

AN AQUACULTURE METHOD

FIELD OF INVENTION

The invention relates to a super-intensive aquaculture method for the growth and harvesting of two or more farmed organisms.

BACKGROUND

Aquaculture in developing countries is commonly performed in sea cages, ponds, and estuaries. The capacity of these systems is typically low and exposure to external environments puts the cultured organisms at risk of disease and predation. While advances in technology over the years have helped improve aquaculture production and disease management, there is still room for significant improvement. One strategy to mitigate the risk of disease and increase capacity is the use of a recirculating aquaculture system which is not exposed to the external environment.

As the intensity of aquaculture (i.e. the stocking density of farmed organisms) increases in a recirculating aquaculture system, the requirement for water exchange and filtration increases as oxygen must be replenished and waste must be removed from the system at a greater rate. However, both filtration and water exchange incur significant costs, resulting in reduced profitability. Therefore, it is desirable to minimise water exchange and filtration requirements in order to increase profitability. However, in current systems, reducing the demand for filtration generally requires using more clean water, which increases water exchange costs. Conversely, reducing the water exchange costs typically means that additional filtration will be required to purify the water within the system. As such, there is a need for a system in which both water exchange and filtration costs may be minimised.

A typical aquaculture system will comprise one farmed organism. That is, the system will be designed to grow a specific organism for harvest and sale. However, a system that allows the simultaneous farming of more than one organism may result in increased energy efficiency (i.e. an improved feed input:harvestable organism output ratio) and therefore improved profitability.

A system that is able to minimise water exchange and filtration, whilst culturing more than one farmed organism would result in a significant improvement in profitability and is highly desirable.

SUMMARY OF THE INVENTION

The invention solves the problems of the prior art discussed above. In the aquaculture method of the invention, the system comprises a first farmed organism and one or more additional farmed organisms that are generally of a lower trophic level than the primary farmed organism, such that the one or more additional farmed organisms consume at least part of a waste product produced by the primary farmed organism (or potentially other organisms within the system). The system used in the method may comprise several tanks of decreasing trophic levels in the downstream direction, such that at least part of the suspended solid waste leaving each tank is consumed by an organism located downstream. This results in a circular economy concept that utilizes biological processes to clean and purify the water circulating around the system, whilst also increasing the potential profitability of the system because commercially valuable organisms may be used to consume the suspended solid waste, and these commercially valuable organisms may also be periodically harvested. The use of biological processes to clean and purify the circulating water drastically reduce filtration and water exchange costs because the water reaching the end of the system has been substantially purified and only contains a small amount of organic and nitrogenous waste that requires removal before the water is circulated back to a tank comprising the primary farmed organism. In addition, the use of aquatic plants and/or phytoplankton can replenish oxygen levels in the water.

The invention therefore provides the following numbered clauses.

1. A super-intensive aquaculture method for the growth and harvesting of two or more farmed organisms, the method comprising the steps of:
 - (i) providing an aquaculture system comprising:
 - one or more farming vessels, at least one of the one or more farming vessels comprising water and a first farmed organism;
 - one or more waste reduction vessels, which comprise a first suspended solids reduction vessel comprising water and a second farmed organism that consumes at least part of a suspended solid waste generated by the first farmed organism; and
 - a pumping system suitable for transporting water in the one or more waste reduction vessels to the one or more farming vessels;
 - (ii) feeding the first farmed organism periodically;
 - (iii) periodically providing a volumetric portion of water in at least one of the one or more farming vessels and replacing it with an equal volumetric portion of water from the

one or more waste reduction vessels *via* the pumping system, where the portion of water removed from the at least one of the one or more farming vessels is received by the first suspended solids reduction vessel;

(iv) repeating steps (ii) and (iii) until at least one farmed organism is ready for harvest;

(v) harvesting and replacing the at least one farmed organism ready for harvest;
and

(vi) repeating steps (ii) to (v).

2. The method according to Clause 1, wherein the one or more waste reduction vessels further comprises a second suspended solids reduction vessel comprising water and a third farmed organism that consumes at least part of a suspended solid waste generated by the first and/or second farmed organisms, where the second suspended solids reduction vessel is downstream from the first suspended solids reduction vessel, such that it receives water from the first suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels.

3. The method according to Clause 1 or Clause 2, wherein the one or more waste reduction vessels further comprises a soluble waste reduction vessel comprising water and a fourth farmed organism that consumes soluble waste generated by one or more of the first to third farmed organisms.

