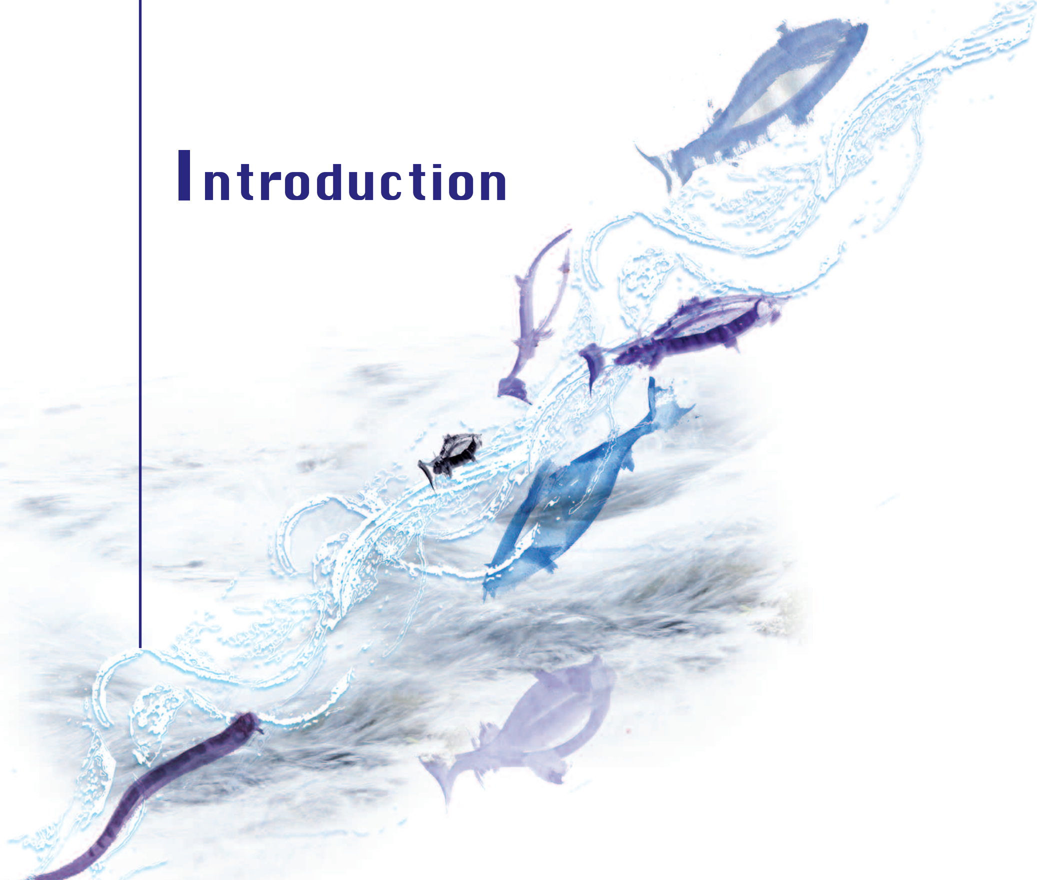
Introduction



Biological communities are in constant interaction both among themselves and with their environment. They support an array of ecological processes that enable ecosystems to function, to regenerate, to evolve, thus providing humanity with the ecosystem services required for its survival. Since the industrial and agricultural revolutions, humans have considerably increased their impact on biodiversity by vastly augmenting the number and the intensity of the pressures that they bring to bear on natural environments. The contemporary period since 1900 has thus seen one of the greatest extinction events that the planet has ever known. Chemical pollution has long been identified as a source of pressures and numerous measures have been taken to reduce chemical emissions, however awareness concerning the effects of physical alterations in environments is more recent. Those alterations are nonetheless of major importance and habitat fragmentation of living communities is now seen as one of the main causes of biodiversity loss. This new awareness is the result of better understanding of the essential role played by the connectivity of natural areas in the biological cycles of living species and of the functions provided by those cycles for the genetic mixing required to ensure the survival of populations and the evolution of species, as well as for numerous geophysical and geochemical processes within ecosystems.

