European Organic Aquaculture - Science-based recommendations for further development of the EU regulatory framework and to underpin future growth in the sector

Deliverable D2.2
Knowledge gaps

Due date of Deliverable: M18

Submitted to EC: M18

Responsible for Deliverable: Wout Abbink, DLO-IMARES

FP7-KBE. 2013.1.2-11 Assessment of organic aquaculture for further development of European regulatory framework
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Outline

The gaps in scientific knowledge on organic aquaculture that are described in this report were identified based on the review on production related issues (Deliverable 2.1). In this review, the art of scientific knowledge on production issues in organic farming was assessed. The review focused in particular on a comprehensive review of fish feed and nutrition (1), health and welfare, veterinary treatments, biosecurity (2), production systems (3) and management, environmental interactions and sourcing of juveniles (4) in organic aquaculture. The knowledge gaps are structured according to the four main chapters and the subtopics of these chapters.

The knowledge gaps are also reported in D2.1, together with the EU regulations that cover the organic aquaculture production, and the scientific review on production related issues.

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Chapter 1: FEED REQUIREMENTS

Fish meal replacement

Considering fish meal replacement, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Sourcing of feed ingredients for organic aquaculture should be supported by experimental data to secure compliance with organic principles of fish welfare and environmental sustainability.
fish meal and fish oil derived from industrial fish caught in sustainable fisheries, should be considered as ingredients in feed for organic carnivorous species until more knowledge is available. This includes feed for fry and brood-stock, as well as for on-growing fish, until sufficient alternative sources of protein and oil are available.
The use of other alternative feed ingredients providing high content of essential amino acids and lipids, where possible produced organically, may be considered to be used in priority to purified or free amino acids as feed supplements/additives.
If not available from organic procedures, essential amino acids and lipids obtained by fermentation or other similar procedures more close to the organic principles should be considered.
Studies have indicated that not only the overall dietary amino acid profile is important for efficient utilization of amino acids, but also the timing by which amino acids from different protein sources appear in the blood stream after a meal. A significantly higher amount of indigestible carbohydrates have been measured in a diet based on vegetables than in a fish meal based diet, which suggested that the uptake of amino acids was affected by dietary carbohydrates. This issue also needs attention.
Procedures in compliance with organic rules for removal of anti-nutrients in plant sources.
Development of relevant organic plant sources to optimize the amino acid profile by mixing the protein sources and hence produce an optimum balanced diet for organic fish.

Fish oil replacement

Considering fish oil replacement, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

It is important to keep focus on human health related to eating (organic) aquaculture products, including high content of long chain omega-3 fatty acids (EPA and DHA) currently sourced from fish oil.
Adjust regulation on request of exchanging fish oil by vegetable oils in accordance to development of vegetable or other sources producing omega-3 fatty acids (HUFAs).
Priority research in alternative sources of Omega-3 fatty acids (HUFAs).
The use of cholesterol as raw material in the feed for supplementing the diet of shrimps is in line with the objectives and principles of organic production and should be allowed.

For preference, lecithin from organically certified sources, such as organic soybean, may be used following mechanical extraction. If unavailable, non-organic natural sources may be used provided they are of non-GMO origin.

Mineral and vitamin supply

Considering mineral and vitamin supply, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Fish meal and fish oil contain necessary vitamins and minerals.
Chemically well-defined analogic substances of minerals and vitamins may be authorised for use if the natural substances are unavailable.

Chapter 2: WELFARE, HEALTH, VETERINARY TREATMENTS AND BIOSECURITY

Husbandry – water quality

Considering water quality, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Water quality parameters are pivotal factors that contributes to fish welfare in aquaculture.
The range of different water quality parameters are species-specific, although the first limiting factor is often oxygen.
Fish and shellfish are poikilothermic animals, which means that temperature is the main factor playing on their metabolism and rapid temperature shifts do impact directly and indirectly their welfare.
The location of farms must ensure the water quality, and hydrodynamics ensure compliance with animal welfare.
The use of oxygen in intensive farming seems a much needed factor. The maximal density without oxygen without negative welfare effects is unknown for many species.

