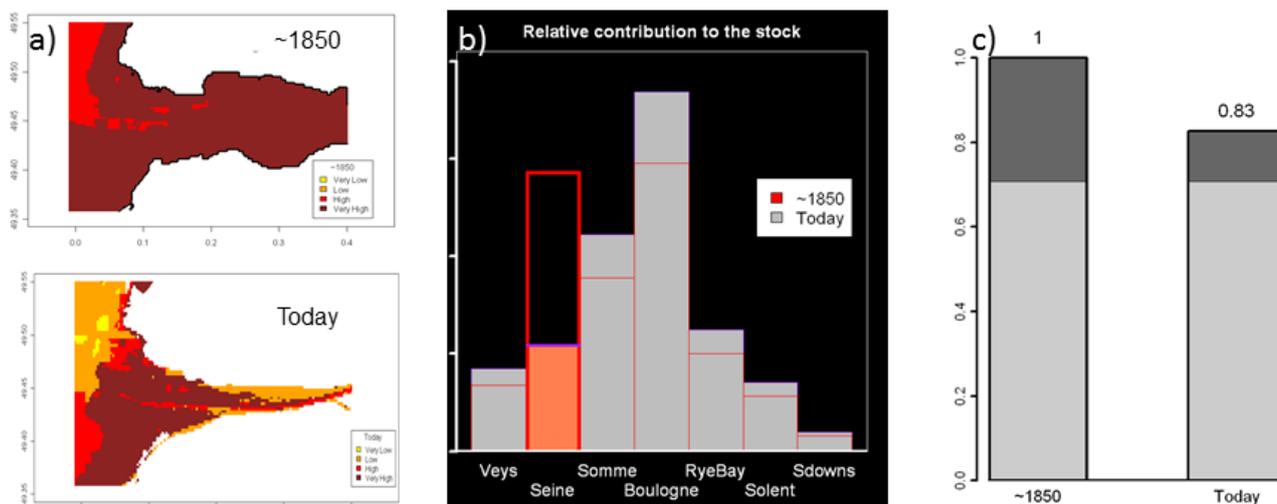


Figure 2 : Consequences of habitat degradation in the Seine estuary nursery ground from 1850 to nowadays for the common sole in the English Channel a) historical quantitative maps of juvenile distribution in the Seine estuary b) loss of nursery capacity in the Seine estuary and respective contribution of the different coastal sectors c) consequences at the population scale

3. Developing an integrated life cycle model for the sole population in the Eastern Channel, integrating various anthropogenic pressures from nursery habitat degradation to fishing

This second part of the project proposed a modelling framework to merge the previous results on larval drift and juvenile habitats, as well as effects of fishing on the adult part of the common sole population for modelling the whole life cycle with a spatial perspective. The developed Bayesian state-space framework combines an age-structured population dynamics model with a model for drift and survival of early life stages and site specific productivity of coastal nurseries. The approach allowed to combine processes of different natures and various sources of observations within an integrated framework for life cycle modelling: (i) Outputs of the individual-based model for larval drift and survival that provided yearly estimates of the dispersion and mortality of eggs and larvae from spawning grounds to settlement in several coastal nurseries (Rochette et al., 2012); (ii) A habitat suitability model based on juvenile trawl surveys to estimate juvenile densities and surface areas of suitable juvenile habitat in each nursery sector (first part of the project; Rochette et al., 2010); (iii) A statistical catch-at-age model for the estimation of the numbers-at-age and the fishing mortality. The methodology was applied to the sole population in the Eastern Channel between 1982 and 2008. The approach allowed estimating hidden variables and parameters of key biological significance such as the spawning biomass, fishing mortality and recruitment which are very similar to the estimations derived from ICES stock assessment working groups. In addition, the model allowed for quantifying mortality along the life cycle and for deriving inferences about the site-specific density-dependent mortalities between settled larvae and age-0 juveniles in each nursery ground. This provided insights for a better understanding of the productivity and the specific contribution of each nursery ground to the recruitment and the population renewal.

The estimated contribution of each nursery ground highlighted that the “Seine” estuary only contributes to 14% of the total amount of juveniles in spite of a surface representing 21% of nurseries of the Eastern Channel. This low contribution has to be related to the high level of habitat degradation of the Seine estuary.

4. Conclusion

Results of the first part of the project suggest that the loss in habitat surface combined with habitat degradation in the Seine estuary has led to an important loss (~17%) in the contribution of the Seine estuary nursery to the whole sole population in the Eastern Channel. A complementary approach estimated that a comparable loss affected the related fisheries (Cordier et al., 2011).

The combination of the quantitative nursery maps with outputs of a larval drift model and an age-structured dynamic for subadults and adults within a spatial life cycle model laid the foundations of a methodological framework offering interesting developments and new perspectives. Further development of the modelling framework and applications to other fish species will allow to disentangle the effect of multiple interacting anthropogenic stresses (e.g. nursery habitat degradation, fishing pressure) on population renewal, will provide useful tools for risk analysis for suitable management and will help decision – making for suitable spatially structured management.

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