PATENT 338.10-100

# *PNEUMATICALLY CONTROLLED AQUACULTURE APPARATUS*

by

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## CROSS REFERENCES

[0001] This application is a continuation-in-part application of U.S. Application No. 16/681,562, filed November 12, 2019, which application is incorporated herein in its entirety by reference.

## FIELD OF THE INVENTION

[0002] The present invention refers generally to an aquaculture apparatus and, more specifically, to a pneumatically controlled apparatus for use in varying depths of water.

## BACKGROUND

[0003] It is estimated that over 90% of oysters, clams, and mussels produced for consumption worldwide come from aquaculture farms. In particular, due to loss of wild oyster reefs, small-scale aquaculture of oysters has increased significantly in recent years. Typical shellfish aquaculture farms utilize baskets, cages, trays, racks, or similar containers for holding the oysters either on the water bottom or off-bottom. Generally, oysters grow best when submerged in nutrient-rich brackish water elevated above the bottom to prevent contact with predators such as destructive worms and snails or suffocation from silting. When growing oysters, approximately once a week they should be raised above the surface for approximately a 24-hour period. This permits the oysters to air dry, killing barnacles, algae and other micro-organisms which attach to their shells. This weekly process is referred to as desiccation.

[0004] Once the oysters have dried they must be re-submerged to grow until the next desiccation is required. Between desiccations, the oysters and aquaculture equipment remain submerged in natural water bodies for extended periods of time during the growth of the oyster to a matured state suitable for harvest. During submerged periods, a biofilm of microorganisms may form on outer surfaces of the shellfish and the submerged aquaculture equipment, which can lead to the attachment of nuisance bio-fouling organisms such as barnacles and unwanted bivalve shellfish. Bio-fouling organisms create nuisance by clogging mesh or pores in shellfish containers, which reduces water flow through the containers and food availability for the shellfish, thereby slowing growth of culture shellfish. Additionally, bio-fouling organisms attach directly to shellfish causing visual defects that reduce market value. Unwanted organisms also add excessive weight to the system and can damage moving parts of the aquaculture equipment. Periodic emergence of the equipment and shellfish in the air above the sea surface desiccates the biofilm before it sufficiently establishes to permit attachment of bio-fouling organisms. Emergence of the equipment eliminates the need to pressure wash or clean equipment and shellfish by other means after bio-fouling organisms colonize the exposed surfaces.

[0005] In productive shellfish growing areas such as the Gulf of Mexico, desiccation of gear at weekly intervals is typically required to control bio-fouling.

Currently employed methods for bio-fouling control rely on intensive and potentially unsafe manual labor practices. Typical aquaculture systems comprise rectangular containers constructed of heavy plastic coated wire mesh that are assembled with multiple container compartments for holding flexible plastic mesh bags of varying mesh sizes that contain shellfish at various growth stages. The containers typically have two air-filled floats attached to the top of the containers on the outside edges on opposing sides to maximize stability to wave action. The air-filled floats provide adequate buoyancy to float the oyster-filled containers below the surface of the water for growing the oysters. The normal bio-fouling practice employed with floating aquaculture systems is to manually flip the containers upside down so the floats are then on the bottom of the containers. Float buoyancy elevates the oysters and the containers in the air above the water surface. In shallow areas, flipping the containers is often done by wading, but boats are required to work deeper or colder waters. Relatively calm waters are required to flip the containers from boats. After a desiccation period of about 24 hours, the containers are manually flipped back into the growth position until the next desiccation treatment.

[0006] This method of bio-fouling control is labor intensive and time consuming, which drives up oyster production costs. In addition, there are safety risks involved with the manual flipping of the oyster-filled containers, which can be extremely heavy. To limit the weight, smaller containers or groups of containers must be utilized, thereby limiting the potential scale of an operation. Floating shellfish gear is vulnerable to high wave energy and debris fields during hurricanes or other storm events. While sinking gear in advance of such events reduces vulnerability and losses, sinking numerous small floating gear units is very time consuming and should be done well in advance of storm conditions. Raising gear is even more laborious and time consuming. Current methods of shellfish aquaculture require large tracts of publicly-owned water bottoms and the waters located above to grow oysters. Significant manual labor is required to manipulate and maintain the gear associated with these methods and to accomplish the desiccation process while also protecting gear and crop from storm damage. In 2018 alone, oyster farmers in North Carolina lost an estimated $10 million, while farmers in Florida lost an estimated $20 million due to damage caused by Hurricanes Florence and Michael, respectively.