Husbandry - Light and photoperiod

Considering light and photoperiod, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Light represents an important environmental factor that could influence severely fish behaviour and physiology. Sudden changes in light intensity from the dark to the light phases of the dark/light cycle can induce behavioural stress responses.
There is evidence of photoperiod influence on changes in the immune system in sea bass, as well as in sea bream, while the welfare consequences of artificial photoperiod treatments in salmonids are not yet fully known.
On the other hand, photoperiod is actually considered as one of the most important environmental parameters triggering puberty and reproduction in fish.

Husbandry - Stocking density

Considering stocking density, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Rearing density encompasses a complex web of interacting factors, such as water quality, social interactions, fish to fish interaction and fish to housing interaction that can have an effect on many aspects of welfare. Depending on the type of rearing system and species, the recommendations range from 4 to more than 300 kg m^{-3}.
Such a wide range of recommendations is in part due to a lack of complete understanding of how the different environmental factors interact with each other and with stocking density to affect welfare. Another reason maybe that the effect of density measures on welfare may vary greatly between studies due to the study-specific nature of experiments, e.g. studies

vary in experimental duration, water quality, density levels used, feeding method, size of the fish, life history of the fish, level of domestication, type of rearing system used and environmental conditions.
It is worth to highlight that most of the experiments on the stocking density reported in literature are supported by the use of oxygen to adapt the water quality to the increased stocking density, which would be not in line with several principles/rules of the organic regulation (e.g. "… *organic production should be as close as possible to nature* …" Reg. EC 710/09, recital 11).
Concerning shellfish, carrying capacity of the production areas has to be evaluated to defined appropriate stocking density for their aquaculture.

Husbandry - Transport, handling and behavioural interactions

Considering transport, handling and behavioral interactions, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

The most important issue with transport of live fish is to maintain water quality during the transport. Private standards have set up recommendations.
Water can be cooled during transport to alleviate a fish's need for oxygen and to reduce ammonia production. Freedom Foods Welfare Standard for farmed salmon transport state i) the maximum chilling rate should be 1.5°C per hour, ii) the maximum permitted drop in temperature should be no more than 50% of ambient temperatures at the start of chilling within 24h, and iii) minimum temperatures at the end of chilling should be no less than 4°C.
Debio Organic Aquaculture Standard for farmed salmon transport and Freedom Foods Welfare Standard state "As a minimum the oxygen content in the water shall be at least 7 mg oxygen per litre."
Freedom Foods Welfare Standard for farmed salmon road transport suggest maximum stocking densities of 60-100 kg m^{-3}, whilst for salmon transported by well boat suggest maximum stocking densities of 40-50 kg m^{-3}.
Debio Organic Aquaculture Standards suggest: live fish can be transported for a maximum of 6 hours by truck. Without water exchange. Max density with transportation of fry is set at 10 kg m^{-3}. There can be at most 30 kg m^{-3} in closed well boat transportation. Well boat with constant water exchange can at most have a fish density of 50 kg m^{-3}.
Other possible suggestions could be derived by the pertinent scientific literature cited, such as to monitor CO_2 levels and behaviour, using isoeugenol or eugenol for sedation or using physical enrichment materials during transport.

For shellfish, as organic farms shall minimise risks to species of conservation interest, transfer of shellfish has to be controlled, to avoid the risk of alien, translocated species, or diseases introduction. Risk assessment methodologies could be applied to minimize the impact of transfers and to prevent the introduction of invasive species. An example of a practical plan for shellfish farmers including advice on hygiene, biosecurity and good husbandry practices is provided by.

