What Is the Future of Siberian Sturgeon Farming?

Asking the entitled question means that some doubts might be expressed on the future of the farming of the species as compared with other sturgeon species. The deep crisis in the world caviar market in the introduction of the present volume has been mentioned (Williot et al. 2017). These recent changes made precarious the functioning of most sturgeon farms worldwide especially those of which investments are still not redeemed and/or those of which production costs are incompressible. Among the diverse alternatives to go through is to look for a more in-depth choice for the species notwithstanding the legal aspect of rearing a non-native species which can be restrictive depending on the country. A very recent example unfortunately illustrates this comment with the status of the species in Florida (USA) in potentially changing the legislation.

Therefore, reasons to support the choice of a sturgeon species have to be rigorously conducted in comparing (1) biological and breeding characteristics of the species and (2) marketing aspect depending on species. More, there might be present evidence arguing to favour the choice of supporting a species that may not take into account in long-term perspective. For example, whatever their ecology, all sturgeon species are farmed in freshwater. But what could be the long-term impact of such farming conditions regarding species of which the ecology exhibits long spending period into high water salinity during ongrowing phase? No one knows. In contrast, there is no risk for those species which exhibit a quasi-exclusive freshwater status alike the Siberian sturgeon.

Regarding the biological characteristics, we have gathered in volume 1 the main documented issues; even some of them remained unsolved, e.g. the sex determination. As far as breeding is concerned, i.e. the present volume 2, the first two parts deal with two key issues for the farming of any species, i.e. reproduction and food-feeding-related issues. Once puberty is achieved, the main interval between two spawning events is 2 years, but the different recorded complicated occurrences are reported that allow building a long-term reproductive planning if needed (Chap. 26). This might be interpreted as an illustration of the plasticity of the species which is

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able to either reduce or increase this interval and then to increase or not its spawning frequency. Similarly, this allows planning caviar production within a given cohort. The management of brood fish for the reproduction is then extensively given in detail in order to provide the best quality products (eggs and further larvae) (Chap. 27). This includes the few months before the spawning sensu stricto up to the collection and management of gametes to further obtain fertilized eggs, viable embryos and good-quality larvae. In case farmers would like to separate the management of both sexes, effective cryopreservation of sperm is given (Chap. 28). The process might be of use when aiming at increasing the genetic variability of brood stock by acquiring other sperms. Due to lack of global traceability and references, great care should be brought about the origin and characteristics of sperm. Besides reproduction, food and the related feeding issues constitute a challenge from a long-term view. Despite the pertinence of each of the different issues of this group, there is an overlapping of the different chapters of this group (Chaps. 30–33) that reveals a high level of intricacy of these questions all the more so since that immunology (Chap. 43); a very new and updated chapter is also concerned by this remark. A brief overview of current practices on food and feeding is given (Chap. 30). A synthesis of available literature in the field of nutritional requirements is provided (Chap. 11) as has been given in volume 1. The optimum level for the main ingredients is provided. As the optimum level for protein is relatively high (~40%) of fish-originated ingredients, there were attempts to substitute plant protein for animal protein to lower the cost (Chaps. 31 and 32). There are risks in using some plant protein, e.g. soy which may be considered as an endocrine disruptor (Chap. 32). It is interesting from the historical point of view and for those interested in research planning to briefly recall the origin of these findings. In the early 1980s, a key question was to discriminate the gender as early as possible within the whole French research program. At that time, the search for plasmatic vitellogenin was considered to be the appropriate tool as this complex molecule produced in the liver under the stimulation of estradiol accumulates in the eggs and then was supposed to be female specific. Thanks to male control, it was shown that males also produced vitellogenin, and the reason was the presence of phytoestrogen components in the compound food (Chap. 32). Indeed, instead of using plant protein, there are suggestions to work preferably with terrestrial rendered animal protein (Chap. 31). This may suppose a change in legislation in some countries. There was another reason for such a search in substituting animal protein for plant protein that was related to the wastes. The wastes from fish and sturgeon are no exception, fed animal protein is more pollutant than plant protein, and some Western countries have obliged fish farmers to respect low threshold levels of nitrogen in the outlets (Chap. 34).

The third part of the volume deals with production. A broad overview of the world production of both meat and caviar for human consumption is given as well as an example fingerling production destined to be restocked with the hope of species preservation. With regard to the first type of production, it is worthy to note that obtaining species-specific data is complicated because (1) the species is not individualized in the statistics (if any), (2) sturgeon farms may produce several sturgeon species and (3) the main stakeholders are often reluctant to provide data and/or

information related to production and its related financial and marketing issues. Whatever, a tentative assessment of the world production for meat and caviar and its main characteristics is proposed. Among the characteristics are the recent trends in caviar production based on ovulated eggs instead of the traditional ovarian follicles and on the geographical extension of producing countries. Currently, Siberian sturgeon is the object of aquaculture in more than 50 countries; the whole volume of yearly world production is assessed about 22,000–23,000 thousand tons of gross production and 150 tons of caviar (Chap. 38).

Regarding the fingerling production, an example of restocking is given (Chap. 37) with the Ob-Irtysh catchment which is being impacted by oil and gas exploitation (Zaytsev 2012) so that the species is totally protected. The extremely long transportation and the related management of young fish from the hatchery up to the released areas downstream the river needed the help of an adapted boat that appears to be species specific. Out of the Siberian river catchments, that of the Lena River is the only one where the Siberian sturgeon population is not listed in the Russian Red Book, and this catchment, the Lena River, is where the two batches of Siberian sturgeon juveniles which arrived in France in 1975 and 1982 came from (Williot et al. 2017; Malyutin and Ruban 2009[1]).

