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Systematics and Aquaculture: What Could They Bring to Each Other?

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Abstract: Systematics is traditionally based on morphological characters to both define species and establish classifications. In the past decades, partly due to the advent of molecular biology, traditional systematics has declined while molecular systematics has tremendously increased. This results in that fewer funding are generally provided to traditional systematics, particularly for searching new morphological characters. Aquaculture, the farming of aquatic animals, has increased exponentially in the past decades, providing today more than half of fish consumed worldwide, and is expected to continue to rise. Aquaculture requires controlling the life cycle of the farmed fish in captivity, including the rearing of early life stages. Therefore, by coupling systematics and aquaculture, it could be possible to bring new funds and facilities to the former to study the early life stages of numerous fish species and to the latter it would offer a conceptual framework to perform comparative ontogeny. Together, this could help improving our knowledge on the early life stages that could be useful for both taxonomists and zootechnicians.

Key words: Systematics, taxonomy, aquaculture, early life stages, fish.

1. Introduction

Systematics aims at describing, classifying and naming Earth's biodiversity, among which species is the fundamental unit [1-4]. The first main task of taxonomists is to circumscribe, describe and then give names to new species, for the latter, they have to follow the rules of the International Codes of Nomenclature such as the binominal description of an organism by its genus and species [1, 2]. The second main task is to group species into various taxa within a hierarchical classification, using Linnaean categories, among which the most common are family, order, class, phylum, and kingdom [3]. Thus, systematics provides a reference system for the whole of biology and can be viewed as both the most basic and largest area of biology [3].

Systematics is traditionally based on morphological characters to both define species and establish classifications or phylogenies [5]. However, in the past decades, morphology-based systematics has

strongly declined partly due to the tremendous development of molecular biology [4]. Today, most systematic works published are based on the analysis of molecular characters, particularly with the advent of DNA barcoding in 2003 [5, 6]. This has resulted in that fewer funds are generally allocated to traditional systematics, particularly for searching new morphological characters useful to reconstruct phylogenetic relationships between species. One typical example of this evolution is the Gadidae, which includes some of the most valuable fish species for marine fisheries, such as Atlantic cod (*Gadus morhua*), Alaska pollock (*Theragra chalcogramma*) or European hake (*Merluccius merluccius*). From the early 1940s up the late 1980s, several morphology-based classifications were proposed [8-11]. However, since our publication in 2006, which summarized and analyzed available morphological characters [12], several molecular phylogenies were published [13-17], but, to my best knowledge, no new morphological characters have been described.

The aim of the present study is to try to demonstrate that the tremendous development of aquaculture in the

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past few decades could help the renewal of traditional systematics and in return systematics could help domesticating new fish species.

2. Aquaculture

Aquaculture, the farming of aquatic animals, has increased exponentially over the past few decades, resulting in the today more than half of fish destined to human consumption worldwide is farmed [18]. During this period of time, more than 360 fish species have been reared globally [18]. Only for marine fish, the number of farmed species has raised from 2 in 1950 up to 65 in 2013 [19]. However, the top ten marine farmed species account today for nearly 90% of global production [19]. This illustrates that only a fraction of farming trials has resulted in a significant production, such as for Atlantic salmon *Salmo salar* [20] or European sea bass *Dicentrarchus labrax* [21], while numerous others have either failed or resulted in low productions [22, 23]. The past few decades have thus demonstrated that the farming of new fish species is somewhat difficult, and requires, among others, both time and money in the long run [22, 23].

Farming implies to progressively control the life cycle of the targeted species in captivity, a process known as domestication [23-25]. During domestication, animals become, generations after generations, more adapted to both humans and captive conditions [26, 27]. Once the whole life cycle of the farmed species is controlled in captivity, then the process can proceed further up to the establishment of groups of individuals or breeds with specific desired traits, such as better growth performance or specific carcass quality traits [23-25, 28]. Most often, the domestication of a new fish species, particularly at the beginnings, relied on the work of very small groups of people, including technicians, researchers and fish farmers, and each group focused on its species of interest [29-31]. This may partly explain why so many farming trials failed and also highlights the limits of the current monospecific approach to continue to truly

diversify aquaculture production. Indeed, important investments cannot be operated for each of the numerous candidates for fish aquaculture, especially if local size-limited markets are targeted [31, 32].

One possible way to lower the uncertainty when trying to domesticate a new species and thus save both time and money is to take advantage of the available information on various species regarding characteristics of their life history to evaluate whether it is possible to apply or quickly adapt existing zootechnical technologies acquired on one species to others [30, 31]. Such a comparative approach has been developed over the past few years focusing on reproduction, as its control is a prerequisite for domestication to establish fish stocks, be able to develop genetic selection and maintain production all year round, for 65 European freshwater fish species [31]. Yet, further developments of such comparative approaches in aquaculture focusing either on other fish species (*e.g.*, marine, tropical) or other biological functions (*e.g.*, nutrition, growth) will probably require integrating more concepts and methods of systematics, as explained below.

3. What Could They Bring to Each Other?

From the 1960 still the 1980s, numerous researchers working on the early life stages of fish were at the same time taxonomists, ecologists, fisheries managers as well as zootechnicians, one of the best example being Edward D. Houde [33-36]. Perhaps the most seminal work that summarized these multidisciplinary approaches was published after the international symposium held August 15-18, 1983, at La Jolla, California, and dedicated to the memory of Elbert Halvor Ahlstrom [37]. However, afterwards, scholars progressively specialized in one of these different scientific disciplines resulting in that today probably very few researchers would be able to lead alone a multidisciplinary research on early life stages of fish, as performed a few decades ago.

One of the main consequences is that the study of

early life stages have strongly declined in systematics and today very few taxonomists are trained to work on fish larvae [38]. Most comparative anatomical and phylogenetic investigations, particularly with the advent of molecular phylogenies, have overlooked the rich and critical source of character information that larval stages can provide [38]. Thus, the enormous potential for solving long-standing questions of homology remains largely untapped [39, 40], and in the future we might completely ignore the most morphologically dynamic part of the life history of fish in systematics [38, 41].

The recent boom of aquaculture could bring both funds and facilities to study the early life stages of fish, allowing providing, for instance, new informative larval characters and ontogenetic character transformations for phylogenetic analyses, of numerous fish species globally. In return, systematics could bring a conceptual framework to perform comparative ontogeny that could allow to help domesticating new fish species: species displaying similar early life stages characteristics (*e.g.*, incubation time, incubation temperature, larval size at hatching, mouth gape...) could be reared in similar conditions. This might be particularly useful to better understand how skeletal anomalies develop, which is currently a major problem in aquaculture [42, 43], and enhance larval nutrition [44, 45].

4. Conclusions

Systematics and aquaculture are apparently two strongly different scientific disciplines with their own goals and methods. Yet multidisciplinary projects involving both taxonomists and zootechnicians, and probably other researchers working for instance in evolutionary developmental biology or Evo-Devo [46] might help the renewal of morphology-based taxonomy [47] as well as the promotion of diversification of aquaculture production.

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