Environmental interactions of fish farming in the Mediterranean: research achievements and policy requirements

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Abstract
The main target of fish farming is the production of high nutritional value food for humans, with the lowest possible cost. This goal should be achieved in the shortest feasible time, without causing any damage to the environment, mainly the aquatic one. Many years of human involvement in various fish farming practice has been finally expressed in different production systems. Considering the given Mediterranean Sea conditions' status, theoretically, it could be emphasized that along Mediterranean coastline sites all types of production systems could be applied in accordance with specific demands, using suitable both water and land. The so far carried out research related to fish farming issues in the Mediterranean Sea has been mainly focused on the interactions-interrelations of farming conditions (e.g. rearing water quality, constructions, feeding practice) and various human interactions concerning the homeostasis status (e.g. living ethology, metabolism-physiology of nutrition, reproduction, genetics, growth) of farmed fish species. Also, it should be emphasized that the official regulations and monitoring procedures and the real practice at many Mediterranean fish farms are more or less 'far away' from scientific evidence. This, could be due, to some extend, to insufficient involvements in dissemination of existing and well documented research achievements. However, the existing policy requirements could be satisfied by nothing more than a continuous and sincere collaboration between science-research, farmers, local societies, consumers' demands and policy makers. Finally, it must be strongly underlined the fact that almost all research dimensions of farmed fish could be directly or not (according to the existed evidences) based on their brain plasticity abilities, although they lack cortex. So, fish using their brain, under welfare rearing conditions, can easily 'communicate' with humans, for the benefit of both sides and their living environment.

INTRODUCTION

The main target of fish farming is the production of high nutritional value food for humans, with the lowest possible cost. These goals should be achieved in the shortest feasible time, without causing any damage to the environment, mainly the aquatic one (Papoutsoglou 1991; Wells, 2009).

The expected positive social dimension of fish farming practice should be connected with a sufficient answer to the following order of questions: **I)** where a fish farm is planning to be established? That means that a consolidated and detailed evaluation of the entire local water (chemical, physical, biological and hydrological), as well as, those of the adjacent land (easy or not to approached, coastline morphology) characteristics, for long time, should be known. **II)** Which fish specimens could be suitable for farming given the assessed properties of the locality? A positive answer should cover at least all the biological-ecological demands of a selected fish species. **III)** Which could be the most adequate production system for the given fish species and location? A proper choice should be mainly based on a precise combination of fitness location-fish species and farmers' desire. **IV)** Which could be the financial profit of the farm, as well as, which could be the impact of the farm's operation in the local natural

and social environment? The answer must satisfy both parts of the question (Papoutsoglou, 2010).

FISH FARMING INTERACTIONS WITH THE MEDITERRANEAN ENVIRONMENT

Fish farming practice has been expressed, for many years, by human involvement of various-different performances, by which finally, is formed that which are called production systems. The Human Involvements (H.I.) could be summarized as follows:

I. Improvement of trapping effectiveness of wild fish populations, living in natural water bodies (mainly lagoons), using traps and enclosures of special types.

II. Increase the production of a known fish population by the improvement of the natural productivity of a man-made earthen pond, using various combinations of constructions and types of fertilization.

III. Involves number 2 H.I., plus occasional use of supplementary food.

IV. Involves number 2 H.I., plus permanent use of supplementary food.

V. Exclusive use of man–made fish diets (food).

VI. Control of stress related physiology aspects of fish in relation or not to their reproduction and sex, using updated methodology.

VII. Exclusive use of tanks, raceways, net cages, as rearing place.

VIII. Control of rearing water quality parameters (chemical, physical, biological, hydrological, lighting, sound conditions etc).

By a correct combination of H.I.s the following fish production systems could be resulted: The **extensive** (only I), the **simple semi-extensive** (by II and VI) the **semi-extensive** (by II, III and VI), the **semi-intensive** (by II, IV and VI), the **intensive** (by V, VI and VII) and the **super-intensive** (by V, VI, VII and VIII). It should be mentioned that by their accurate application, from the extensive to super-intensive production systems, it should be expected an increase of annual yield (kg/m^3 or m^2), water exchange rate, production cost, as well as, a decrease of farming water demands and production period for marketable size fish obtaining. Nowadays, the most common production system applied in Mediterranean Sea regions, for sea water fish species production (mainly sea bass and gild-head sea bream), is the intensive one, using mostly the net cages technique (Papoutsoglou, 2000).