[0007] To minimize labor, reduce safety hazards in the desiccation process, and prevent loss of gear and crop, some aquaculture devices have been developed that provide pneumatic control of the floatation of the devices so that the containers holding shellfish may be lifted and held above the surface of the water by adding compressed air to tanks positioned on a bottom side of the device, thereby providing a more efficient desiccation process. The air may then be evacuated from the tanks and displaced by water to return the device to a submerged position to allow shellfish to grow inside the submerged containers. Such devices are effective in relatively shallow bodies of water in which one end of the device can be pneumatically lifted to the water surface while the other end rests on the water bottom, which provides stability of the device during the process of floating the device to the surface and sinking the device to the sea floor so that the device does not inadvertently overturn. However, in deeper bodies of water, the process of floating such an aquaculture device for desiccation does not allow a portion of the device to remain in contact with the water bottom, which may cause instability as the aquaculture device rises or sinks in the water column. Consequently, such devices may be prone to overturning due to a lack of stability when floating the device from the water bottom to the water surface in a deeper body of water.

[0008] Therefore, a need exists in the art for a floating aquaculture device for use in deeper bodies of water. Additionally, a need exists in the art for a method of using such an aquaculture device that allows the device to be floated from the water bottom to the water surface in a stable manner that prevents the device from overturning.

## SUMMARY

[0009] The aquaculture apparatus of the present disclosure allows for aquaculture activities in deeper bodies of water by providing pneumatic control of movement of the apparatus through the water column in a stable manner. The present aquaculture apparatus also provides for automated air desiccation of shellfish produced in off-bottom containerized aquaculture systems for the purposes of controlling bio-fouling on the surfaces of the shellfish and aquaculture equipment. In one aspect, a pneumatically controlled apparatus for shellfish aquaculture comprises a lift vessel, a container for holding shellfish, an inflatable buoy bladder, and a compressed gas source configured to independently supply gas to each of the lift vessel and the buoy bladder. The buoy bladder is disposed above both the container and the lift vessel when the apparatus is in an upright position for normal use. The buoy bladder is retained in a centered position of the apparatus, preferably by a frame secured to the apparatus. A lift vessel fluid supply line connects the lift vessel to the compressed

gas source, and a buoy bladder fluid supply line connects the buoy bladder to the compressed gas source. In a preferred embodiment, these gas lines are connected to a manifold having valves for independent control of gas flows. The compressed gas is preferably air, and the compressed gas source is preferably a pressurized tank, such as a SCUBA tank, or an air compressor.

[0010] The aquaculture apparatus is adapted for use in three positions: a floating position, a suspended position, and a submerged position. When in the submerged position, the apparatus may be resting on the sea floor or, alternatively, positioned at a desired depth in the water column. When in the floating position, the lift vessel is filled with gas and the container holding shellfish is positioned above the surface of the water. Thus, in the floating position, the shellfish may be held out of the water for a period of time sufficient to allow air desiccation in order to prevent the formation of biofilm on the containers and shellfish, and various aquaculture activities may additionally be performed while the apparatus is floating. While in the floating position, the apparatus can also be towed to a different location to enhance growth and flavor or to avoid hazards to the health of aquatic species or human health, such as pollution from pathogens or harmful chemicals. When in the suspended position, the buoy bladder is inflated with gas so that it floats on the water surface with both the container holding shellfish and the lift vessel suspended under the water surface below the buoy bladder. To sink the lift vessel down to the suspended position, gas is evacuated from the lift vessel. In a preferred embodiment, the lift vessel comprises a lift tank having rigid walls, and gas is evacuated from the lift tank by displacing the air in the lift tank with water. In an alternative embodiment, the lift vessel may comprise an inflatable lift bladder, which is preferably disposed within a rigid cage to protect the lift bladder and to retain it in a fixed position. In this embodiment, gas may simply be evacuated from the lift bladder, which results in the lift bladder collapsing into a flattened state. When the apparatus is in the submerged position, the buoy bladder is deflated and gas is evacuated from the lift vessel so that the apparatus is resting on the water bottom. The apparatus may be left in the submerged position for a desired period of time to allow for shellfish growth before harvesting or to avoid storm waves. Alternatively, the apparatus may optionally further comprise a second buoy tethered to the apparatus so that the apparatus can be positioned at any desired depth in the water column rather than resting on the water bottom. The second buoy floats at the water surface, and the length of the tethering line determines the depth of the apparatus in the water column.