4. The method according to Clause 3, wherein:

(a) when dependent upon Clause 1 or 2, the soluble waste reduction vessel is downstream from the first suspended solids reduction vessel, such that it receives water from the first suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels; or

(b) when dependent upon Clause 2, the soluble waste reduction vessel is downstream from the second suspended solids reduction vessel, such that it receives water from the second suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels.

5. The method according to any one of the preceding clauses, wherein the second farmed organism consumes suspended solids having a particle size of from about 200 μm to about 500 μm .

6. The method according to any one of Clauses 2 to 5, wherein the third farmed organism consumes suspended solids having a particle size of less than about 100 μm .
7. The method according to any one of the preceding clauses, wherein the one or more farming vessels are located at an elevated position with respect to at least one of the one or more waste reduction vessels.
8. The method according to any one of the preceding clauses, wherein the aquaculture system comprises one or more valves that control the flow of water from each of the one or more farming vessels to the one or more waste reduction vessels.
9. The method according to any one of the preceding clauses, wherein:
 - (a) the one or more farming vessels are provided within a greenhouse; or
 - (b) the one or more farming vessels and the one or more waste reduction vessels are provided in a greenhouse; or
 - (c) the aquaculture system is provided within a greenhouse.
10. The method according to any one of the preceding clauses, wherein the first farmed organism is selected from one or more of the group consisting of fish and aquatic invertebrates
11. The method according to Clause 10, wherein the fish is selected from one or more of the group consisting of Tilapia, Milkfish, Grouper, Carp, Snakehead, Catla, Mullet, Rohu, Seabass, Seabream, Snapper, Perch, Pompano, and Rabbit fish.
12. The method according to Clause 10 or Clause 11, wherein the aquatic invertebrate is selected from one or more of the group consisting of Sea cucumbers, crustaceans and molluscs.
13. The method according to Clause 12, wherein:
 - (a) the crustacean is selected from one or more of the group consisting of Shrimp, Prawn, Crab, Lobster, and Crayfish; and/or
 - (b) the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.
14. The method according to any one of the preceding clauses, wherein the first farmed organism comprises Shrimp and/or Prawn.

15. The method according to any one of the preceding clauses, wherein the second farmed organism is selected from one or more of the group consisting of fish and aquatic invertebrates.

16. The method according to Clause 15, wherein the second farmed organism comprises a fish.

17. The method according to Clause 15, wherein the aquatic invertebrate is selected from one or more of the group consisting of Sea cucumbers, and molluscs, optionally wherein the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

18. The method according to any one of the preceding clauses, wherein the second farmed organism comprises Tilapia.

19. The method according to Clause 2 or any one of Clauses 3 to 18 as dependent upon Clause 2, wherein the third farmed organism comprises one or more aquatic invertebrates.

20. The method according to Clause 19, wherein the one or more aquatic invertebrates are selected from one or more of the group consisting of Sea cucumbers, and molluscs, optionally wherein the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

21. The method according to any one of the preceding clauses, wherein the third farmed organism comprises one or more molluscs, optionally wherein the one or more molluscs comprises one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

22. The method according Clause 3, or according to any one Clauses 4 to 21 as dependent on Clause 3, wherein the fourth farmed organism is one or more aquatic plants, optionally wherein the one or more aquatic plants comprise one or more seaweeds (e.g. such as one or more seaweeds selected from the group consisting of Kelp, Kombu, Wakame, Sea grape, Nori, Dulse, Carrageen Moss, Arame, and Hijiki).

22. The method according Clause 3, or according to any one Clauses 4 to 22 as dependent on Clause 3, wherein the first farmed organism is shrimp and/or prawns, the

second farmed organism is Tilapia, the third farmed organism is clams and the fourth farmed organism is one or more seaweeds.

23. The method according to any one of the preceding clauses, wherein the aquaculture system further comprises one or more filters, optionally wherein the one or more filters are selected from the group consisting of mechanical filters (e.g. sand filters) and protein skimmers.

24. The method according to any one of the preceding clauses, wherein the method is a zero-water exchange method.

25. The method according to any one of the preceding clauses, wherein at least one of the one or more farming vessels further comprises a plankton colony, and a bacteria colony.

26. The method according to Clause 25, wherein the plankton comprises one or more phytoplankton and one or more zooplankton.

27. The method according to Clause 26, wherein the one or more zooplankton comprise one or more copepods and/or one or more rotifers.