Generally, the Mediterranean Sea is a non tidal sea which is characterized by a vast diversity of depth, coast line morphological conditions – lagoons, gulfs of various sizes, rivers' discharge in the sea, as well as, by various human activities (e.g. touristic). Also, the same level of differences define its water chemical composition, physical and circulation properties, aquatic life communities composition, a big number of various size of islands (uninhabited or not). Its surface water masses are subjected to the action of various intensity local or not winds blowing from various directions, as well as, to different intensity rainfalls (most of the heavy ones occur ones unexpectedly almost everywhere), while in many cases coastal cold or hot water springs of various chemical composition are present. It should also be emphasized that Mediterranean Sea shows a warming trend according to global climatic warming alteration, the impact of which, however, could be called uncertain and almost completely different, not only among its major areas, but also regarding relatively small sized sites. Furthermore, it has to be pointed out that for the formation of the final impact of the interactions, of the above mentioned factors, to the Mediterranean Sea environment, the different way of human behavior to it, as a result of different lows-

policy existed or due to different ways of application of the same lows should be added (Sara *et al*., 2006; Kuspilie *et al.*, 2007).

Considering the given Mediterranean Sea conditions' status, theoretically, it could be emphasized that all types of fish production systems could be applied, according to each one of them special demands, along Mediterranean coastline sites, using suitable both water and land areas.

The accepted ideal picture of the interactions among fish farming procedures and the environment should be expressed by mutual obligations and claims of both sides. The final impact of these interactions must be characterized by a proper (in terms of producers and consumers satisfaction) fish production and ecologically undisturbed environment (Papoutsoglou, 1996).

The main points of the above mentioned interactions can be summarized by the following:

a) Impact of farmed fish to the aquatic environment.

Increase of the levels of CO_2, various chemicals, PO_4, NO_3, NO_2, NH_4, suspended matter (both organic and inorganic) and decrease of the levels of O_2 and pH. The expected results of these procedures could be summarized as:

I). Possible creation of anoxic conditions, due to the oxidation of the organic material (almost 1.3 tons released from 1 ton farmed fish production), as well as, to the uneaten food (in the cases that fish are consuming only, or not, man made diets). It is worth noting that for the production of 1 kg of live weight (independently from the time needed) of a carnivorous farmed fish, the oxygen demands are almost 2 kg.

II). Possible creation of unwanted super-eutrophic conditions in the aquatic mass receiving the outlet of fish farms due to their high loud of nutrients. As it has been estimated the production of 1 ton of a carnivorous farmed fish could cause the release of about 12 kg of NO_2 and NO_3 ions and almost 16 kg of P.

III). Possible ecological degradation of the aquatic environment due to water pH level decrease and increase the levels of NH_3 (almost 55 kg of total N-NH_4 from 1 ton fish production), suspended matter (of inorganic origin), colloids, various chemicals– pharmaceuticals, antibiotics, as well as, to release and dissemination of pathogens, benthic communities' composition changes and to accidently escapes of famed fish specimens.

b). *Impact of the aquatic environment to farmed fish populations.*

Possible rearing water quality and environment degradation due to:

I). Chemical composition fluctuations mainly in terms of salinity and oxygen content, caused by unexpected mixing of the rearing waters with those of rivers or torrent.

II). The presence of various kinds of pollutants (oils etc.) and pathogens transferred from nearby sites, mostly of anthropogenic origin.

III). A relatively sudden change of the existed water currents due to either the appearance of surface fresh water inlet to the rearing water, in relation or not to strong winds and increase of water temperature.

Considering the type of human involvement, the intensive production systems and especially that which is using the net cages constructions, as farmed fish rearing place, should be accepted as the most risky for both the farmed fish populations and the aquatic environment (Simard *et al.,* 2007; Donavaro *et al*. 2004; Papoutsoglou *et al*., 1996).

RESEARCH ACHIEVEMENTS

The so far gained research experience-achievements on fish farming issues in the Mediterranean Sea, has been mainly focused on the interactions–interrelations of farming conditions and various human interventions concerning the homeostasis status of farmed fish species especially gilt-head sea bream and sea bass.

a) Farming conditions

The research achievements on fish farming conditions contain mostly applied research works on fish rearing environment (rearing water quality and hydrology, fish rearing density and fish farms' constructions) and farmed fish nutritional practice, as well as, prevention and disease treatments.