[0011] The apparatus may be moved sequentially in steps from the floating position to the suspended position to the submerged position, and then, by reversing the steps, from the submerged position to the suspended position to the floating position. To move the apparatus from the submerged position to the suspended position, air is supplied to the buoy bladder to inflate the buoy bladder, thereby causing the apparatus to rise in the water column until the buoy bladder is floating on the water surface with both the container and the lift vessel suspended in the water below the buoy bladder. To then move the apparatus from the suspended position to the floating position, air is supplied to the lift vessel, which causes the lift vessel to rise from the suspended position to the floating position in which the container holding shellfish is lifted and held above the water surface. In a preferred embodiment, the lift vessel is a tank having an opening located on a bottom side of the tank. In this embodiment, when air is supplied to the lift tank, the air displaces water inside the lift tank by forcing the water out of the opening. By retaining the buoy bladder in a centered position of the apparatus, stability is maintained so that the apparatus does not inadvertently overturn due to one side of the lift tank floating before an opposite side of the lift tank, which could cause instability. The process of floating the apparatus may be repeated each time bio-fouling treatment is required.

[0012] To reverse this process and move the apparatus from the floating position back to the suspended position, pressure in the lift tank may be relieved to the atmosphere so that water then displaces the air in the lift tank via water entering the lift tank through the opening on the bottom side of the lift tank, thereby causing both the lift tank and the container to sink to the suspended position while the buoy bladder is inflated and floating on the water surface. Once pressure is removed from the lift tank, the weight of the apparatus will cause water to displace the air inside the lift tank. To then move the apparatus from the suspended position to the submerged position, pressure on the buoy bladder is relieved so that the buoy bladder deflates, thereby causing the entire apparatus to sink to the bottom of the body of water. The rate of deflation of the buoy bladder may be controlled so that the apparatus sinks slowly in a controlled manner.

[0013] In another embodiment, the apparatus may comprise a frame structure designed for holding shellfish therein and attached to the lift vessel. The apparatus may further comprise a floatation control tank and a suspension buoy tethered to the apparatus. The floatation control tank has a rigid tank wall and an opening on the bottom of the tank for the displacement of water from the tank by supplying air to the tank to force water out of the opening or for the evacuation of air from the tank through water entering the tank through the opening. The floatation control tank is attached to a top of the frame structure in a generally centered position of the apparatus and is disposed above the lift vessel. The floatation control tank is preferably a generally elongated tank that is disposed in a generally vertical position such that the height of the tank is greater than the width or diameter of the tank. In this embodiment, the apparatus may be deployed at various positions within the water column, including a floating position with the lift vessel floating on the water surface, a first suspended position with the floatation control tank floating on the water surface, a second suspended position with the suspension buoy floating on the water surface and the apparatus suspended in the water column at a depth defined by the length of the tether line, and, optionally, a completely submerged position with the lift vessel resting on the water bottom.

[0014] Accordingly, one object of the present disclosure is to provide an aquaculture apparatus having pneumatic floatation control for sinking and floating the apparatus in a controlled manner that allows for use of the apparatus in deeper bodies of water. Another object of the present disclosure is to provide a method utilizing the present apparatus for aquaculture activities in deeper bodies of water. Yet another object of the present disclosure is to provide an aquaculture apparatus that may be deployed at varying positions within the water column.

## DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. **1** is a top perspective view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **2** is a bottom perspective view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **3** is a side view of an aquaculture apparatus in a floating position while in use in a body of water in accordance with the present disclosure.

FIG. **4** is a side view of an aquaculture apparatus in a suspended position while in use in a body of water in accordance with the present disclosure.

FIG. **5** is a side view of an aquaculture apparatus in a submerged position while in use in a body of water in accordance with the present disclosure.

FIG. **6** is a side view of an alternative embodiment of an aquaculture apparatus in accordance with the present disclosure.

FIG. **7** is a side view of an alternative embodiment of an aquaculture apparatus in accordance with the present disclosure.

FIG. **8** is a side view of an alternative embodiment of an aquaculture apparatus in a submerged, off-bottom position while in use in a body of water in accordance with the present disclosure.

FIG. **9** is a top perspective view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **10** is a bottom perspective view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **11** is a top perspective view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **12** is a bottom perspective view of a floatation control tank for use with an aquaculture apparatus in accordance with the present disclosure.

FIG. **13** is a side view of an aquaculture apparatus in accordance with the present disclosure.

FIG. **14** is a side view of an aquaculture apparatus in a floating position while in use in a body of water in accordance with the present disclosure.

FIG. **15** is a side view of an aquaculture apparatus in a first suspended position while in use in a body of water in accordance with the present disclosure.

FIG. **16** is a side view of an aquaculture apparatus in a second suspended position while in use in a body of water in accordance with the present disclosure.