Husbandry – Slaughter

Considering slaughter, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

When properly done, the most humane stunning methods is percussive and electric stunning. However, percussive stunning may lead to carcass damage, which poses an economical problem. Carcass damage can be avoided by lowering the air pressure in the percussive stunner. However, under the latter conditions it is doubtful that an fish are stunned immediately by percussion.
In case waiting cages are in use, monitoring water quality both with and without crowding should be done. Adding of oxygen when needed.
Pumping should be done with care. Moreover, pumps should be used that were constructed especially for live fish. Make sure to use the correct pump dimensions for the actual fish size and amount. Make sure that the equipment is regularly checked by service
Realistic alternative methods to the ice slurry for stunning and killing marine fish needs to be further investigated. Electrical stunning has to be followed by the application of killing method. However, experiments have shown that fish may recover. To prevent this, further studies are needed to develop protocols for stunning and killing that result in an immediate and irrecoverable stun in fish.

Veterinary treatment

Considering veterinary treatment, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Antibiotic use is an integral part of conventional intensive animal agriculture and aquaculture. Increased public concern about antibiotic resistance and the need to preserve the ever-diminishing arsenal of antimicrobials that work in humans for as long as possible, has brought about increased scrutiny of the use of antibiotics – especially for prophylactic and growth enhancing purposes. In accordance with European regulations and to limit the phenomenon of antibiotic resistance, studies are being implemented on the use of herbal or homeopathic medicine and probiotics, which are administered in addition to the feed.

In recent years increasing experimental evidence of probiotics and herbal medicine in aquaculture have come up, and the first results seem to confirm their effectiveness in the prevention and management of diseases affecting aquatic animals breeding.
The use of these substances is permitted in accordance with article 25(t) of Regulation 889/2008, but does not describe in what way and in what quantities are to be administered and they are authorized. It would be appropriate to make a list of such microorganisms and plants which can be used in the composition of the feed.

There are initial investigations and tests with regard to the preparation of vaccines derived from the study of genetic engineering, such as DNA vaccines (Regulation 2003/1829 article16), and proteins produced from GMOs. From the first studies we can see how it is possible to produce new solutions for disease prevention obtaining vaccines and immunostimulants low-cost and low environmental impact. It would be interesting to continue to do studies and tests in this direction, since the Regulation 834/2007 article 4 allows for the use of GMOs for Veterinary Medicinal Products.

Husbandry - Biosecurity

Considering biosecurity, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Good hygiene practices and farm management prevent the onset of diseases. Unfortunately, there is currently no European guidelines on biosecurity in animal husbandry, but there are at national level, in the various countries of the EU, for certain species. It would be appropriate in future years draft biosecurity measures recognized at Community level.

Chapter 3: PRODUCTION SYSTEMS

Breeding

Considering breeding, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

At present it is not clear if the breeding objectives and thus targeted traits are sufficiently different to warrant developing genetic material specifically for organic farmers. Traits like salmon lice and some disease resistance traits are most likely of higher importance for organic farmers, compared to conventional salmon farmers, since organic farmers have strict limitations to the use of chemical treatments.
Considering that for breeding purposes or for improving genetic stock and when organic aquaculture animals are not available, wild caught or non-organic aquaculture animals may be brought into a holding. Conventional broodstock can be used which has been selected based on specific traits. Indeed, some breeding companies offer genetic material, which has a high resistance to IPN, PD or salmon lice.

Hatchery and nursery

Considering hatchery and nursery, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

There are no official data on the number of certified organic hatcheries in Europe, except for some information on a few trout hatchery in Denmark that have recently converted or are in the process of conversion to organic production. Therefore, the present production of organic juveniles seems inadequate to supply the growing demand of the organic aquaculture industry certified according to the European regulation.
There is a lack of specific organic rules for managing the life cycle stage between the hatching and the weaning of juveniles. This lack of organic regulation concerns fresh water species (e.g. stocking density, feeding) and, even more, marine species (e.g. phytoplankton and zooplankton production, essential nutrients in the trophic chain, feeding, stocking density during larval rearing and weaning, husbandry environment).
Production rules for the phase of the life stage between hatching and weaning of juveniles would have a strong influence in determining the characteristics of the adult (e.g. skeletal and pigmentation anomalies, immune resistance, etc.).
For marine fish, there is evidence that juveniles produced with “mesocosm” or “large volume rearing” systems are more similar in behaviour and morphology to their wild counterparts.