I). Farmed fish rearing environment. a) Rearing water quality: The aim of this research area was and still is the achievement of a better understanding of the combined impact of water chemistry and temperature on fish metabolism-physiology and growth rate. In detail, these research works are related to consecration of updated methods-techniques for heavy metals and unwanted trace elements accumulation in farmed fish tissues for the benefit of fish metabolic procedures and consumers safety. Also, this research is related to undated simple methods' application for the determination of acid/basic changes-balance of farmed fish (especially when rearing water is often subjected to changes of its chemistry-salinity, CO_2, pH, etc.), as well as, to better understanding the influence (direct or not) of suspended matter on fish metabolic mechanisms and especially those which are related to consumed (amount and quality) by the fish proteins and lipids and their neurohormonal status. Of almost the same importance research work should be considered the one which tents to investigate the consequences on fish homeostasis level of rearing water hydrology conditions within the rearing spaces. So, the interactions of water inlet-outlet rates, the velocity levels, the circulation mode and turbidity status should be clearly–detailed known, not only on a general fish species basis, but also on each fish species biological stage's. **b) Rearing space constructions:** Generally, this research aims to cover a major part of fish living ethologic demands, in order to achieve the less possible stress induced energy expenses during the rearing period. The main points for further and detailed research work which is needed, is related to the rearing space-facilities constructive material, form-dimensions of tanks, color of the walls of the tanks, lighting conditions and waterborne airborne noise-sound, as well as, music (classical or not) transmission in the rearing space, suitable for each biological stage of farmed fish species'. **c) Fish rearing density:** The already achievements of this kind of research should be enriched with more knowledge concerning the combined effect of the number of fish specimens /m^3 or m^2 of rearing water with proper interrelation with all rearing space constructions, as well as, with the feeding ethologic and nutrition type-biological stage of farmed fish.

II). Farmed fish nutrition-feeding practice: Apart from the needs for accurate determination of chemical composition (in terms of energy and nutrient content) and texture of man-produced (alive or not) food/diets, as long as, fish cannot be fed individually, more information should be available concerning the mode of food/diet given to fish, feeding rate level and daily amount, as well as, the number of meals of a day –week basis.

III). Prevention and fish disease treatment: The already research achievements on this topic, which however have to be continuously improved, are related to the possibility in using rapid, effective, low cost, secure and timely diagnostic methods for prevention and confronting any kind of pathological signs caused by various pathogens (viruses, bacteria, parasites), in relation or not with

improper rearing conditions. The continuously improved, especially nowadays, vaccine research achievements seem to be one of basic of this area (Costello *et al.* 2001; Papoutsoglou and Lyndon 2006; Papoutsoglou and Abel, 1988; Papoutsoglou and Tziha, 1994; Vassallo *et al*., 2007).

b) Fish homeostasis status.

This research area has been and it is expected to try to cover all issues related to farmed fish living ethologic, metabolism-physiology of nutrition reproduction, genetics and molecular biology and growth.

I). Farmed fish living ethology: This research topic is related to all issues associated with detailed investigation and improving of welfare level on a farmed fish species-specific basis, especially regarding the interaction in between various components of rearing environment and skills of management.

II). Metabolism-physiology of nutrition: This research activity has and is representing a major part of total investigation interest given to all fish species biological stages under various rearing conditions. According to the nutritional types-demands of farmed fish the relative research attention, mainly in terms of applied research, has continuously been focused, among others, on the relation of quality and quantity of nutrients and the level of energy of food/diets, on better understanding the metabolic-biochemical procedures of phospholipids, polyunsaturated fatty acids, and proteins-amino acids, as well as, peptic enzymes efficiency, especially in relation to their special involvement (apart of that related to consumed food digestion) in cell membrane component synthesis and function. Also, it is important to emphasize the research significance related to the identification of the interaction of the involved genes which are forming the biochemical procedures of physiology of nutrition on an individual specimen's basis of a farmed population.

III). Reproduction: Although the gained research achievements on this topic have been well experienced, regarding especially sea bass and gilt-head sea bream, there are several points needed more updated attention. Among them, is the selection of suitable for reproduction wild or farmed origin specimens using phenotypic (specific body and hematological), as well as, genotypic (strains' identification) criteria and their evaluation, in the cases of known species, according to already existed protocol. Also, during the maturation of their genital material rearing period, the selected specimens have to be taken of a special care, the impact of the interactions of the interactions of several points of which are under a continuous investigation. These are their nutrition, the rearing water chemical, physical and hydrological parameters, the lighting conditions, the shape, the dimensions, and the color of the internal side of the rearing tanks, the sound/noise conditions, as well as, the determination of the age and the number of male and female specimens which should be reared (continuously or not) together. Generally, the intention of the present research topic should be the establishment, as much as possible, of an artificial "natural" environment by keeping the fish unstressed, recognizing the great importance of obtaining high quality and quantity of mature sperm and eggs and their simultaneous release (possible activation of mechanisms for pheromone synthesis) and naturally or not fertilization procedure.

