

Floating solar-powered multi-unit fish cage

The present invention is directed to a floating solar-powered multi-unit fish cage, comprising a floating planar grid defining at least two grid interspaces, at least one or more solar units, and at least one or more fish cages, wherein at least one fish cage is allocated to at least one grid interspace, at least one solar unit is allocated to at least one grid interspace, at least partially or completely covering said grid interspace, thus forming a solar unit-covered grid interspace, at least one solar unit-covered grid interspace partially spans at least one fish cage forming a partially covered fish cage and which partially covered fish cage allows for caged fish to voluntarily position under the at least one at least partially solar unit-covered grid interspace, and wherein the at least one solar unit-covered grid interspace (6) provides any of electric energy, protection of fish from direct solar radiation, predator protection for fish, for example, from fish-predatory birds, and optionally heat to the water in fish cage (5), or any combination thereof. Furthermore, the invention provides for a method of raising fish using said floating solar-powered multi-unit fish cage (1).

With increased demand for fish and fish protein coinciding with overfishing the oceans and continental fresh water reserves, fish farming or pisciculture is expanding rapidly. Fish are hatched, fed and raised in tanks and ponds (aquaculture) or ashore (mariculture). The most important cultured fish species produced in fish farming are carp, tilapia, salmon, trout and catfish, but also shrimp, lobsters and eatable aquatic plants such as seaweed and algae enjoy increased popularity. All are part of the current invention and will be generically by called "fish" in this document.

Most commonly, fish cages are placed in lakes, bayous, ponds, rivers or oceans to contain and protect fish until harvest. When placed in the sea the method is called "off-shore cultivation". One problem with permanently located fish cages is the bio-pollution from the unfed food and the feces of the caged fish, that is most intense on the ground below. Where necessary fish farmers rely on water exchange and water treatment, which requires energy for pumps. At present, diesel and electricity costs are significant for the aquaculture industry. Already governments are tightening the regulations. By 2021 diesel will be banned from Norwegian off shore fish farms.

Where shore-based electricity is not available, solar energy produced on-site is a "green" option. However, solar energy requires a lot of space, in particular, if strong pumps need to be

operated for longer time periods. Already today, there are large floating planar islands, so called solar islands, that provide solar energy and are linked via cable to shore-installed power stations.

Furthermore, it is known by fish culture experts that water temperature and fish comfort have a strong influence on weight gain and time to harvest. For example, fish growing in fish farms near nuclear power plants that give off excess heat to rivers in the winter grow significantly faster than the fish further up the river in the colder water. Also, fish under stress will swim more erratically and, thus, consume more energy.

In view of the above, it is the objective of the present invention to provide an improved floating fish cage that is optimized for energy-efficient fish culture.

In a first aspect, the objective is solved by a floating solar-powered multi-unit fish cage, comprising

- (i) a floating planar grid, the grid defining at least two grid interspaces,
 - (ii) at least one or more solar units, and
 - (iii) at least one or more fish cages,
- wherein
- (a) at least one fish cage is allocated to at least one grid interspace,
 - (b) at least one solar unit is allocated to at least one grid interspace, at least partially or completely covering said grid interspace, thus forming a solar unit-covered grid interspace,
 - (c) at least one solar unit-covered grid interspace partially spans at least one fish cage forming a partially covered fish cage,
 - (d) the partially covered fish cage allows for caged fish to voluntarily position under the at least one solar unit-covered grid interspace, and
 - (e) the at least one at least partially solar unit-covered grid interspace provides any of
 - a. electric energy,
 - b. protection of fish from direct solar radiation,
 - c. predator protection for fish, for example, from fish-predatory birds, and
 - d. optionally heat to the water in fish cageor any combination thereof.

The multi-unit fish cage comprises a floating, essentially planar grid, wherein the grid defines at least two grid interspaces, each of the grid interspaces forming a or part of a solar unit and/or a fish cage, or other functional units. The grid itself can float by itself, e.g. because it is formed from hollow structures, e.g. tubes, or it comprises additional flotation means, e.g.

pontoons. Optionally, the term floating grid includes grids that stand firmly on the ground and protrude above water level.