28. The method according to any one of Clauses 25 to 27, wherein the bacteria comprises one or more autotrophic bacteria and/or one or more heterotrophic bacteria, optionally wherein:

- (a) the heterotrophic bacteria comprise *Bacillus* spp. and/or *Lactobacillus* spp; and/or
- (b) the autotrophic bacteria comprise *Nitrosomonas* spp. and/or *Nitrobacter* spp.

29. The method according to any one of Clauses 25 to 28, wherein:

(aa) the ratio of plankton:bacteria in one of the one or more farming vessels is greater than 1 when a first farmed organism is introduced to the farming vessel; and

(ab) the ratio of plankton:bacteria in the one of the one or more farming vessels in (aa) reduces as the method proceeds through steps (ii) to (iv) until the at least one first farmed organism in said one of the one or more farming vessels is harvested.

30. The method according to any one of the preceding clauses, wherein after step (iv) the density of the at least one farmed organism in at least one of the one or more farming vessels is:

- (a) from 40 to 140 kg/m³, where the one farmed organism in at least one of the one or more farming vessels comprises a fish; or
- (b) from 20 to 25 kg/m², one farmed organism in at least one of the one or more farming vessels comprises Shrimp and/or Prawn.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a schematic of an exemplary recirculating aquaculture system useful in the method of the invention.

Figure 2 shows a schematic of another exemplary recirculating aquaculture system useful in the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In embodiments herein, the word “comprising” may be interpreted as requiring the features mentioned, but not limiting the presence of other features. Alternatively, the word “comprising” may also relate to the situation where only the components/features listed are intended to be present (e.g. the word “comprising” may be replaced by the phrases “consists of” or “consists essentially of”). It is explicitly contemplated that both the broader and narrower interpretations can be applied to all aspects and embodiments of the present invention. In other words, the word “comprising” and synonyms thereof may be replaced by the phrase “consisting of” or the phrase “consists essentially of” or synonyms thereof and *vice versa*.

In embodiments herein, various features may be described in the singular or the plural. It is herein explicitly contemplated that references to the singular are to be understood as including the plural, and references to the plural are to be understood as including the singular, unless such an interpretation would be technically illogical.

Thus, there is disclosed a super-intensive aquaculture method that comprises the steps of:

- (i) providing an aquaculture system comprising:
 - one or more farming vessels, at least one of the one or more farming vessels comprising water and a first farmed organism;
 - one or more waste reduction vessels, which comprise a first suspended solids reduction vessel comprising water and a second farmed organism that consumes at least part of a suspended solid waste generated by the first farmed organism; and

a pumping system suitable for transporting water in the one or more waste reduction vessels to the one or more farming vessels;

- (ii) feeding the first farmed organism periodically;
 - (iii) periodically providing a volumetric portion of water in at least one of the one or more farming vessels and replacing it with an equal volumetric portion of water from the one or more waste reduction vessels *via* the pumping system, where the portion of water removed from the at least one of the one or more farming vessels is received by the first suspended solids reduction vessel;
 - (iv) repeating steps (ii) and (iii) until at least one farmed organism is ready for harvest;
 - (v) harvesting and replacing the at least one farmed organism ready for harvest;
- and
- (vi) repeating steps (ii) to (v).

The method of the invention is a super-intensive aquaculture method. As used herein, a super-intensive aquaculture method is a method that is able to culture shrimp or prawns to a harvest density of 20 to 25 kg/m² and/or fish to a harvest density of 40 to 140 kg/m³.

The one or more farming vessels comprise water and a first farmed organism. The first farmed organism is typically the highest tropic level organism in the system, and is generally also the most profitable or highest value organism in the system.

The system comprises one or more waste reduction vessels, which comprise a first suspended solids reduction vessel comprising water and a second farmed organism, which may be downstream from the first farmed organism. The waste reduction vessels are designed to remove waste from the system whilst also culturing additional organisms that may be sold to increase profitability of the system. The waste reduction vessels comprise at least a first suspended solids reduction vessel comprising water and a second farmed organism. The second farmed organism is selected to consume at least part of a suspended solid waste produced by the first farmed organism, which means that the second farmed organism may not require direct feeding as they can feed on the faecal organic waste present in the effluent from the first farm organisms as well as the biological flocs and bacteria present in the water. This minimises the additional cost involved in growing the second farmed organism.

As used herein, suspended solid waste refers to waste (e.g. excrement, moulted exoskeleton) and dead organic matter (e.g. dead shrimps, plankton) present in the water of the system.

