Optimizing biological monitoring (long-term surveys, restoration assessments) in large rivers and other environments

Optimisation des échantillonnages biologiques (suivis long-terme, évaluations de restauration) en grands fleuves et autres milieux

Lamouroux N. (1), Cauvy-Fraunié S. (1), Vaudor L. (2), Olivier J.-M. (3), Trenkel V. (4), Maire A. (5), Forcellini M. (1), Roset N. (6)

(1) Irstea UR MALY, Villeurbanne, France (nicolas.lamouroux@irstea.fr), (2) CNRS UMR 5600 Isig, ENS de Lyon, Université de Lyon, Lyon, France, (3) UMR CNRS 5023, Villeurbanne, France, (4) Ifremer EMH, Nantes, France, (5) Edf LNHE Hynes, Chatou, France (6) Agence Française pour la Biodiversité, Bron, France.

RÉSUMÉ

Les études comparant l'efficacité vs. le coût des suivis biologiques de long-terme sont peu fréquentes et particulièrement utiles en grandes rivières. Nous nous basons sur des analyses récentes des données collectées dans le cadre des suivis de poissons et de macroinvertébrés du fleuve Rhône pour discuter du potentiel et des limites des stratégies d'échantillonnage mise en place en grands fleuves et dans d'autres milieux. Une première étude concerne une analyse numérique de la probabilité de détecter des changements d'abondance (poissons, invertébrés) après des mesures de restauration des débits à l'aval des barrages. Une seconde étude concerne la détection des patterns les plus attendus dans les séries annuelles d'abondance de poissons, comme les suivis de cohortes. Cette étude compare les résultats du Rhône avec ceux obtenus sur de petits cours d'eau (où l'échantillonnage est meilleur) et en mer (plus difficile). Les résultats montrent que les échantillonnages en cours permettent de détecter les tendances interannuelles majeures, mais sont limités pour discuter des évènements à l'échelle annuelle. Ces études s'appliquent à d'autres systèmes que les grandes rivières et peuvent conduire à la mise en place de stratégies de suivi plus efficaces et moins coûteuses.

ABSTRACT

Studies of the efficiency vs. the cost of long-term biological monitoring strategies are particularly infrequent and needed in large rivers. We used recent studies concerning the long-term monitoring of fish and macroinvertebrates in the Rhône River to discuss the potential and limits of monitoring strategies in large rivers and other environments. A first study is a numerical analysis of the probability to detect changes in fish abundance after flow restoration in the river. A second study concerns the detection of "most expected" relationships in annual fish time series, such as fish cohort follow-ups. It involves a comparison of the Rhône results with those obtained in smaller rivers (where sampling is easier) or in the ocean (where sampling is even more difficult). Results indicate that the long-term biological strategies used in the Rhône River are efficient for detecting major inter-annual trends, but are limited for detecting annual events. Such studies apply to other systems than large rivers and we hope that they will contribute to an increased efficiency and a reduced cost of monitoring strategies.

KEYWORDS

Abundance time series, ecological restoration, monitoring design, statistical power analysis

1 LONG-TERM MONITORING STRATEGIES NEED STRONGER EVALUATION

Long-term biological surveys are essential for the study of population dynamics, the assessment of the ecological effects of global change or the evaluation of ecological restoration. They are becoming more and more frequent and coordinated internationally. Optimized designs of long-term biological surveys are obviously needed to balance monitoring cost and efficiency. Nevertheless, the assessment of monitoring strategies is complicated by statistical difficulties related to the heterogeneous distribution of animals (e.g. schooling behavior) and strong temporal variations in abundances. In addition, scientists may be reluctant to question their practices and habits.

Studies of the statistical power of monitoring strategies (i.e. the probability that they detect actual changes) are particularly infrequent in large rivers, where sampling populations/communities requires a high degree of subsampling, due to the impossibility to collect all individuals (e.g., fish or macroinvertebrates) in a river reach. For example, a recent review of studies of ecosystem responses to managed environmental flows from reservoirs (Gillepsie *et al.*, 2015) indicates that only 2/76 studies raised monitoring issues. Analysing the efficiency of monitoring strategies is particularly needed for the evaluation of restoration actions, because the duration of surveys before restoration actions is often reduced (Lamouroux *et al.*, 2015).