Phyto-Zoo massive culture

Considering phyto-zoo massive culture, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

It appears difficult to find characteristics sufficiently different between organic and conventional phytoplankton productions, enough to justify the existence of organically

certified phytoplankton as a separate product. However, in view of the necessity to use phytoplankton in hatchery, its use could be authorized without requiring organic certification, with the sole exclusion of GMO strains of algae.
Unlike phytoplankton, there could be the technical possibility of an organic production of zooplankton, which would differ from conventional zooplankton in several aspects. Rules for organic production would need to be based on use of organic yeast, other microorganisms (e.g. *thraustrochytrids*), and only natural antioxidants, vitamins and emulsifiers. Unfortunately, at moment, there are no organic enrichment diets available and an evaluation whether their production would be commercially viable would be very useful to be explored.

Land based and cage systems

Considering land based and cage systems, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

A main aim for the revision is to strengthen and harmonize the rules of production and to raise confidence of the consumers to organic production. However, EU covers an extensive geographic area, which migth impose climatic related challenges for organic production systems in rural areas to fulfil the organic principles.
Another important challenge is, that the current regulation is not sufficiently specific and hence allows different interpretations in different countries, i.e. different conditions of control and anti-competitiveness between the countries. The opposite was the aim.

For ponds, the way the aquaculture is managed already has many quasi-organic principles and the shift to certified organic farming is not as demanding as it is for some other species. Many common circumstances, which belong among the requirements for organic carp pond farming, fully cope with conventional farming, such as stock density and fertilization limits. Conversion to carp pond organic culture is a process of developing farming practices that encourage and maintain a viable and sustainable aquatic ecosystem. Management techniques, especially when applied to influence production levels and growth rates must maintain and protect fish good health and welfare. Location of land based organic production units must maintain the health of aquatic environment and surrounding terrestrial ecosystems.
The future research activities should be focused on the environmental aspects of organic pond farming to bring and support the arguments about the eco-friendly way of pond production supporting biodiversity of pond ecosystems. Also the issues of regular and steady organic feed (cereals) supply are of extremely high relevance. The necessity of avoidance of hormonal preparations for induced carp and pond fish spawning is still questionable because pituitary glands, which are used for these purposes, may also be of organic origin, if necessary. However current legislation about organic farming principles does not allow this exception.

Recirculation Aquaculture Systems (RAS)

Considering RAS, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Most of traditional organic farms are open-air flow through systems. However, due to the limitations of water resources, national regulations in some countries require that farms are only allowed to take a limited amount of new water from the water courses. In such cases the re-use of water could be a solution in line with the principles of organic production.
Closed recirculation systems (RAS) have several environmental advantages, but require significant input of external energy, high stocking densities (for economic reasons), advanced waste water treatment devices, use of UV radiation and use of pure oxygen. All the above, together with the disconnection of the aquaculture production from the external natural aquatic environment, makes the closed recirculation systems (RAS) not in line with the principles of organic production.

Mussel and oyster culture

Considering mussel and oyster culture, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

According to the actual organic legislation, seed from non-organic bivalve shellfish hatcheries may be introduced to the organic production units with 0% by 31 December 2015. This could be extremely restrictive, both for oysters because organic hatcheries are still not really developped, and for mussel as well, because mussel seeds are collected from natural areas.
As defined by the ICES and FAO codes of conduct for responsible fisheries, oyster and mussel sustainable production is linked to the carrying capacity of the environment; shellfish excretion can impact local sediment and associated populations (both animal and macrophyts). Carrying capacity of the production areas has to be evaluated to defined appropriate stocking density for shellfish aquaculture.
As organic farms shall minimise risks to species of conservation interest, transfer of shellfish has to be better controled, to avoid the risk of alien, translocated species, or diseases introduction. Risk assessment methodologies could be applied to minimize the impact of transfers and to prevent the introduction of invasive species.