As used herein, when a vessel (e.g. B) is “downstream” from another vessel (e.g. A), this means that during the course of normal water flow around the system, the water will flow into vessel A before flowing into vessel B. As used herein and in this context, “downstream” does not require that the vessels (e.g. A and B) are adjacent to or in direct contact to each another. Thus, a situation where a vessel B (e.g. the soluble waste reduction vessel) is described as “downstream” from a vessel A (e.g. first suspended solids reduction vessel) encompasses at least the following situations:

- (i) where water flows from vessel A directly to vessel B;
- (ii) where water flows from vessel A to a third vessel C (e.g. the second suspended solids reduction vessel), and then to vessel B;
- (iii) where water flows from vessel A to a vessel C (e.g. the second suspended solids reduction vessel), before flowing back to vessel A and then to vessel B; and
- (iv) where “vessel C” in situations (ii) and (iii) comprises more than one vessel, e.g. two vessels D and E.

In the above situations, water flow may be controlled by a series of valves and/or pumps. Thus, while a skilled person will understand that the vessels A, B and C are fluidly connected to each other, water flow to and from specific vessels may be controlled using one or more valves, and in some cases, one or more pumps. For example, in situation (iii), water flow from vessel A to vessel C without flow to vessel B may be controlled by closing a valve present between vessels A and B, such that the only route for water to leave vessel A is to flow into vessel C. A valve between vessels A and C may then be closed to contain water within vessel C. When it is desired for water to flow from vessel C back into vessel A, the valve between vessels A and C may be opened. Once water has flowed into vessel A, a valve between vessels A and C may then be closed, while a valve between vessels A and B may be opened to allow water to flow into vessel B. Water flow around the system may be driven by gravity and/or one or more pumps, and the necessary configurations will be clear to a person skilled in the art. By way of example, in situation (iii) water flow from vessel A to C and then back to A cannot purely be driven by gravity, and so a skilled person will understand that the use of one or more pumps may be advantageous in order to provide fast and efficient water flow. This may provide more efficient flow than having vessels A and C at the same level and allowing water to mix between the tanks.

The system comprises a pumping system that is able to transport water around the system and recirculate cleaned/purified water from the one or more waste reduction vessels back to the one or more farming vessels. As described in more detail below, the system may be one in which the farming vessel(s) are relatively higher than the waste reduction vessels, which may allow flow of water by gravity from the farming vessel to the waste reduction vessels.

During the aquaculture process, the first farmed organisms will be fed periodically. The nature of the feed will depend on the specific first farmed organism, and suitable feeds for any given first farmed organism will be well known to a person skilled in the art.

Periodically, a volumetric portion of water in at least one of the one or more farming vessels is removed and passed to the first suspended solids reduction vessel, and replaced in the one or more farming vessels by an equal volumetric portion of water supplied from the one or more waste reduction vessels *via* the pumping system.

These steps may be repeated until one of the farmed organisms is ready for harvest, at which time said farmed organism will be harvested and replaced. It will be appreciated that the different farmed organisms in the system may become ready for harvest at different times.

It will be appreciated that the use of only a single waste reduction vessel (i.e. only a first suspended solids reduction vessel) will remove suspended solid waste from the system, reducing the filtration and water exchange requirements. However, the use of multiple waste reduction vessels (i.e. multiple suspended solids reduction vessels) may allow for greater waste removal and for additional farmed organisms to be cultured.

Thus, the one or more waste reduction vessels may comprise a second suspended solids reduction vessel comprising water and a third farmed organism that consumes at least part of a suspended solid waste generated by the first and/or second farmed organisms. The second suspended solids reduction vessel may be downstream from the first suspended solids reduction vessel, such that it receives water from the first suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels. In other words, a first suspended solids reduction vessel may comprise a second farmed organism that consumes suspended solid waste, and a second suspended solids reduction vessel may be located downstream from the first suspended solids reduction vessel and comprise a third farmed organism that also

consumes suspended solid waste. In some embodiments of the invention, the second farmed organism may consume suspended solid waste particles that are larger than those consumed by the third farmed organism. In this way, the third farmed organism may consume suspended solid waste that is not consumed by the second farmed organism, and may also consume waste produced by the second farmed organism. This results in improved purification and cleaning of the water in the system.