FIG. **17** is a side view of an aquaculture apparatus in a submerged position while in use in a body of water in accordance with the present disclosure.

FIG. **18** is a side view of an alternative embodiment of an aquaculture apparatus in accordance with the present disclosure.

FIG. **19** is a schematic view of water distribution piping of an alternative embodiment of an aquaculture apparatus in accordance with the present disclosure.

## DETAILED DESCRIPTION

[0015] In this disclosure, reference is made to particular features, including method steps, of the invention. It is to be understood that the disclosure of the invention in this specification includes all possible combinations of such particular features. For example, where a particular feature is disclosed in the context of a particular aspect or embodiment of the invention, or a particular claim, that feature can also be used, to the extent possible, in combination with/or in the context of other particular aspects of the embodiments of the invention, and in the invention generally.

[0016] The term “comprises” and grammatical equivalents thereof are used herein to mean that other components, ingredients, steps, etc. are optionally present. For example, an article “comprising” components A, B, and C can contain only components A, B, and C, or can contain not only components A, B, and C, but also one or more other components. The term tubes, tanks, and pontoons, as used herein, are interchangeable.

[0017] Where reference is made herein to a method comprising two or more defined steps, the defined steps can be carried out in any order or simultaneously (except where the context excludes that possibility), and the method can include one or more other steps which are carried out before any of the defined steps, between two of the defined steps, or after all the defined steps (except where the context excludes that possibility).

[0018] Turning now to the drawings, Figs. **1-5** illustrate a preferred embodiment of an aquaculture apparatus **10** that may be utilized for shellfish aquaculture activities in relatively deep bodies of water. Figs. **9-18** illustrate another preferred embodiment of an aquaculture apparatus **100** for use in deeper water. The present aquaculture apparatus **10** provides pneumatic control of movement of the apparatus through the water column in a stable manner. The present aquaculture apparatus **10** also provides for automated air desiccation of shellfish **28** produced in off-bottom containerized aquaculture systems for the purposes of controlling bio-fouling on the surfaces of the shellfish and aquaculture equipment.

[0019] The aquaculture apparatus **10** comprises a lift vessel **12**, a container **26** for holding shellfish **28**, an inflatable buoy bladder **30**, and a compressed gas source **50** configured to independently supply gas to each of the lift vessel **12** and the buoy bladder **30**. The buoy bladder **30** is disposed above both the container **26** and the lift vessel **12** when the apparatus **10** is in an upright position for normal use. Fig. **1** and Figs. **3-5** each show the apparatus **10** in an upright position, while Fig. **2** shows the apparatus inverted to illustrate a bottom side of the apparatus (some components have been omitted from Fig. **2** to better illustrate certain components of the apparatus). As best seen in Fig. **1**, the buoy bladder **30** is retained in a centered position of the apparatus, preferably by a frame **32** secured to the apparatus. As used herein, a "centered position" indicates that the buoy bladder **30** is retained in a position that is generally centered between a front end **14** and a rear end **16** of the apparatus, as well as being retained in a generally centered position between two sides of the apparatus between the front and rear ends. The buoy bladder **30** is made of a flexible material so that it can be inflated and deflated. Due to the flexible nature of the material, the buoy bladder **30** may shift off-center within certain tolerances during normal operation of the apparatus, though the bladder is generally retained in the centered position in order to maintain stability when the apparatus is being moved between different positions, as well as when the apparatus is moving through all segments of the water column.

[0020] A lift vessel fluid supply line **56** connects the lift vessel **12** to the compressed gas source **50**, and a buoy bladder fluid supply line **58** connects the buoy bladder **30** to the compressed gas source **50**. In a preferred embodiment, these gas lines are connected to a manifold **60** having valves **62, 64** for independent control of gas flows. The compressed gas is preferably air, and the compressed gas source **50** is preferably a pressurized tank, such as a SCUBA tank, or an air compressor. In alternative embodiments, other suitable gases may be utilized, such as nitrogen or helium.

