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著者	BLANCO GONZALEZ Enrique
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Biological Control of Sea Lice Infestation in the Norwegian Salmon Aquaculture: Are Cleaner Fish a Solution?

Enrique BLANCO GONZALEZ

Norwegian College of Fisheries Science, UiT - The Arctic University of Norway, Tromso N-9037, Norway

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Corresponding Author
Enrique BLANCO GONZALEZ,
enrique.blanco@uit.no

Abstract

Norway leads the world aquaculture production of Atlantic salmon (*Salmo salar*). However, salmon lice infestation remains a major challenge for the industry which is continuously evolving towards mitigating the sea lice problem. Among the different prevention and treatment measures available, the biological control of sea lice infestation by cleaner fish has been suggested to be the most economic and environmentally friendly option. However, the intensive fishing pressure on natural populations and the potential risks of genetic introgression associated to fish translocations have questioned this perception. Moreover, the increasing number of transparent lice as well as cleaner fish health and welfare issues have raised concerns regarding current cleaner fish practices. This manuscript provides a general overview of the biological control of sea lice infestation through the use of cleaner fish in Norway, and highlights recent concerns regarding this approach to tackle the sea lice problem.

1. Norwegian salmon production and the sea lice problem

Norwegian annual Atlantic salmon (*Salmo salar*) aquaculture production exceeds 1.2 million tons and a value of approximately 800 bilion JPY (Anonymous, 2019). In line with the other main salmon producer countries, further growth of Norwegian salmon aquaculture industry is constrained to reduce sea lice infestation which has become a growing economic burden (Liu and Bjelland, 2014; Abolofia *et al*., 2017). A wide range of prevention and treatment measures have been developed and tested against parasitic sea lice; including the use of chemotherapeutants, administered either orally or bathing the fish, and non-medical approaches such as mechanical, thermal and biological treatments using cleaner fish (Overton *et al*., 2018). Salmon delousing by cleaner fish has increased popularity in recent years as it has been considered the most sustainable approach (Treasurer, 2012; Liu and Bjelland, 2014). Indeed, the efficiency of several cleaner fish species for lice removal is currently investigated in several countries worldwide.

2. Cleaner fish species used for sea lice removal in Norwegian salmon aquaculture

In Norway, the group of cleaner fish used for sea lice removal comprises five main species which can be divided in two major groups. In northern regions, salmon farms use the cold-water adapted lumpfish, *Cyclopterus lumpus*, a species traditionally harvested for their roe. Wild lumpfish populations are believed to be small, and display significant phenotypic differences and low genetic variability (Whittaker *et al*., 2018). Their supply to the salmon industry (over 30 million fish in 2017, Anonymous, 2019) relies on commercial production from wild broodstock whose eggs are often translocated over long distances (Jonassen *et al*., 2018). Further south, the use of lumpfish decreases in favor of mainly four temperate wrasses: ballan (*Labrus bergylta*); corkwing (*Symphodus melops*), goldsinny (*Ctenolabrus rupestris*), and rock cook (*Centrolabrus exoletus*) wrasse to a lesser extent. Commercial rearing techniques for wrasses are limited to ballan wrasse which represented less than 5% of the over 22 million wrasses deployed in salmon cages in 2017 (Anonymous, 2019). Rising sea water temperatures registered in the last decades have favored a drastic increase in abundance of wrasses in southern Norway (Knutsen *et al*., 2013). The mismatch between the

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large number of wrasses available and the low number of salmon farms operating along the Skagerrak coast of Norway and Sweden, has promoted that millions of adult wrasses fished annually in southern regions are translocated to salmon farms located in northern areas where local stocks cannot cope with their high demand (Blanco Gonzalez and de Boer, 2017).

3. Major concerns of the recent expansion in the use of cleaner fish

The biological control of sea lice through the use of cleaner fish is expected to be the main salmon delousing treatment over the next years (Bolton-Warberg, 2018; Brook *et al*., 2018). However, the large number of cleaner fish recently employed in the salmon industry, and the sex- and size-selectivity of the fishery have raised concerns regarding the vulnerability of natural populations to overfishing (Blanco Gonzalez and de Boer, 2017; Halvorsen *et al*., 2017; Powell *et al*., 2018). The strong spatial patterns of phenotypic and genetic differentiation and high proportion of potentially translocated individuals escapees in the proximities of salmon farms raised additional concerns in relation to putative genetic introgression (Blanco Gonzalez *et al*., 2016; Jansson *et al*., 2017; Faust *et al*., 2018; Whittaker *et al*., 2018). Ongoing efforts to develop selective breeding programs for lumpfish and ballan wrasse may help to reduce the fishing pressure on wild populations; yet, increase the risk of genetic introgression. In this regard, the low proportion of lumpfish feeding actively on sea lice (Imslad *et al*., 2016) is one of the main issues to be solved. The rapid increase in number of transparent sea lice found in some regions has also questioned previous perceptions promoting the use of cleaner fish due to the inability of sea lice to develop resistant mechanisms against them. Cleaner fish health and welfare is another point of concern requiring further research (Rimstad *et al*., 2017).

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