IV). Genetics and molecular biology: The so far research achievements on these topics and their closely associated disciplines (which generally could be induced under the terms cytology, biochemistry, embryology, immunology, neurophysiology etc.) are proving the fact, using the updated-modern technology and knowledge, that they are representing an unlimited-endless research field of fish species (farmed or not), characterized by unclear borders between its basic and applied dimensions. As the most important research issues of this area could be mentioned the improvement of

farmed fish zootechnical characteristics by applying specimens' controlled selection techniques, combined or not with DNA manipulations.

V). Growth: It is well known that the research concerning the growth-growth rate of farmed fish has been and still is not only the most popular and the most complicated one, but also that which will never stop being the end research test of the interactions of farmed fish nature, raring environment factors, level of management applied, existed financial-market status, consumers' demand for quality and quantity of farmed fish production, as well as, policy-lows and their application. In other words by this research area the anytime new information and data from the fish biological and environmental, as well as, humans' society's characteristics and demands point of views, could be combined (Karakatsouli *et al*. 2010; Papoutsoglou, 1995, 2005, 2010; Papoutsoglou and Lyndon 2006; Papoutsoglou *et al*., 2008, 2010; Vassallo *et al.,* 2007).

POLICY REQUIREMENTS

Fish farming requirements in terms of laws and their application in the Mediterranean countries appear with two dimensions. One is related to the officially existed laws regarding regulations and monitoring (licensing regulatory control and monitoring guidelines and procedures). The other one refers to the impact of the interactions in between fish farming and Mediterranean environment. The first one is associated with the establishment, of a general regulatory and monitoring system (common, more or less, mainly in EU belonging Mediterranean countries) by which the environmental standards (e.g. distance in between farms, scientific coverage of the operation and management of the farms, proper fish feeding operation, stocking density limits), the food/diet quality standards (e.g. formulation of artificial diets, as well as, their staff proper storage, techniques-methods and procedures for their regular quality control) and the medicines and pesticides licenses for fish disease control (e.g. manufacturing, transportation and quality control) should continuously be in full accordance. The second one illustrates the actual practice at fish farms by which it is quite easy to conclude that it is rather difficult all the demands of any regulation system to be successfully covered. This is due, among others, to the existed bureaucratic and to the continuous appearance of new "legislation" complexities, in association with the diversity of the farms (in terms of fish species, production systems, feeding practice, constructions, sites etc.), as well as, to the farms' management level. However, the fact that the official regulations-monitoring procedures and the real practice at fish farms is more or less "far away", could be due, to some extent, to insufficient (for some reasons) quantity, quality and publicity involvements of the already existed and well documented research achievements. Thus, actually the anytime existing policy requirements could be satisfied by nothing more than a continuous tendency for a real honest-clear collaboration-communication in between science-research, farmers, local societies, consumers' demands and policy makers. Nevertheless, it is more than obvious that this kind of collaboration, as one of the continuously existing numerous social issues, will never could completely be accomplished, although the present and the future of all the Mediterranean countries should be considered as common issues in between them, regarding, among others, the obligatory share of their aquatic environment (Kuspilie *et al*., 2007; Papoutsoglou, 2000; Simard *et al*. 2007).

CONCLUSIONS

Considering the great importance of the environmental and fish farming interactions, the present and the future related research should be mainly aiming to all farmed fish physiology issues. Especially to those connected with welfare procedures causing and relief farmed fish from stress, particularly the chronic one. The currently and continuously improving techniques and analytical methods involve genetic manipulations (e.g. DNA consequence) in association or not with predictable determinations of the levels of various neurotransmitters and hematological parameters, as well as, peptic enzymes activity and liver and spleen biochemical functions, combined with fish various rearing conditions and nutritional coverage (e.g. use of pre-probiotics etc).

Also, it should be mentioned the significance of research aspects connected with the application of simple extensive, semi-extensive and semi-intensive production systems, mostly in relation with the present intention for "biologically» reared fish production.

Finally, it must be strongly underlined the fact that almost all research dimensions of farmed fish could be directly or not (according to the existed evidences) based on their brain plasticity abilities, although they lack cortex. How else, anyway, could be explained the already reported anti-stress response of various farmed fish species to combined effects of tank color and lighting conditions and, especially, classical music transmission, since it is impossible for them to have such kind of experience to hear/listen, e.g. Mozart, living in their natural environments? So, fish using their brain, under specific rearing conditions, can easily "communicate" with humans, for the benefit of both sides and their living environment.

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