[0021] As shown in Figs. **3-5**, respectively, the aquaculture apparatus **10** is adapted for use in three positions: a floating position, a suspended position, and a submerged position. When in the floating position, as shown in Fig. **3**, the lift vessel **12** is filled with gas and the container **26** holding shellfish **28** is positioned above the surface **72** of the water **70**. Thus, in the floating position, the shellfish **28** may be held out of the water **70** for a period of time sufficient to allow air desiccation in order to prevent the formation of biofilm on the containers **26** and shellfish **28**, and various aquaculture activities may additionally be performed while the apparatus **10** is floating. When in the suspended position, as shown in Fig. **4**, the buoy bladder **30** is inflated with gas with both the container **26** holding shellfish **28** and the lift vessel **12** suspended under the water surface below the buoy bladder **30**. The suspended position provides a transition between the floating and submerged positions that allows stability when moving the apparatus between the floating and submerged positions. In addition, some aquaculture activities may be performed in the suspended position, if desired. For instance, in some cases, it may be desired to allow shellfish **28** to grow near the water surface, depending on certain environmental conditions. In such cases, the apparatus may be left in the suspended position for a period of time for shellfish growth. When in the submerged position, as shown in Fig. **5**, the buoy bladder **30** is deflated and gas is evacuated from the lift vessel **12** so that the apparatus **10** is resting on the water bottom **74**. The apparatus may be left in the submerged position for a desired period of time to allow for shellfish growth before harvesting or to avoid storm damage from high wave energy. In an alternative embodiment, as shown in Fig. **8**, the apparatus **10** may be held at a desired depth in the water column by a second buoy **80** tethered to the apparatus even when the buoy bladder **30** is deflated and gas is evacuated from the lift vessel **12**.

[0022] The lift vessel **12** preferably comprises a lift tank **12** having rigid walls and an opening **24** on a bottom side of the lift tank **12**, which can be seen in Fig. **2**. The opening **24** allows water to enter the interior of the lift tank **12** to displace air in the lift tank **12** when moving the apparatus from the floating position to the suspended position. The opening **24** also provides a passageway through which air may displace water in the lift tank **12** by forcing the water out through the opening **24** when moving the apparatus from the suspended position to the floating position. In a preferred embodiment, as best seen in Figs. **1** and **2**, the apparatus **10** comprises a plurality of lift tanks **12** that each have an elongated tubular shape and that are spaced apart. In this embodiment, the apparatus **10** further comprises a plurality of lift vessel fluid supply lines **56** each connecting a respective one of the plurality of lift tanks **12** to the compressed gas source **50**. Each lift tank **12** has a first end **14** and a second end **16**. As shown in Fig. **1**, each lift vessel fluid supply line **56** is connected to a respective first end **14** of a lift tank **12**, and each lift tank **12** has an opening **24** located on the bottom side of the lift tank **12** and positioned at the second end **16** of the lift tank **12**, as shown in Fig. **2**. Fig. **1** illustrates the apparatus with two lift tanks **12**, though additional spaced lift tanks may be utilized to increase the capacity of the apparatus.

[0023] As shown in Fig. **1**, the tubular lift tanks **12** may preferably be constructed of a length of pipe, such as PVC (polyvinyl chloride) pipe, with end caps. In a preferred embodiment, the lift tanks **12** may be constructed of 12-inch diameter pipes sealed with end caps to provide a sealed enclosure for floatation. Although lift tanks of other sizes or configurations may be utilized, cylindrical tubular tanks spaced apart may be preferred because such a lift tank configuration may function in a similar manner as a catamaran, thereby allowing the apparatus to be towed more easily by a motorized vessel by reducing drag as the apparatus **10** moves on the water surface when in the floating position. To facilitate towing, one or both ends of each tubular lift tank **12** may have a loop **22** installed thereon for securing a tow rope, chain, or similar type of tow line. Enhanced mobility of the apparatus makes it possible to more easily escape adverse environmental conditions such as oil spills, sewerage discharges, algae blooms and storm water pollution. An additional advantage of mobility is the ability to relocate mature oysters from a brackish water area where they are grown to a water body with a higher salt content. The oysters can be relocated and submerged there for several days to obtain a salty taste prior to going to market, which may increase the market value of the shellfish.