The term grid, as used herein, encompasses any planar grid-like structure that forms essentially planar interspaces, e.g. square, rectangular, hexagonal, octagonal, round, oval, etc.

Typically, the grid's beam structure allows for walking, feeding, harvesting and working on the interstitial spaces and supports the solar units and further machinery for fish farming.

Regularly, at least one fish cage is allocated to at least one grid interspace, or, optionally, at least one fish cage is allocated to at least two or more grid interspaces, so that the grid beams align and cross the fish cage.

The same, at least one solar unit is allocated to at least one grid interspace, at least partially or completely covering said grid interspace, thus forming a solar unit-covered grid interspace. For example, the solar unit may comprise solar panel(s) that can be hinged, folded and or slid to uncover or partially uncover the at least one grid interspace beneath.

Because the floating fish cage is designed so that at least one solar unit-covered grid interspace partially spans at least one fish cage forming a partially covered fish cage, this arrangement allows for caged fish to voluntarily locate, i.e. position themselves under the at least one solar unit-covered grid interspace.

Depending on climate, sun irradiation, water temperature, day and nighttime, predatory risk and the fish's comfort, the fish relocate, i.e. reposition themselves and choose between the solar unit-covered part of the fish cage (sun and predator-protected) and the open part of the fish cage (sun-heated, daylight). And optionally, the degree of coverage can be adapted, e.g. incrementally, i.e. increased or decreased, by hinging, folding and sliding the solar unit. In one alternative, the solar modules are slidable to cover or uncover the fish cage partially or even completely. In another alternative, when the solar module is mounted on a foil that at least partially covers a grid interspace, this foil can be at least partially furled or folded to decrease the effective solar module area and coverage.

At the same time, the at least one solar unit-covered grid interspace advantageously provides electric energy, protection of fish from direct solar radiation, predator protection for fish, for example, from fish-predatory birds, and optionally heat to the water in the fish cage. And with the overlap of fish cage(s) and solar unit(s) the available useful area of the multi-unit fish cage is optimized.

In an alternative embodiment, the floating fish cage of the present invention is one, wherein at least one grid interspace is a solar unit-covered grid interspace, and at least one grid interspace is an open grid interspace.

The fish cage(s) may comprise a mesh or grid for free water exchange from the aqueous fish compartment with surrounding water. One alternative for practicing this embodiment are copper-alloy nets, e.g. made from copper-nickel or copper-silicon. Copper alloys are antimicrobial and kill bacteria, viruses, fungi, algae and other microbes, thus preventing biofouling, i.e. the undesirable accumulation, adhesion and growth of microorganisms, plants, algae, tube worms, barnacles, mollusks and other organisms. To the contrary, traditional netting involves regular and labor-intensive cleaning. Copper netting also has strong structural and corrosion-resistant properties in marine environments.

In an alternative embodiment, the floating fish cage of the present invention is one, wherein the at least one fish cage is a closed fish cage forming a closed aqueous fish compartment, thus hindering water exchange with surrounding water. For such embodiments, water regeneration is regularly required in order to avoid accumulation of remaining fish feed, urine and feces.

The closed fish cage (8) can be constructed from rigid inflexible and watertight materials that keep a container-like shape even under pressure from surrounding moving water. Or the closed fish cage (8) can be constructed from flexible watertight materials, e.g. the closed fish cage (8) may comprise a watertight flexible sheet(s) or membrane (9), e.g. made from polyethylene (e.g. HDPE or LDPE), polyvinylchloride, and ethylene propylene diene methylene rubber.

When the closed fish cage comprises a watertight flexible sheet(s), it optionally has an inner water level extending above the outer water level floating the fish cage, thus exerting hydropressure on the flexible sheet(s) of the fish cage to stabilize its maximum volume and shape.

In short, the weight of the water above the outer water level pushes down by its gravity on the water inside the flexible sheet(s), thereby exerting a homogenous pressure on all flexible walls.

