OYSTER TRANSFERS: A MAJOR VECTOR FOR MACROPHYTE INTRODUCTIONS

Marc Verlaque [1] *, Charles François Boudouresque [1] and Frédéric Mineur [2]
[1] UMR 6540, COM - Luminy, 13288 Marseille, France - verlaque@com.univ-mrs.fr
[2] Queen's University ofBelfast, Belfast, U.K.

Abstract
Oyster transfers, as a vector of primary introduction and secondary dispersal of exotic macrophytes, were assessed on the basis of (i) two major French aquaculture sites: the Thau Lagoon and the Arcachon Basin; (ii) a bibliographical analysis of 34 Mediterranean coastal lagoons; and (iii) an experimental simulation of oyster transfers. The resultsconfirmed the tremendous efficiency of the vector. The oyster trade is by far the main vector of macrophyte introduction into the Mediterranean Sea, ranking above the shipping and the opening of the Suez Canal.
Keywords : Algae, Aquaculture, Lagoons, Strait Of Messina.

Introduction
Transfers of oysters for aquaculture purposes (both importation from exotic areas and livestock transfer between basins; i.e. primary and secondary vectors) have resulted in the introduction of a number of pathogens, parasites and pests [1]. Elton argued that 'The greatest agency of all that spreads marine animals to new quarters of the world must be the business of oyster culture' [2]. 46 % of the exotic marine species in northern Europe and 20 % in Australia probably arrived via oyster imports [3]. However according to [4], shellfish transfers rank below shipping (hull fouling and ballast waters) for the introduction of species. As a part of the European ALIENS program, we investigated the shellfish transfer vector (http://www.uniovi.es/ecologia/aliens/E-aliens.htm).

Results
In the Mediterranean, Crassostrea gigas production is wholly dependent on spat or adult importation. In France, massive importations from the northern Pacific occurred during the 1970s. Nowadays, only the spat produced inthe NE Atlantic is authorized, but livestock transfers between basins frequently occur to ensure an optimum growth.
In the Thau Lagoon (Mediterranean), 25 % (57 taxa) of the total number of macrophyte species were identified as introduced. Introduction by shipping, via the harbour of Sète, is likely for only a few species. 89% of taxa may originate from the northern Pacific, introduced either directly via importation or indirectly via shellfish transfers (fixed on oysters, mussels, clams and the packing materials) from other aquaculture basins.
In the Arcachon Basin (NE Atlantic), 19 exotic macrophytes were identified [5]. Oyster transfers to and from the other European basins regularly occur [6]. Again, with the exception of the oldest introductions for which shipping cannot be ruled out as a vector, shellfish transfer and the Pacific appear as the most probable vector and origin, respectively, for introduction.
In the 34 Mediterranean coastal lagoons we studied, 67 exotic macrophytes (78% from the Pacific and 94% via shellfish transfer) have been reported, with the lowest number (1 - 2 taxa) in the lagoons without aquaculture facilities, and the highest in the major aquaculture basins: Mar Piccolo (10 taxa), Salses-Leucate (11 taxa), Venice (25 taxa) and Thau (57 taxa).
The experimental simulation of transfer showed that oyster shells cleaned out (visually without epibionts) can still bear a high diversity of viable native and exotic macrophyte propagules (41 and 16 taxa, respectively). The abundance of propagules may be due to the fact that after cleaning, the oysters are re-immersed for two weeks before each transfer.

Discussion and conclusion
The ALIEN program has evidenced oyster transfer as the most efficient vector for macrophyte introduction into the Mediterranean. In addition, our census probably represents only the tip of the iceberg because the exotic cryptic species and gene introductions from remote populations are very difficult to detect. The conditions of livestock transfers appear as very favorable for the survival of the organisms with fewer constraints hindering the introduction than for the other vectors (hull fouling, ballast waters, Suez Canal) [7]. Within Europe, large amounts of shellfish are being transported from one basin to another and the European authorities even encourage this practice [1]. However, the inadequacy of current legislation is such that these transfers still result into species introductions. The adoption of comprehensive guidelines for preventing the introductions is urgently needed to stem the rising tide of aquatic invasions [8,9].
Guidelines to reduce the unintentional introductions by shellfish aquaculture.
- Awareness of farmers concerning the risks associated with uncontrolled importation has to be increased.
- Aquaculture has to be based on native, local stock whenever possible. Imports and transfers of livestock have to be minimized, thoroughly inspected, and quarantined for an appropriate observation period.
- Special attention has to be paid during aquaculture trials with new exotic species (even with livestock from hatcheries).
- Non-native livestock for introduction has to be produced in hatcheries.
- Live products destined for consumption, processing, and aquarium or display must not be placed into the natural environment.
- In the case of livestock transfers (including interregional ones), decontamination processes and/or quarantine as proposed by ICES have to be followed.
- Efficient treatments (e.g. hot-seawater for oysters) to avoid introduction or secondary dispersal of exotic or native species have to be carried out prior to each transfer, i.e., after the period of re-immersion preceding the transfer, and have to be repeated on arrival.

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