Seaweed culture

Considering seaweed culture, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Most seaweed is produced not for direct human use, there is not much attention for organic production of seaweeds. In general, seaweed production is seen as environmental friendly and sustainable. Therefore there is not much research to organic production of algae.
There is sufficient knowledge present on the use of seaweeds as biofilter, less information is present on the use as feed for aquaculture products, impact on the environment, biofuel and the use for human (food) products. Production of seaweed is considered to have only a low impact on the environment, so not much research is conducted on this.

There is not much scientific information on harvesting issues and on farm management. However, many articles in the regulation concern farm management issues (administration, production) and not directly linked to the production systems. Production is mainly linked with IMTA, together with abalone, where the seaweed is cultured in the system growing on nutrients from the abalones, and the macro algae on their turn serve as food source for the abalones.

IMTA

Considering IMTA, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

It is important to co-cultivate species that are ecologically compatible, requiring similar environmental conditions and do not compete for food and space in an aquaculture system. In addition, it is necessary to assess the oxygen demand of each component of the system. Heterotrophs may increase oxygen demand and decrease the oxygen budget of the fish culture. Respiration by autotrophs may also consume oxygen, although oxygen production during the day may compensate for night time consumption. Bio-deposition rates of each component of the system and the dispersal pattern of particulate and nutrients must be determined to evaluate the efficiency of an integrated system and when evaluating the environmental carrying capacity of a site.
It is unclear how to determine nutrients naturally occurring in the environment and nutrients coming from watershed.
There is a lack of information on co-culture between bivalves and organic fish or seaweed. In addition, there is a lack of information between possible disease/parasite positive and negative interactions between species composing the IMTA system.

Chapter 4: ENVIRONMENTAL IMPACTS

Energy use and LCA

Considering Energy use and LCA, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

A major problem at the moment is the lack of defined criteria and reference points for determining what an environmental sustainable food production is. Developing methodology for measuring environmental load without allocating environmental effects between products and co-products will benefit organic aquaculture productions such as salmon where trimmings from fisheries are used as a feed ingredient. The current regulations say that energy used in the production should preferably come from renewable energy sources. Most of the energy used for production of salmon is diesel oil used in growing and harvesting of feed ingredients. At the moment there is no alternative that can fully replace this energy source, but biodiesel may be an alternative in near future.

Escapes from cage culture

Considering escapes from cage culture, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

Species-specific distinctions could be made between escapes of fish and escapes of viable gametes. As the majority of juvenile and adult escape events within Europe are attributable to storm damage or the formation of holes in the net walls of cages, attention should be given to implement something similar to Norwegian technical standard NS 9415, which has led to a marked reduction in the severity of escapes from Norwegian cage aquaculture since 2004. NS 9415 governs "requirements for the physical design of the installation and the associated documentation. This includes calculation and design rules, as well as installation, operating and maintenance requirements. This standard could include (for each species/production system): robust regulation and appropriate technical standards for equipment, independent auditing of the implementation of these standards and guidelines for improved staff training,

It has been suggested that to better protect wild fish stocks from the potential detrimental consequences of aquaculture escapes, attention should be focused on preventing escapes. However, if an event were to occur, organic farmers and regulatory bodies must attempt to mediate against the impacts of the escapes by e.g. initiating a recapture and recovery program. A better understanding of the post-escape dispersal of escaped fish can improve recapture efficiency (as it can help focus and direct recapture efforts. For example, fish can disperse rapidly and widely after an escape event and can disperse >1 km from the farm in a few hours. This rapid migration is not always the case though; it depends on species, life-stage, locality, time of year, and in some cases fish can remain around the farm for weeks. However, a recovery program should be initiated as soon as an escape has been discovered to increase the likelihood of potential recapture.