Ecological continuity

Ecological continuity is a fairly recent concept that was introduced for the first time by the British botanist Francis Rose (Rose, 1974). Continental aquatic ecosystems, organised around the water cycle and the continuum of water flow, naturally evoke the idea. The initial research work on the topic, however, took place in the field of terrestrial ecology, in particular landscape ecology and the study of forestry systems. A number of terms are regularly and fairly indifferently used in the field, such as landscape continuity, biological continuity, connectivity, ecological corridors and ecological networks. Though several definitions of ecological continuity exist, the most common and widely used for aquatic ecosystems is very close to the concept of landscape continuity (Økland et al., 1996; Fritz and Larsson, 1996; Ohlson and Tryterud, 1999), i.e. "*such habitat has been available in patches for a long time within the limits of a landscape, in which the juxtaposition of habitat patches is important for dispersal and metapopulation dynamics of species. The spatial scale of 'landscape continuity' is usually undefined and may be different for different organisms*" (Norden and Appelqvist, 2001). The Water framework directive (WFD) generalised the use of this neologism within the environmental field, but simplified the concept by considering that it could be understood as the conditions enabling "*undisturbed migration of aquatic organisms and sediment transport*".

In France, the 2006 law on water and aquatic environments confirmed the importance of ecological continuity and sharpened the definition. The ecological continuity of a river is defined as "*the free movement of living organisms and their access to the areas required for their reproduction, growth, feeding and shelter, good functioning of natural sediment transport and good functioning of biological reservoirs (connections, notably lateral connections, and favourable hydrological conditions)*".

Obstacles to river flow

The presence and increasing numbers of transverse structures created by humans in rivers (for power generation, drinking water, irrigation, roads and railroads, navigation, bed-stabilisation systems, aquaculture, recreational activities, etc.) have significantly limited the natural free movement of aquatic living communities. These structures also profoundly disturb the hydromorphology of rivers (slowing of flow velocities, increased depths, reduction or halt of coarse sediment transport, etc.) and provoke major physical-chemical modifications in water. In addition to the more limited movement of living communities, obstacles to river flow also impact ecological continuity by altering the quality and reducing the diversity of the habitats available to the various aquatic species. The consequences for biological communities can be drastic. The decline of many populations of diadromous fish is a dramatic example, due notably because access to functional spawning grounds is partially or totally blocked.

A method to assess obstacle passability

This *Knowledge for action* document presents an assessment method, namely the ICE protocol to produce information on ecological continuity, and the general principles guiding its design.

Given the currently available scientific knowledge, the method described here is intended exclusively as a means to determine the impact of transverse structures on the movement of fish. These structures can create obstacles of various types, including thermal, chemical (oxygen, nutrients, toxic substances, etc.) and physical (head-drop, slope, flow velocity, turbulences, depth of the sheet of water, etc.). In this document, only physical, transverse obstacles are discussed.

The ICE protocol is based on a comparison of the topographical and hydraulic characteristics of obstacles with the physical capabilities (swimming, jumping or crawling) of the fish species analysed. It requires the gathering of descriptive information on each obstacle and avoids bringing in experts as much as possible. The result of the analysis is an indication on the risks of a structure constituting a more or less severe obstacle for a given fish species or group of species. Particular attention was paid to the practical aspects of the method (time required and necessary human resources) to facilitate its use in a wide variety of situations and areas.

This *Knowledge for action* document is divided into four chapters.

■ **Chapter A discusses the importance of ecological continuity for fish**, based on a review of the current scientific knowledge. It looks at the bio-ecological issues involved in the free movement of fish, the main types of physical barriers and their impacts on fish populations. It also summarises the physical capabilities to overcome obstacles of different species found in continental France, indicating the parameters used to assess those capabilities and the main factors on which passage depends.

■ **Chapter B describes the general principles underlying the ICE protocol.** It presents method implementation and the main types of obstacle analysed. In addition, it lists eleven ICE species' groups according to their swimming and jumping capabilities and precisely defines five "passability" classes intended to inform on the impact of obstacles.

■ **Chapter C goes into the details of the assessment procedure to determine obstacle passability during upstream migration.** It discusses the calculation method for the indicators for each of the five main types of obstacle considered here and also addresses the special case of the European eel, which has some very specific movement techniques. Each procedure is presented as a flow chart to assist in decision-making, thus making the protocol easy to use for a wide range of people.

■ **Chapter D is devoted to obstacles equipped with a fish pass.** It summarises and discusses the design principles behind the different technical solutions now encountered. In addition, the chapter presents a pre-assessment method for obstacles equipped with a fish pass in order to rapidly identify those fish passes that are clearly not (or not well) suited to the species in question.