In some embodiments of the invention, the second farmed organism may consume suspended solids having a particle size of from about 200 μm to about 500 μm . In some embodiments of the invention, the third farmed organism may consume suspended solids having a particle size of less than about 100 μm . As will be appreciated by a person skilled in the art, the second and third farmed organisms may also consume suspended solids having particle sizes outside of these ranges, and there may be overlap of particle sizes consumed by the second and third farmed organism. The invention is based on the concept that different species may be used to consume a large proportion of the waste produced by the various farmed organisms.

The suspended solids in the system that are removed in the one or more suspended solids reduction vessels are generally insoluble organic waste. In contrast, nitrogenous and phosphoric waste is generally soluble in the water within the system. As such, the waste reduction in the method of the invention may be further enhanced by use of a soluble waste reduction vessel that removes soluble waste from the system.

Thus, the one or more waste reduction vessels may comprise a soluble waste reduction vessel comprising water and a fourth farmed organism that consumes soluble waste generated by one or more of the first to third (where present) farmed organisms. Typically the soluble waste reduction vessel will be the most downstream of the one or more waste reduction vessels, for example:

- (a) when the one or more waste reduction vessels comprise only a first suspended solids reduction vessel, the soluble waste reduction vessel is downstream from the first suspended solids reduction vessel, such that it receives water from the first suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels;
- or
- (b) when the one or more waste reduction vessels comprise a first and second suspended solids reduction vessel, the soluble waste reduction vessel is downstream from the second suspended solids reduction vessel, such that it receives water from

the second suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels.

As will be appreciated by a person skilled in the art, the second and third farmed organisms may also consume soluble waste, and the fourth farmed organism may also consume suspended solid waste.

In order to assist with water flow around the system, the one or more farming vessels may be located at an elevated position with respect to at least one of the one or more waste reduction vessels. This allows for water flow through the system to be driven by gravity, while return of water from the waste reduction vessels to the farming vessels may be *via* the pumping system. Alternatively, water flow around the system may be powered entirely by the pumping system. The system may also comprise one or more valves that control the flow of water from each of the one or more farming vessels to the one or more waste reduction vessels. This ensures that the water flow may be controlled by an operator and maintained at a desired level.

The entire system, or certain components within the system, may be housed within a greenhouse. For example, the one or more farming vessels may be provided within a greenhouse; or the one or more farming vessels and the one or more waste reduction vessels may be provided in a greenhouse; or the aquaculture system may be provided within a greenhouse. This may be advantageous to control the temperature of the water within the system and prevent or reduce fluctuations caused by the environment.

As will be appreciated by a person skilled in the art, many different species may be used within the system as one of the various farmed organisms. Exemplary species for each farmed organism are discussed below.

The first farmed organism may be selected from one or more of the group consisting of fish and aquatic invertebrates.

When the first farmed organism comprises a fish, the first may be selected from the group consisting of Tilapia, Milkfish, Grouper, Carp, Snakehead, Catla, Mullet, Rohu, Seabass, Seabream, Snapper, Perch, Pompano, and Rabbit fish.

When the first farmed organism comprises an aquatic invertebrate, the aquatic invertebrate may be selected from one or more of the group consisting of Sea cucumbers, crustaceans and molluscs. Suitable crustaceans include one or more of the group consisting of Shrimp, Prawn, Crab, Lobster, and Crayfish. Suitable molluscs include one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

In some particular embodiments of the invention, the first farmed organism may comprise Shrimp and/or Prawn.

The second farmed organism may be selected from one or more of the group consisting of fish and aquatic invertebrates.

The second farmed organism may comprise a fish. Suitable fish include Tilapia.

The second farmed organism may comprise an aquatic invertebrate, which may be selected from one or more of the group consisting of Sea cucumbers and molluscs. Suitable molluscs include one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

The third farmed organism may comprise one or more aquatic invertebrates. The one or more aquatic invertebrates may be selected from one or more of the group consisting of Sea cucumbers and molluscs. In some embodiments of the invention, the third farmed organism comprises one or more molluscs. Suitable molluscs include one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

In some embodiments of the invention, each of the first, second and third farmed organisms are different species.

The fourth farmed organism may be one or more aquatic plants. The one or more aquatic plants may comprise one or more seaweeds, such as one or more seaweeds selected from the group consisting of Kelp, Kombu, Wakame, Sea grape, Nori, Dulse, Carrageen Moss, Arame, and Hijiki.

In particular embodiments of the invention, the the first farmed organism may be Shrimp and/or Prawn, the second farmed organism may be Tilapia, the third farmed organism may be Clam and the fourth farmed organism may be one or more seaweeds.

