Modelling the historical distribution of fish species in large alpine catchments (Rhone, Upper Danube) at the beginning of the 20th century: comparison with historical fish maps and long term change

La modélisation des distributions piscicoles dans les grands bassins alpins (Rhône, Haut Danube) au début du 20ème siècle : comparaison avec les données historiques et évolution sur le long-terme

Didier Pont(1), M. Logez(2), G. Carrel(3) and G. Haidvogl(4)

(1) Irstea, UR HBAN, 1 rue Pierre-Gilles de Gennes, FR-92761 Antony, France.
(2) Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale. UMR CNRS-INEE - IRD -Aix Marseille Université. Facultés des Sciences St Jérôme 13397 Marseille cedex 20.
(3) Irstea UR HYAX, 3275 Route de Cézanne, FR-13182 Aix-en-Provence Cedex 5, France.
(4) Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences Vienna, Max-Emanuel-Strasse 17, A-1180 Vienna, Austria

RÉSUMÉ

Les modèles (SDM) mettant en relation les conditions environnementales et l'occurrence des espèces sont largement utilisés pour prédire les changements futurs des distributions de ces dernières sous l'influence des modifications climatiques attendues. Mais ils sont beaucoup plus rarement utilisés pour reconstruire les distributions spécifiques durant les siècles passés. En compilant des observations historiques sur les occurrences piscicoles dans les bassins du Rhône (Alpes, Saône, Vallée du Rhône) et du Haut-Danube (Salzach) et en les confrontant à des prédictions issues de modèles SDM calibrés sur des données piscicoles actuelles collectées sur des sites de référence (peu à non perturbés), nous avons pu tester l'efficacité de ces modèles à reconstituer les distributions de poissons observés au début du XXème siècle. Nos résultats sont également discutés en fonction des différences de pressions anthropiques s'exerçant dans les zones étudiées et des possibilités de modifications des conditions dites de référence (shifting baseline). Finalement les modifications des occurrences annuelles des différentes espèces ont été reconstituées sur la période 1800-2000 et comparées avec les occurrences attendues dans le futur (2000-2060) sous hypothèse d'un scénario de réchauffement climatique.

ABSTRACT

Species distributions models (SDM) that rely on estimated relationships between present environmental conditions and species presence-absence are widely used to forecast changes of species distributions caused by global warming but far less to reconstruct historical assemblages. By compiling historical fish data from the turn to the middle of the 20th century in a similar way for the Rhône catchment and the upper Austrian Danube catchments (Salzach river), and using already published SDMs based on current observations, we tested the predictive accuracy of such models for past climatic conditions by comparing the observed and the expected historical species occurrences. The results are discussed in relation with past anthropogenic pressures and long-term change in fish species distributions. Finally, we reconstructed the annual variability of the probability of species presence during the last century and compared with the predictions under a future climate scenario during the 21th century. Our study highlights the interest of historical data to document fish range changes in relation to human activities, environmental modifications and global warming.

KEYWORDS

Historical ecology, species distribution model, fish, anthropogenic disturbances, climate change, Rhone and Danube catchments

MODELLING THE HISTORICAL DISTRIBUTION OF FISH SPECIES IN LARGE ALPINE CATCHMENTS (RHONE, UPPER DANUBE) AT THE BEGINNING OF THE 20TH CENTURY: COMPARISON WITH HISTORICAL FISH MAPS AND LONG TERM CHANGE.TITRE (STYLE "TITRE 2", ARIAL 12PT GRAS)

Species distributions models (SDM) that rely on estimated relationships between present environmental conditions and species presence-absence are widely used to forecast changes of species distributions caused by global warming but far less to reconstruct historical assemblages. By compiling historical fish data from the turn to the middle of the 20th century and using already published SDMs based on current observations, we tested the predictive accuracy of such models for past climatic conditions by comparing the observed and the expected historical species occurrences. Our first objectives were: i) to compile historical data in a comparative manner for these two catchments, ii) to use the previously published SDM (Logez et al. 2012) to predict the species occurrences in the historical period and to compare them with the historical observations, iii) to compare the SDM's performances between catchments and to analyze the capability of predicted occurrences to reflect the historical community structure within the different studied catchments, and iv) to compare the annual variability in the predictions under a future climate scenario to that reconstructed during an extended historical period (1800-2000).

Among the different types of written fish historical sources, historical maps are one of the most informative because i) they are based on fish surveys conducted by experts educated in biology and aimed at depicting the occurrence of all fish species, and ii) the species occurrences and species range limits are located on precise river sections of a few kilometers in length (Haidvogl et al. 2013).

The study area comprised river sections belonging to the Danube and to the Rhône catchment. The Salzach River is a 225-km-long tributary of the Inn River, which is itself the largest sub-catchment of the Upper Danube. Within the French part of the Rhône catchment, the studied rivers belong to three main sub-catchment types: the alpine tributaries situated on the Rhône's left eastern bank, flow from the highest alpine mountains, the Rhône valley tributaries join the Rhône along its course, and the Saône River comes from the North.

Two main sources were used to describe the occurrences of 26 fish species at the turn of the 20th century in the Salzach catchment: the Kollmann's map (1898) and the Fishery Cadastre of the Federal State Salzburg (1904). Within the Rhône catchment, the historical occurrences of 45 fish species were obtained from 13 district or catchment fish maps drawn from 1910 to 1956. Most fish species could be determined without doubt, but the identification of some at the species level is not absolutely certain. These fish observations are of great interest as they enable analyzing with good accuracy the spatial distribution of species and their habitat requirements during industrialization, prior to the construction of the large dams and hydropower plants and just after the end of the little ice age.

We focused on the 14 fish species common to the Rhône and the Salzach catchments. We predicted their past occurrences using Logez et al. (2012) SDM and environmental conditions prevailing in the past (temperature and rainfall). These SDM are calibrated with current sites which are minimally disturbed and could be considered as representative of present reference conditions. The associated uncertainties were estimated by computing upper and lower limits of confidence intervals at 95%. These predictions were compared with historical observations to test the predictive accuracy of such models.

Our results demonstrate the utility of SDM in reconstructing past fish assemblages and their long-term changes. Uncertainties associated with SDM predictions were very useful to assess the efficiency of these models. In general, the efficiency of SDM based on current fish sampling in minimally disturbed river segments to describe historical reference conditions is acceptable, especially for the alpine sub-catchments (Rhone and Danube). One could argue that historical observations could be used to define reference conditions. Historical data, however, do not always reflect undisturbed conditions. Our results highlight also that fish assemblages were seriously altered in several areas by human activities at the turn of the twentieth century in some of the studied areas (mainly the Saone sub-catchment). The 19th century was already a period of intense human pressures within most European catchments, reflecting the dense human

population, deforestation, agriculture, mining and the presence of industries. In addition, major changes in river morphology occurred in Europe long before the industrialization period. This, in particular, refers to deforestation and implementation of small structures (water mills) along the river course. The long-term evolution of fish species distribution also depends on environmental variables acting at the large scale, such as climate. Past variability in temperature and rainfall during the two last centuries may have considerably modified the composition of fish assemblages, in particular during warmer and low rainfall periods. We then used the SDMs to reconstruct the long term evolution of species occurrence during the last centuries (1800-200) and compared these values with the predictions under a future climate scenario for the period 2000-2060).

Finally, our results highlight the importance of historical data, in combination with SDMs, to document fish range changes in relation to human activities, environmental modifications and global warming.

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