2 LESSONS FROM THE RHÔNE RIVER BIOLOGICAL MONITORING

Here, we used recent studies concerning the long-term monitoring of fish and macroinvertebrates in the Rhône River to discuss the potential and limits of monitoring strategies in large rivers and other environments. Fish and macroinvertebrates have been extensively surveyed in many reaches of the river, sometimes over >30 years, to infer the ecological effects of the construction of dams, water warming, and/or restoration of minimum discharge downstream of dams. These surveys have a high degree of subsampling, because abundances are estimated based on series of electrofishing points (fish) or local Hess samples (invertebrates) that cover less than 0.1% of the surface area.

A first analysis (Vaudor *et al.*, 2015; Fig. 1) consisted in using numerical simulations to test how a given sampling strategy (e.g. number of surveys, of sampling points) influenced the probability to detect given changes in population abundance, for example due to restoration operations. The advantage of such simulations is that they can be done *a priori*, for example before restoration occurs. However, such analyses require making debatable assumptions about animal spatial distributions and temporal variations. A second analysis (Cauvy-Fraunié *et al.*, in prep.) consisted in analysing if the most obvious hypotheses about population dynamics, such as the expectation that year with very high abundance of juvenile fish are followed by years with higher abundance of adults, are observed in the fish time series. Such *a posteriori* analyses are interesting because they need fewer assumptions and can be repeated in different systems with different degrees of sampling difficulties. Actually, they were repeated in small rivers (where sampling is more efficient) and in the ocean (where sampling is even more difficult). Other analyses concerned community metrics rather than population abundance.

Results of these analyses indicate that the long-term biological strategies used in the Rhône River are efficient for detecting inter-annual changes in population abundances such as those due to restoration operations, but only when these changes are strong. Difficulties may increase for species with heterogeneous spatial distributions. By contrast, it is difficult to detect annual effects (e.g., immediate effects of a large flood or a very dry year) in large rivers or in the ocean using current long term monitoring. These results indicate that various monitoring strategies should be combined to detect various ecological effects (e.g., long term trends vs. extreme events). Such studies apply to other systems than large rivers and we hope that they will contribute to an increased efficiency and a reduced cost of monitoring strategies.

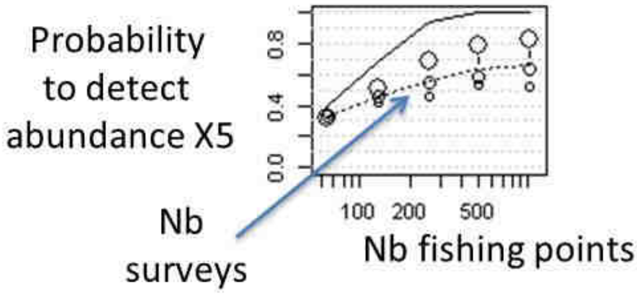

Fig. 1 The probability to detect a given change in population abundance varies with the monitoring strategy (number of surveys, number of sampling points) and the type of animal (e.g., degree of gregarism). Numerical simulations can help quantifying *a priori* the statistical power of different strategies. From Vaudor et al. (2015).

LIST OF REFERENCES

Gillespie, B.R., Desmet, S., Kay, P., Tillotson, M.R. and Brown, L.E. (2015) A critical analysis of regulated river ecosystem responses to managed environmental flows from reservoirs. *Freshwater Biology*, 60, 410-425

Lamouroux, N., Gore, J.A., Lepori, F., and Statzner, B. (2015) The ecological restoration of large rivers needs science-based, predictive tools meeting public expectations: an overview of the Rhône project. *Freshwater Biology*, 60, 1069-1084.

Vaudor, L., Lamouroux, N., Olivier, J.-M., and Forcellini, M. (2015) How sampling influences the statistical power to detect changes in abundance: an application to river restoration. *Freshwater Biology*, 60, 1192-1207.