As will be appreciated by a person skilled in the art, the specific examples of first to fourth farmed organisms listed above are non-limiting examples, and the method of the invention may readily be implemented using other farmed organisms.

The system may comprise one or more filters. The one or more filters may comprise one or more mechanical filters (such as sand filters) and one or more protein skimmers. When one or more filters are present they are typically located after the one or more waste reduction vessels, so that they can remove any remaining waste that was not removed in the one or more waste reduction vessels, before the water is circulated back to the one or more farming vessels.

The method of the invention may be a zero-water exchange method, i.e. there may be no requirement to exchange water with the environment. This may be achieved by removing waste from the system and ensuring sufficient oxygenation to the water by use of various waste reduction vessels as described herein. A skilled person will appreciate that even in a zero-water exchange system, water may be added to the system to counteract evaporation. Such water may be provided by a municipal water supply so as to avoid introducing contaminants or pathogens to the system.

At least one of the one or more farming vessels and one or more waste reduction vessels may comprise a plankton colony and/or a bacteria colony. In some embodiments, at least one of the one or more farming vessels further comprises a plankton colony and a bacteria colony. The plankton colony may comprise one or more phytoplankton and one or more zooplankton. The one or more zooplankton may comprise one or more copepods and/or one or more rotifiers. The bacteria colony may comprise one or more autotrophic bacteria and/or one or more heterotrophic bacteria. The heterotrophic bacteria may comprise *Bacillus spp.* and/or *Lactobacillus spp.* The autotrophic bacteria may comprise *Nitrosomonas* and/or *Nitrobacter spp.*

When plankton and bacteria are added to the one or more farming vessels as described above, typically:

- (aa) the ratio of plankton:bacteria in one of the one or more farming vessels is greater than 1 when a first farmed organism is introduced to the farming vessel; and
- (ab) the ratio of plankton:bacteria in the one of the one or more farming vessels in (aa) reduces as the method proceeds through steps (ii) to (iv) until the at least one first farmed organism in said one of the one or more farming vessels is harvested.

The ratios of plankton:bacteria may be in the one or more farming vessels may be manipulated by adding nutrients during predetermined periods as described in PCT patent publication no. WO 2013/191642, which is incorporated herein by reference. For example, the method may comprise the following additional steps that may be performed as the method proceeds through steps (ii) to (iv) until the at least one first farmed organism in said one of the one or more farming vessels is harvested:

(1) providing at least one phytoplankton nutrient and at least one bacteria nutrient to one of the one or more farming vessels during a first predetermined period, allowing phytoplankton and bacteria to grow in a first predetermined phytoplankton:bacteria ratio of more than 1;

(2) providing at least one phytoplankton nutrient and at least one bacteria nutrient to said one of the one or more farming vessels during a second predetermined period, allowing phytoplankton and bacteria to grow in a second predetermined phytoplankton:bacteria ratio, wherein the second predetermined phytoplankton:bacteria ratio is lower than the first predetermined phytoplankton:bacteria ratio; and

(3) providing at least one phytoplankton nutrient and at least one bacteria nutrient to said one of the one or more farming vessels during a third predetermined period, allowing phytoplankton and bacteria to grow in a third predetermined phytoplankton:bacteria ratio, wherein the third predetermined phytoplankton:bacteria ratio is lower than the second predetermined phytoplankton:bacteria ratio.

In this case, the first predetermined phytoplankton:bacteria ratio may be at least about 60:40 (such as at least about 72:25, or at least about 90:10); and/or the second predetermined phytoplankton:bacteria ratio may be between about 75:25 to about 25:75 (such as between about 60:40 to about 40:60); and/or the third predetermined phytoplankton:bacteria ratio may be less than about 40:60.

The at least one phytoplankton nutrient and at least one bacteria nutrient may be provided during the first, second and third predetermined periods at respective concentrations suitable to grow phytoplankton and bacteria in the first, second and third predetermined phytoplankton:bacteria ratios.

The method of the invention may comprise adding bacteria to one or more of the one or more farming vessels, wherein the added bacteria is capable of maintaining the concentration of ammonia and/or nitrites and/or nitrates in said farming vessel(s) at a level that is not toxic to the at least one farmed organism and/or wherein the bacteria is not toxic or pathogenic to the at least one farmed organism in said farming vessel(s).