[0024] The apparatus **10** may further comprise a frame **32** that is adapted to retain the inflatable buoy bladder **30** in a centered position of the apparatus. The frame **32** also provides a rigid connection between the spaced lift tanks **12**. As shown in Fig. **1**, the frame **32**, as well as the lift tanks **12**, may preferably be constructed of PVC pipe and pipe fittings, which may provide inexpensive and lightweight construction materials that may be sized to construct aquaculture apparatuses of varying dimensions. However, it should be appreciated by one skilled in the art that other suitable materials may be utilized in constructing the frame **32**, such as metal or other types of polymers, which may optionally be formed from a solid structure rather than having a hollow interior. In a preferred embodiment, as best seen in Fig. **1**, the frame **32** comprises four frame members **40** that generally meet at a centered position of the apparatus **10** above the containers **26** and lift tanks **12**. The frame **32** preferably includes cross-support members **34** to provide structural support between the spaced lift tanks **12**. In a preferred embodiment, the frame **32** may be secured to each of the lift tanks **12** with a plurality of tapping saddles **18** (although the tapping saddles **18** are used only to secure the frame **32** to the lift tanks **12** and do not tap into the piping used to form the lift tanks). The tapping saddles **18** are preferably positioned toward each end **14, 16** of each of the tubular lift tanks **12**. Each tapping saddle **18** may comprise two halves, which may be bolted together around the pipe forming each lift tank **12**, and may have a tee **36** attached to a top half of the saddle **18**. The tee **36** may be used to connect the cross-support members **34** thereto in order to form structural supports between lift tanks **12** and to connect the frame members **40** to the lift tanks **12**. Elbow joints **38**, which are preferably 45-degree elbows, are preferably used to connect the frame members **40** to the tees **36** so that the four frame members **40** may generally meet at a centered position of the apparatus **10** to retain the buoy bladder **30** in the center of the apparatus. In a preferred embodiment, as shown in Fig. **1**, additional elbow joints **42** may be connected to the opposite end of each frame member **40** so that the elbow joints **42** physically contact each other and provide a space between the elbow joints **42** through which the buoy bladder fluid supply line **58** may run to supply gas to the buoy bladder **30** positioned inside the frame **32**. The elbow joints **42** may be bound together by a band **48** tightened around the elbow joints **42** or any similar type of fastening mechanism suitable for holding the elbow joints **42** together to maintain structural integrity of the frame **32**.

[0025] In a preferred embodiment, each of the elbow joints **42** may have an open end **44** facing upward. The open ends **44** may allow water to displace air inside the frame members **40** when moving the apparatus to the submerged position so that the apparatus sinks to the water bottom **74** easily. An opening (not shown) may be formed in each tee **36** or at another low point of the frame **32** so that water inside the frame members **40**, as well as the cross-support members **34**, can drain out of the frame **32** when moving the apparatus to the floating position in order to minimize the weight of the apparatus when it is out of the water.

[0026] In a preferred embodiment, as best seen in Fig. **1**, the frame **32** further comprises a plurality of retaining members **46** secured to the frame members **40** in a position suitable to prevent the buoy bladder **30** from inadvertently sliding between any of the frame members **40** during normal operation of the apparatus **10**. For instance, when moving the apparatus from the suspended position to the floating position, the first end **14** of each lift tank **12** may rise to the water surface **72** before the second end **16**, which may cause the buoy bladder **30** to shift toward a position between the two frame members **40** closest to the first end **14** of each lift tank **12**. In this case, the retaining members **46** may prevent the buoy bladder **30** from sliding between those frame members **40**, thereby retaining the buoy bladder **30** in a generally centered position, which may be defined by a perimeter formed by the retaining members **46**. When lowering the apparatus from the floating position to the suspended position, the opposite retaining member **46** may prevent the buoy bladder **30** from sliding between frame members **40** in a similar manner. In alternative embodiments, other types of retaining structures, such as a netting or a cage structure, may be utilized to retain the buoy bladder **30** in a centered position between frame members **40**, though it is preferred that a solid structure not be used in order to minimize drag as the apparatus moves up and down in the water column.

[0027] Although Fig. **1** illustrates one preferred embodiment of a frame **32** suitable for retaining the buoy bladder **30** in a generally centered position above the containers **26** and lift tanks **12**, it should be understood that any frame structure suitable for retaining the buoy bladder **30** in such a centered position may be utilized, which may include frames having various shapes and configurations, and still fall within the scope of the present disclosure.

[0028] The aquaculture apparatus **10** comprises at least one container **26** for holding shellfish **28**. As best seen in Fig. **1**, the container is preferably a cage, and the apparatus preferably comprises a plurality of cages **26** for holding the shellfish **28**, though any type of container or carrier suitable for use in shellfish aquaculture may be utilized. The container **26** should be designed to provide sufficient water flow around the shellfish **28** to allow for adequate shellfish growth. One or more planks **20**, beams, or similar support structure may be utilized to help support the weight of the cages **26** and shellfish **28**. The planks **20** may preferably be secured to each of the lift tanks **12**. The containers **26** may be secured to the planks **20**, lift tanks **12**, and/or frame **32** by any suitable securing or fastening means known in the art. For instance, shellfish cages **26** may be bolted to the planks **20** and may optionally also be tied down to or strapped to the lift tanks **12** and/or cross-support members **34** in order to ensure that the cages **26** remain secured to the apparatus **10** at all times during normal operation, which may include the apparatus **10** being tilted when moving it between the floating, suspended, and submerged positions.