The efficacy of recapture methods for i) Atlantic salmon, ii) Atlantic cod and iii) gilthead seabream shows some knowledge gaps;

For species that have the potential to spawn within the cages, such as Atlantic cod and gilthead seabream, the use of a curtain-like egg collector may be used to mitigate against the occurrence of an egg escape. An aquaculture site planning and locality policy could also be to limit the farming of large seabream that are viable spawners in areas near wild seabream nursery grounds. The risks of escapes through spawning from cage aquaculture is currently not well documented for all relevant European species. The potential efficacy of curtain-like egg collectors that can be used to mitigate against the occurrence of an egg escape has also not been tested at a commercial scale.

For escapes involving juvenile and adult fish, the majority of all recapture methods are only partially effective, and focus should be on prevention. However, organic farmers can diligently monitor their farms for escapes via a robust and rapid surveillance of the farm infrastructure and fish e.g. during and after extreme weather events or large-scale fish handling, as the first few hours may be crucial.

Species-specific escape mitigation and recapture plans should be drawn up for organic cage aquaculture.

Net biting behaviour in Atlantic cod and gilthead sea bream should be investigated further in commercial farm settings, with a particular focus on the efficacy of using environmental enrichment to reduce net biting frequency, which has not been well demonstrated at the commercial scale.

Current recapture methods may not be a robust tool for recapturing escaped fish, thus hindering the development of a robust species-specific recapture and escapee recovery program. They may also lead to a high bycatch of none-target species. More research is needed on how best to deploy existing recapture methods and practices and develop new ones.

Sea bottom, wild fish feeding and pond water quality

Considering sea bottom, wild fish feeding and pond water quality, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

The EC regulations regarding environmental impact and interactions in relation to the sea bottom are not very specific.

Norwegian rules for conventional farming state that the allowed biomass on a location is based on the recipient capacity to handle organic load. The farmers have to document the status of the sea bottom annually by undertaking third party NS 9410 inspections. Minimising the organic load from the farms include reducing feed waste and faecal material, there is little knowledge regarding the amount of lost feed but it has been assumed to be as high as 5%.

With regard to wild fish feeding there are no EC regulations that apply specifically. Attraction of wild fish to open cage farms is a global phenomenon, and more than 160 species belonging to about 60 families have been detected in the near vicinity of such farms.

Marine fish farms attract wild fish by providing uneaten fish feed, structural habitats and by attracting small prey species. The more ecological consequences of attracting wild fish, and wild fish feeding on waste feed may be regarded as environmental effects, at least in a wider definition; it is well known that farm aggregated species, will achieve different liver size, and different lipid content and fatty acid composition.The amount and composition of fatty acids also affect the quality of the offspring.

The negative impacts of pond aquaculture on the environment are highlighted in particular as:

-Modification of water temperature and flow rate profiles

-Increased concentration of suspended solids, BOD, COD, forms of N (including ammonia) and phosphorus.

-Reduced concentration of dissolved oxygen.

-Alteration of water quality due to the use of chemicals and antibiotics.

-Generation of organic-rich sediments.

-Occurrence of algal blooms in eutrophic waters.

-Modification of the biotic index (based on invertebrate communities) and of the index of biotic integrity (based on fish populations).

-Genetic pollution and escape of undesirable and invasive fishes.

-Increased risk of disease spread.

Recycling and waste

Considering recycling and waste, more elaborated scientific knowledge is needed for the following issues that can help the organic aquaculture production:

At present, knowledge and technology for a near complete recycling of nutrients from salmon farming is not developed. Altering the regulations is therefore not recommended. However, solutions for collection, de-watering and re-use of waste are presently being sought for in non-organic salmon farming. The technology is therefore expected to be improved during the next years and thus there may be a basis for reconsidering the regulations for organic salmon farming within near future.