As described herein, the method of the invention is a super-intensive aquaculture method. As such, after step (iv) the density of the at least one farmed organism in at least one of the one or more farming vessels (i.e. the harvest density) is typically:

- (a) from 40 to 140 kg/m³, where the one farmed organism in at least one of the one or more farming vessels comprises a fish; or
- (b) from 20 to 25 kg/m², one farmed organism in at least one of the one or more farming vessels comprises Shrimp and/or Prawn.

The invention is described in more detail below with reference to the Figure.

Figures 1 and 2 show schematic views of an exemplary system useful in the invention.

Figure 1 depicts a system in which one or more farming vessels 101 contain the first farmed organism. Water may flow from the one or more farming vessels 101 to the one or more waste reduction vessels 102 and 103, which may comprise one or more suspended solids reduction vessels 102, and one or more soluble waste reduction vessels 103 located downstream from the suspended solids reduction vessels 102. The system is completed by a pumping system 104 that pumps water from the one or more waste reduction vessels 102 and 103 to the one or more farming vessels 101. As described herein, the pumping system may also comprise one or more filters such as mechanical filters, biological filters and/or protein skimmers.

In a particular embodiment the farming vessels may have an area of about 50x6 metres. In the same, or different, embodiments, the suspended solids reduction vessels may have a volume of about 10x10x3.5 metres. In the same, or different, embodiments, the soluble waste reduction vessels may have a volume of about 10x10x1 metres.

Figure 2 depicts a system in which one or more farming vessels 101 contain the first farmed organism. Water may flow from the one or more farming vessels 101 to the one or more waste reduction vessels 102, which may comprise one or more suspended solids reduction vessels 102. Water will then flow to vessel 103, which may comprise one or more soluble waste reduction vessels 103 located and return to vessel 102. The system is completed by a pumping system 104 that pumps water from the one or more waste reduction vessels 102 and 103 to the one or more farming vessels 101. As described herein, the pumping system may also comprise one or more filters such as mechanical filters, biological filters and/or protein skimmers.

In an exemplary embodiment the system comprises one or more farming vessels 101 comprising shrimp or prawn, the one or more waste reduction vessels 102 and 103 comprise a first suspended solids reduction vessel comprising tilapia, a second suspended solids reduction vessel comprising clam (where the first and second suspended solids reduction vessels are represented by 102), and a first soluble waste reduction vessel 103 comprising one or more seaweeds.

CLAIMS

1. A super-intensive aquaculture method for the growth and harvesting of two or more farmed organisms, the method comprising the steps of:

(i) providing an aquaculture system comprising:

one or more farming vessels, at least one of the one or more farming vessels comprising water and a first farmed organism;

one or more waste reduction vessels, which comprise:

(a) a first suspended solids reduction vessel comprising water and a second farmed organism that consumes at least part of a suspended solid waste generated by the first farmed organism;

(b) a second suspended solids reduction vessel comprising water and a third farmed organism that consumes at least part of a suspended solid waste generated by the first and/or second farmed organisms;;
and

(c) a soluble waste reduction vessel comprising water and a fourth farmed organism that consumes soluble waste generated by one or more of the first to third farmed organisms; and

a pumping system suitable for transporting water in the one or more waste reduction vessels to the one or more farming vessels;

(ii) feeding the first farmed organism periodically;

(iii) periodically providing a volumetric portion of water in at least one of the one or more farming vessels and replacing it with an equal volumetric portion of water from the one or more waste reduction vessels *via* the pumping system, where the portion of water removed from the at least one of the one or more farming vessels is received by the first suspended solids reduction vessel;

(iv) repeating steps (ii) and (iii) until at least one farmed organism is ready for harvest;

(v) harvesting and replacing the at least one farmed organism ready for harvest;
and

(vi) repeating steps (ii) to (v),

wherein:

the second suspended solids reduction vessel is downstream from the first suspended solids reduction vessel, such that it receives water from the first suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels;

the soluble waste reduction vessel is downstream from the second suspended solids reduction vessel, such that it receives water from the second suspended solids reduction vessel when water from the one or more waste reduction vessels is provided to the at least one of the one or more farming vessels;

the first farmed organism is selected from one or more of the group consisting of fish and aquatic invertebrates;

the second farmed organism is selected from one or more of the group consisting of fish and aquatic invertebrates;

the third farmed organism comprises one or more aquatic invertebrates; and

the fourth farmed organism comprises one or more aquatic plants.

2. The method according to Claim 1, wherein:

(a) the second farmed organism consumes suspended solids having a particle size of from about 200 μm to about 500 μm .