For a form-stable, watertight, flexible closed fish cage comprising a flexible sheet(s) it is of advantage that the vertical difference between the inner water level and the outer water level, i.e. water column height, of the closed fish cage is at least 5 to 100 cm, optionally at least 10 to 70cm, optionally 15 to 60 cm, and optionally 20 to 50 cm.

For this embodiment, for example, the volume of the closed fish cage is at least 2 to 100 m³, optionally at least 3 to 80 m³, optionally 4 to 70 m³, and optionally 5 to 50 m³.

In an alternative embodiments of the flexible closed fish cage for practicing the invention, the vertical difference between the inner water level and the outer water level of the closed fish cage is at least 5 to 100 cm, optionally at least 20 to 50 cm, and the volume of the closed fish cage (8) is at least 3 to 80 m³, optionally at least 5 to 50 m³.

Of course, the floating fish cage of the invention can feature grid interspaces having different sizes and shapes. However, the at least one grid interspace may have substantially the same planar dimensions for receiving and/or mounting the at least one or more solar units and/or the at least one or more fish cages, thus rendering the grid interspaces suitable for receiving both options interchangeably. Moreover, this gives to possibility to layout the floating fish cage in accordance with the given environmental conditions, wishes of the fish farmer and needs of the fishes.

The at least one or more solar units of the floating fish cage may comprise solar panels that can be hinged, folded and/or slid to uncover, e.g. partially and/or incrementally, the at least one grid interspace beneath. This way, the covered space can be adjusted to increase or reduce the solar unit coverage.

The one or more solar units of the floating fish cage of the invention can provide heat to the water of at least one fish cage by supplying electricity to an electric heater and/or by direct contact to the water by lost heat during electricity generation. As mentioned before, warmer water can lead to less energy losses and better weight gain of the fish. This is particularly useful in colder waters, e.g. in Canada and northern Europe.

Of course, the solar units on the floating fish cage may be flexibly positioned to

- (i) optimize solar radiation input and energy output,
- (ii) optimize shade and/or predator-protection for fish, and/or
- (iii) contact water of the fish cage to transfer lost heat during electricity generation.

In alternative embodiments, the floating fish cage of the invention can be constructed so that the at least one fish cage and/or the at least one solar unit is connected to the floating grid by detachable connecting means, optionally selected from the group consisting of screws, hooks, eyes, slide fastener and hook-and-loop fastener. This way, the grid interspaces can be adapted as needed to reduce or increase the number of solar unit-covered interspaces and fish cage-forming interspaces.

In a further aspect, the present invention is directed to a method for raising fish in a floating fish cage, comprising the steps of

- (i) providing a floating solar-powered multi-unit fish cage according to any of claims 1 to 14,
- (ii) introducing, feeding and growing fish in the at least one or more fish cages, and
- (iii) producing electric energy by means of the at least one or more solar units.

Optionally, the method of raising fish further comprises the step of heating the water in the at least one fish cage by electricity from the at least one or more solar units or its lost heat during electricity generation.

In a further alternative of the method of the invention the method may further comprise the step of flexibly positioning the one or more solar units to (a) optimize solar radiation input and energy output, (b) optimize shade and/or predator-protection for fish, and/or (c) contact water of the fish cage to transfer lost heat during electricity generation.

In the following, the invention will be described by reference to representative figures, none of which are to be considered as limiting the scope of the claims as appended.

Figure legend

(1) Floating solar-powered multi-unit fish cage	(7) Partially covered or uncovered fish cage
(2) Floating planar grid	(8) Closed fish cage
(3) Grid interspaces	(9) Watertight flexible sheet
(4) Solar unit comprising solar panels (4')	(10) Inner water level
(5) Fish cage	(11) Outer water level
(6) Solar unit-covered grid interspace	(12) Flotation means

Fig. 1 shows an optional embodiment of a floating solar-powered multi-unit fish cage 1 in side view featuring a floating planar grid 2 with three grid interspaces 3 from left to right and flotation means 12, e.g. pontoons. The grid interspace 3 on the left side forms a small fish cage 5 for large fish that is uncovered on top, e.g. fish ready for harvest and/or fish too large to be prey. The middle and right interspaces 3 form a continuous large fish cage for small fish with the middle grid interspace 3 being covered by a solar unit 4 comprising solar panels 4', e.g. angled and hinged solar panels 4', for better radiation uptake and/or aeration and/or fish protection from predators. The fish can position themselves under solar unit-covered grid interspace 6 or uncovered fish cage 7. Aquatic plants may grow better in the shade of the solar unit, the opening in the interspaces 3 allowing for easy harvesting.