[0029] In a preferred embodiment, the apparatus **10** further comprises a manifold **60** configured to independently supply gas from the compressed gas source **50** to each of the lift vessel **12** and the buoy bladder **30**. As best seen in Fig. **1**, the manifold **60** comprises a plurality of valves for controlling the gas flow. The manifold **60** is fluidly connected to the compressed gas source **50** through a primary fluid supply line **54** and has a primary gas supply valve **55** for controlling the flow of gas from the compressed gas source **50** into the manifold **60**. The manifold **60** is fluidly connected to the buoy bladder **30** through a buoy bladder fluid supply line **58**, which preferably extends through an opening between the frame members **40** and is connected to a top side of the buoy bladder **30**. The manifold has a float valve **64** for supplying gas to the buoy bladder **30** in order to float the apparatus **10** from the submerged position to the suspended position in which the buoy bladder **30** is floating at the water surface **72**. The manifold **60** further comprises at least one lift valve **62** for supplying gas to one or more lift vessels **12** through at least one lift vessel fluid supply line **56**.

[0030] In a preferred embodiment in which the apparatus **10** comprises a plurality of tubular lift tanks **12**, the apparatus **10** further comprises a plurality of lift tank fluid supply lines **56** individually connecting each respective lift tank **12** to the manifold **60**. The manifold **60** preferably comprises a plurality of lift valves **62** arranged to individually control the flow of gas to each respective lift tank **12**. Alternatively, a single lift valve **62** may control the flow of gas to multiple lift tanks **12**, though independent control to each lift tank **12** is preferred to maintain stability by ensuring that all lift tanks rise simultaneously when floating the apparatus. In a preferred embodiment, each lift tank fluid supply line **56** is connected to the first end **14** of each respective lift tank **12**, and the opening **24** on the bottom side of each lift tank **12** is positioned at the second end **16**. In addition, each lift tank fluid supply line **56** is preferably connected to a top side of the lift tank **12**. This configuration allows tubular lift tanks **12** to move between the floating and suspended positions while maintaining stability of the apparatus.

[0031] A method of controlling floatation of an aquaculture apparatus **10** is also provided. Fig. **3** shows the apparatus **10** in the floating position, Fig. **4** shows the apparatus **10** in the suspended position, and Fig. **5** shows the apparatus **10** in the submerged position. In the floating position, the lift vessel **12**, which may comprise a plurality of lift tanks **12**, is filled with gas, which is preferably air, so as to lift the containers **26** and shellfish **28** out of the water **70**. In the floating position, the buoy bladder **30** may be in an inflated or a deflated state. Fig. **3** shows the buoy bladder **30** in an inflated state, but it may preferably be deflated to minimize its size if work is to be done on the apparatus, such as harvesting shellfish. In the suspended position, the buoy bladder **30** is inflated so that the buoy bladder **30** floats on the water surface **72** with the container **26** suspended in the water below the buoy bladder **30**. In the suspended position, gas is evacuated from the lift vessel **12** so that the lift vessel **12** sinks below the water surface. In the preferred embodiment utilizing rigid lift tanks **12**, the air evacuated from inside the lift tanks **12** is displaced with water **70** as the air is evacuated to sink the lift tanks **12**. In the submerged position, the buoy bladder **30** is deflated, and air is evacuated from the lift tanks **12** so that the apparatus **10** sinks to the bottom **74** of the body of water **70**.

[0032] The apparatus **10** may be moved sequentially in steps from the floating position to the suspended position to the submerged position, and then, by reversing the steps, from the submerged position to the suspended position to the floating position. To move the apparatus from the submerged position to the suspended position, air or another suitable gas is supplied to the buoy bladder **30** to inflate the buoy bladder **30**, thereby causing the apparatus **10** to rise in the water column until the buoy bladder **30** is floating on the water surface **72** with both the container **26** and the lift tanks **12** suspended in the water **70** below the buoy bladder **30**, as shown in Fig. **4**. Air may be supplied to the buoy bladder **30** by opening the primary gas supply valve **55** to supply air from the compressed gas source **50** to the manifold **60**. The float valve **64** may then be opened to supply air from the compressed air source

**50** to the buoy bladder **30** through the manifold **60**. The rate of air flow to the buoy bladder **30** may preferably be controlled so that the apparatus **10** rises through the water column at a slow, steady rate to maintain stability. The rate of air flow may be controlled manually using the float valve **64** and/or the primary gas supply valve **55**, or optionally, the apparatus **10** may include automated control equipment to control the air flow rate.