3. The method according to Claim 1 or 2, wherein the third farmed organism consumes suspended solids having a particle size of less than about 100 μm .

4. The method according to any one of the preceding claims, wherein the one or more farming vessels are located at an elevated position with respect to at least one of the one or more waste reduction vessels.

5. The method according to any one of the preceding claims, wherein the aquaculture system comprises one or more valves that control the flow of water from each of the one or more farming vessels to the one or more waste reduction vessels.

6. The method according to any one of the preceding claims, wherein:

(a) the one or more farming vessels are provided within a greenhouse; or

(b) the one or more farming vessels and the one or more waste reduction vessels are provided in a greenhouse; or

(c) the aquaculture system is provided within a greenhouse.

7. The method according to any one of the preceding claims, wherein the first farmed organism comprises a fish selected from one or more of the group consisting of Tilapia, Milkfish, Grouper, Carp, Snakehead, Catla, Mullet, Rohu, Seabass, Seabream, Snapper, Perch, Pompano, and Rabbit fish.

8. The method according to any one of the preceding claims, wherein the first farmed organism comprises an aquatic invertebrate selected from one or more of the group consisting of Sea cucumbers, crustaceans and molluscs;

optionally wherein in part (ii):

(a) the crustacean is selected from one or more of the group consisting of Shrimp, Prawn, Crab, Lobster, and Crayfish; and/or

(b) the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

9. The method according to any one of the preceding claims, wherein the first farmed organism comprises Shrimp and/or Prawn.

10. The method according to any one of the preceding claims, wherein the second farmed organism comprises a fish, for example Tilapia.

11. The method according to any one of Claims 1 to 9, wherein the second farmed organism comprises an aquatic invertebrate selected from one or more of the group consisting of Sea cucumbers, and molluscs,

optionally wherein the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

12. The method according to any one of the preceding claims, wherein the third farmed organism comprises one or more aquatic invertebrates selected from one or more of the group consisting of Sea cucumbers, and molluscs,

optionally wherein the mollusc is selected from one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

13. The method according to any one of the preceding claims, wherein the third farmed organism comprises one or more molluscs,

optionally wherein the one or more molluscs comprises one or more of the group consisting of Oyster, Clam, Mussel, Scallop, Carpet shell, and Abalone.

14. The method according to any one of the preceding claims, wherein the fourth farmed organism comprises one or more seaweeds (e.g. such as one or more seaweeds selected from the group consisting of Kelp, Kombu, Wakame, Sea grape, Nori, Dulse, Carrageen Moss, Arame, and Hijiki).

15. The method according to any one of the preceding claims, wherein the first farmed organism is shrimp and/or prawns, the second farmed organism is Tilapia, the third farmed organism is clams and the fourth farmed organism is one or more seaweeds.

16. The method according to any one of the preceding claims, wherein the aquaculture system further comprises one or more filters, optionally wherein the one or more filters are selected from the group consisting of mechanical filters (e.g. sand filters) and protein skimmers.

17. The method according to any one of the preceding claims, wherein the method is a zero-water exchange method.

18. The method according to any one of the preceding claims, wherein at least one of the one or more farming vessels further comprises a plankton colony, and a bacteria colony; optionally wherein:

(i) the plankton comprises one or more phytoplankton and one or more zooplankton, for example wherein the one or more zooplankton comprise one or more copepods and/or one or more rotifers; and/or

(ii) the bacteria comprises one or more autotrophic bacteria and/or one or more heterotrophic bacteria, for example wherein:

(a) the heterotrophic bacteria comprise *Bacillus spp.* and/or *Lactobacillus spp.*; and/or

(b) the autotrophic bacteria comprise *Nitrosomonas* and/or *Nitrobacter spp.*

19. The method according to Claim 18, wherein:

(aa) the ratio of plankton:bacteria in one of the one or more farming vessels is greater than 1 when a first farmed organism is introduced to the farming vessel; and

(ab) the ratio of plankton:bacteria in the one of the one or more farming vessels in (aa) reduces as the method proceeds through steps (ii) to (iv) until the at least one first farmed organism in said one of the one or more farming vessels is harvested.

20. The method according to any one of the preceding claims, wherein after step (iv) the density of the at least one farmed organism in at least one of the one or more farming vessels is:

(a) from 40 to 140 kg/m³, where the one farmed organism in at least one of the one or more farming vessels comprises a fish; or

(b) from 20 to 25 kg/m², one farmed organism in at least one of the one or more farming vessels comprises Shrimp and/or Prawn.