In relation with the most attractive sturgeon product, the caviar, two chapters deal with quality aspect of the product. Biochemical origin and treatment of the potential unpleasant taste are provided (Chap. 36). Besides, a methodology to analyse the taste by the sensorial approach (Chap. 35) of the caviar is also described. There might be other quality aspects of the caviar production, one of them being the crushing character of caviar upon degustation. The main outcomes of a recent study on the matter (Augustin 2007) pointed out that washing and further salting are the main critical phases. The "ionic charge in the water results in tensions within external envelopes," and salting tends to break down the structure of the membranes. Additionally, the author gives a description of a transportable device able to measure the resistance to the breakdown of grain of caviar.

Four chapters constitute the fourth part of the volume 2; they deal with long-term management of brood stock. Two of them present how the genetic variability of brood stocks can be characterized, one in Poland (Chap. 41) and the other in Russia (Chap. 42). The former describes the genetic variability of polish brood stock thanks to microsatellites and the second study both mitochondrial and nuclear (microsatellites) markers for both farmed and wild populations of the species which constitute a great added value to this chapter. A chapter updates the studies aiming at controlling the sex by genome manipulation (Chap. 40) in describing in details the state of the art in the field. Up to now, we have been focusing our efforts on the Siberian sturgeon as a pure species, but given the very extended interspecies crossing in sturgeon, we may wonder which could be the advantages of farming hybrids with the Siberian sturgeon; this is the object of Chap. 39. The fifth part of the volume on

[1] The first batch of Siberian sturgeon arrived in France in 1975 and not in 1980 as mentioned by the authors. If necessary, a strong support to that is the fact that the first controlled reproduction of these fish has been obtained in France in 1981 (Williot and Rouault 1982).

farming includes three chapters which globally deal with the health status of the fish. All three are completely new approaches in sturgeon. The first out of the three consists in a synthesis on the immunology in the sturgeon with a focus on the Siberian sturgeon (Chap. 43). Mechanisms, responses to stress and stimulation are described. The two others tackle the welfare approach, one through plasmatic indicators (Chap. 44) and the second is a global approach of the matter for the species (Chap. 45). The authors of the last one (the three coeditors) tentatively gathered all the available data and methods (with their limits) at field; they show it is a complex approach that needs an extended knowledge of the fish, the environment and the husbandry altogether. A good illustration for that is the great number of references including other chapters of both volumes.

With the development of the farming of the species worldwide, one might be anxious with potential negative impact in case of escapements of specimen far away from their natural geographical distribution. From two examples of introduction of individuals of the species in non-native waters, no installation was recorded. Introduction was voluntary and repeated by numbers (Northwestern Russia, Chap. 46) and escapement from either fish farms or from the angling activities in close water ponds sometimes by number (France, Chap. 47). Thus, this means that the ecological risks of installation post-introduction of the Siberian species proved to be quasi-null. This is one of the very few documented examples in the field, and then it should be interesting to carefully analyse the reasons of this non-invasiveness in both Russia and France and to go further in depth of previous analysis in the field (Williot et al. 2009).

The last part aims at giving methods which focused on in vitro incubation of ovarian follicles (Chap. 48), on echography (Chap. 49) and on oxygen demand (Chap. 50). The first is used to test the in vitro maturation competence (IVMC) of the ovarian follicles as a decision maker bio-test for the selection of the best female to respond to the hormonal injection (Chap. 27). The second is an extremely well-illustrated chapter presenting a library of images (echographies) of the internal parts of the abdomen of fish to support the morphological description. The non-invasive method has been a considerable breakthrough in the early 2000s for early sex discrimination, i.e. for animals as young as 1.5–2.0 years weighing $\leq$2.0 kg (which corresponds to the minimum market requirement in Russia), and thus eases and speeds up the development of caviar-oriented farm (Chebanov and Chmyr 2002; Chebanov et al. 2004; Bonpunt 2006; Chebanov et al. 2006). The third method (Chap. 50), focused on oxygen demand, gives the detailed basements around the oxygen demand which is of the utmost importance to understand the whole physiological regulations involved in controlling the respiration. This allows computing the needed flow rates depending on the activity of fish and on environmental factors.

Altogether, the aforementioned compendium covers all the key items that are needed to carefully manage Siberian sturgeon farming. This means that even though there is still a great need of long-term research (e.g. long-term impact of food) which is not Siberian sturgeon specific, the species has supported a lot of studies worldwide, illustrating the interest focused on it. This is confirmed by a recent analysis on the publications focused on sturgeon during a 15-year period (1996–2010)

(Jarić and Gessner 2011). The species is second behind the white sturgeon (*Acipenser transmontanus*) of which a great part deals with environmental issues. This means that out of all sturgeon species, the Siberian sturgeon has been the most investigated. In other words, this is the species of which the library is the largest which is an advantage at a time when unexpected questions arrived. It has been observed by sturgeon farmers (Sabeau 1998) that the caviar from the species looks like that of the Russian sturgeon (*Acipenser gueldenstaedtii*) commonly known as osetra the species being one of the three of which the image is known worldwide. Finally, the most critical argument in favour of the species most likely relies on its remarkable adaptive capacity that makes the species very much securing from a long-term perspective once environmental conditions remain in the homeostasis range. Indeed, the species, which was not mentioned in the past in the declared landings for sturgeon by the former USSR the quantities of which were completely dominated by the three well-known wild exploited species in the Ponto-Caspian basin (*Huso huso*, *Acipenser gueldenstaedtii*, *Acipenser stellatus*), accounted for about 30% in the late 1990s (Chebanov and Billard 2001). Further, this relative part is similar to date (Chap. 38), which means that the species is very attractive in the sturgeon mother country, Russia.

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