Fig. 2 shows a further embodiment of a floating solar-powered multi-unit fish cage 1 in side view featuring a grid 2 of hollow self-floating tubes and providing for three grid interspaces 3 from left to right. The left grid interspace 3 forms a closed fish cage 8 made from watertight flexible sheet material 9 and the material is a two-layer material providing for temperature insulation. The same as for Fig. 1, the middle and right interspaces 3 of Fig. 2 form a continuous large fish cage 5 with the middle grid interspace 3 being covered by a solar unit 4 comprising solar panels 4', e.g. angled and hinged solar panels 4' for better radiation uptake and/or aeration and/or fish protection from predators. The fish can position themselves under solar unit-covered grid interspace 6 or uncovered fish cage 7.

Fig. 3 is a top view of a floating solar-powered multi-unit fish cage 1 with 4 x 4 grid 2 interspaces 3. Some of the grid interspaces 3 are grouped to form a continuous fish cage 5 spanning 2 or four interspaces 3. Some of the single or grouped interspaces 3 forming fish cages 5 are partially or completely covered by one or more solar units 4 comprising solar panels 4', thus providing for predatory protection, electricity and/or heat.

Fig. 4 is a side view of three embodiments of a grid interspace unit 3 taken from a floating solar-powered multi-unit fish cage 1 featuring flotation means 12, e.g. pontoons.

Fig. 4a describes a rectangular rigid net structure forming the fish cage 5.

Fig. 4b shows the same grid interspace unit 3 taken from a floating solar-powered multi-unit fish cage 1 as in Fig. 2 but with a flexible net and a current impact from the left side that deforms the rectangular shape of the net.

Fig. 4c shows the same grid interspace unit 3 taken from a floating solar-powered multi-unit fish cage 1 as in Figs. 1 and 2 but with a closed fish cage 8 made from a watertight flexible sheet 9, striated. The inner water level 10, i.e. the water level inside the closed fish cage 8, extends above the outer water level 11 floating the fish cage 1, thus exerting hydropressure on the flexible sheets 9 of the closed fish cage 8 to stabilize its maximum volume and shape.

Fig. 5a shows the same grid interspace unit 3 from a floating solar-powered multi-unit fish cage 1 as in Fig. 4c but with a current impact from the left side leading to slight deformation of the closed fish cage 8 made from watertight flexible material 9 and featuring the shape-stabilizing higher inner water level 10.

Fig. 5b is the same as Fig. 5a but with much more deformation by the same current impact from the left side and without a stabilizing inner water level 10, i.e. without hydropressure.

Claims

1. A floating solar-powered multi-unit fish cage (1), comprising
 - (i) a floating planar grid (2), the grid (2) defining at least two grid interspaces (3),
 - (ii) at least one or more solar units (4), and
 - (iii) at least one or more fish cages (5),wherein
 - (a) at least one fish cage (5) is allocated to at least one grid interspace (3),
 - (b) at least one solar unit (4) is allocated to at least one grid interspace (3), at least partially or completely covering said grid interspace (3), thus forming a solar unit-covered grid interspace (6),
 - (c) at least one solar unit-covered grid interspace (6) partially spans at least one fish cage (5) forming a partially covered fish cage (7),
 - (d) the partially covered fish cage (7) allows for caged fish to voluntarily position under the at least one, at least partially solar unit-covered grid interspace (6), and
 - (e) the at least one solar unit-covered grid interspace (6) provides any of
 - a. electric energy,
 - b. protection of fish from direct solar radiation,
 - c. predator protection for fish, for example, from fish-predatory birds, and
 - d. optionally heat to the water in fish cage (5),or any combination thereof.
2. The floating fish cage (1) of claim 1, wherein at least one fish cage (5) is allocated to at least two or more grid interspaces (3).
3. The floating fish cage (1) of claim 2, wherein at least one grid interspace (3) is a solar unit-covered grid interspace (6), and at least one grid interspace (3) is an open grid interspace (3).
4. The floating fish cage (1) of any of claims 1 to 3, wherein the at least one fish cage (5) comprises a mesh or grid for water exchange from an aqueous fish compartment with surrounding water.

5. The floating fish cage (1) of any of claims 1 to 4, wherein the at least one fish cage (5) is a closed fish cage (8) forming a closed aqueous fish compartment, thus hindering water exchange with surrounding water.
6. The floating fish cage (1) of claim 5, wherein the closed fish cage (8) comprises a watertight flexible sheet(s) (9) and has an inner water level (10) extending above an outer water level (11) floating the fish cage (1), thus exerting hydropressure on the flexible sheet(s) (9) of the fish cage (5) to stabilize its maximum volume and shape.
7. The floating fish cage (1) of claim 6, wherein a vertical difference between the inner water level (10) and the outer water level (11), i.e. water column height, of the closed fish cage (8) is at least 5 to 100 cm, optionally at least 10 to 70 cm, optionally 15 to 60 cm, and optionally 20 to 50 cm.
8. The floating fish cage (1) of claim 6, wherein the volume of the closed fish cage (8) is at least 2 to 100 m³, optionally at least 3 to 80 m³, optionally 4 to 70 m³, and optionally 5 to 50 m³.
9. The floating fish cage (1) of claims 7 and 8, wherein the vertical difference between the inner water level (10) and the outer water level (11) of the closed fish cage (8) is at least 5 to 100 cm, optionally at least 20 to 50 cm, and the volume of the closed fish cage (8) is at least 3 to 80 m³, optionally at least 5 to 50 m³.
10. The floating fish cage (1) of any of claims 1 to 9, wherein the at least one grid interspace (3) for receiving and/or mounting the at least one or more solar units (4) and the at least one or more fish cages (5) have substantially the same planar dimensions, thus rendering the grid interspaces (3) suitable for receiving both options interchangeably.
11. The floating fish cage (1) of any of claims 1 to 10, wherein the at least one or more solar units (4) comprise solar panels that can be hinged, folded and or slid to uncover the at least one grid interspace (3) beneath.
12. The floating fish cage (1) of any of claims 1 to 11, wherein the at least one or more solar

units (4) can provide heat to the water of at least one fish cage (5) by supplying electricity to an electric heater and/or by direct contact to the water by lost heat during electricity generation.

13. The floating fish cage (1) of any of claims 1 to 12, wherein one or more of the solar units (4) can be flexibly positioned to
 - (i) optimize solar radiation input and energy output,
 - (ii) optimize shade and/or predator-protection for fish, and/or
 - (iii) contact water of the fish cage (5) to transfer lost heat during electricity generation.
14. The floating fish cage (1) of any of claims 1 to 10, wherein the at least one fish cage (5) and/or the at least one solar unit (4) is connected to the floating grid (2) by detachable connecting means selected from the group consisting of screws, hooks, eyes, slide fastener and hook-and-loop fastener.
15. A method for raising fish in a floating fish cage, comprising the steps of
 - (i) providing a floating solar-powered multi-unit fish cage (1) according to any of claims 1 to 14,
 - (ii) introducing, feeding and growing fish in the at least one or more fish cages (5), and
 - (iii) producing electric energy by means of the at least one or more solar units (4).
16. The method of raising fish according to claim 15, further comprising the step of heating the water in the at least one fish cage (5) by electricity from the at least one or more solar units (4) or its lost heat during electricity generation.
17. The method of raising fish according to claim 15 or 16, further comprising the step of flexibly positioning the one or more solar units (4) to
 - (a) optimize solar radiation input and energy output,
 - (b) optimize shade and/or predator-protection for fish, and/or
 - (c) contact water of the fish cage (5) to transfer lost heat during electricity generation.