[0033] Once in the suspended position, the apparatus may then be moved to the floating position, as shown in Fig. **3**. To move the apparatus from the suspended position to the floating position, air is supplied to the lift tanks **12**, which causes the lift tanks **12** to rise from the suspended position to the floating position in which the container **26** holding shellfish **28** is lifted and held above the water surface **72**. Air may be supplied to the lift tanks **12** by opening the primary gas supply valve **55** and each of the lift valves **62** to supply air to each lift tank **12**. The lift valves **62** are preferably opened simultaneously so that each lift tank **12** rises simultaneously to maintain stability of the apparatus. Alternatively, the lift valves **62** may be opened sequentially to shift shellfish **28** side to side in order to tumble the shellfish **28** within the containers **26** or to balance the load if shellfish **28** have been pushed to one side of the containers **26** by waves or current. As air flows into each lift tank **12** at the first end **14** of the lift tank **12**, the water **70** inside the lift tank **12** is forced out of the opening **24** on the bottom side of the lift tank **12** at the second end **16** of the lift tank **12** until air displaces substantially all of the water in each lift tank **12**. Having the lift vessel fluid supply line **56** connection and the opening **24** at opposite ends of each lift tank **12** ensures that substantially all of the water in each lift tank **12** is displaced.

Once the water is displaced with air and the lift tanks **12** are floating on the water surface **72**, the lift valves **62** may be closed to shut off the flow of air. With the openings **24** positioned on the bottom side of each lift tank **12** and the weight of the apparatus **10** keeping the openings **24** just below the water surface **72**, air pressure inside the lift tanks **12** will be maintained so that the lift tanks **12** remain afloat without requiring a constant flow of air to the lift tanks **12**.

[0034] Because air flows into each lift tank **12** at one end **14**, the first end **14** tends to rise to the water surface **72** before the second end **16**, thereby tilting the apparatus **10** during the process of moving the apparatus between the suspended and floating positions. However, by retaining the inflated buoy bladder **30** in a centered position of the apparatus, the inflated buoy bladder **30** remains floating on the water surface **72** until the lift tanks **12** completely lift it out of the water, which provides leverage that prevents the first end **14** from floating above the second end **16** to an extent that would cause the apparatus to become unstable and inadvertently overturn and that also prevents side-to-side inversion of the apparatus **10**. Thus, the frame **32** retaining the inflated buoy bladder **30** in a centered position maintains stability during the process of moving the apparatus **10** between the suspended and floating positions.

[0035] To reverse this process and move the apparatus **10** from the floating position back to the suspended position, air is evacuated from the lift tanks **12** by relieving pressure in each lift tank **12** to the atmosphere so that water **70** then displaces the air in each lift tank **12** via water **70** entering each lift tank **12** through the openings **24** on the bottom side of each lift tank **12**, thereby causing both the lift tanks **12** and the container **26** to sink to the suspended position while the buoy bladder **30** is inflated and floating on the water surface **72**. If the buoy bladder **30** is deflated, it should be inflated by supplying air to the buoy bladder **30** via the float valve **64** prior to relieving pressure on the lift tanks **12**. Pressure on the lift tanks **12** may be relieved via the lift tank fluid supply lines **56** by disconnecting the primary fluid supply line **54** from the primary gas supply valve **55** and opening the lift valves **62** and the primary gas supply valve **55**. At this point, the float valve **64** should remain closed to maintain air pressure inside the inflated buoy bladder **30**. In an alternative embodiment, the manifold **60** may have one or more separate designated pressure relief valves that may be opened individually for the purposes of relieving pressure on one or more lift tanks **12**, as well as the buoy bladder **30**, to the atmosphere without the need to disconnect the primary fluid supply line **54** from the manifold **60**. Once pressure is removed from each lift tank **12**, the weight of the apparatus **10** will cause water **70** to displace substantially all of the air inside each lift tank **12**. As the air is displace by water **70**, the lift tanks **12** will sink to the suspended position below the buoy bladder **30**, which will then be floating on the water surface **72**, as shown in Fig. **4**.

[0036] Once the apparatus **10** is in the suspended position, it may then be moved to the submerged position, as shown in Fig. **5**. To move the apparatus from the suspended position to the submerged position, pressure on the buoy bladder **30** is relieved so that the buoy bladder **30** deflates, thereby causing the entire apparatus **10** to sink to the bottom **74** of the body of water **70**. Pressure on the buoy bladder **30** may be relieved to the atmosphere via the buoy bladder fluid supply line **58** by opening the float valve **64** and the primary gas supply valve **55** with the primary fluid supply line **54** being disconnected. The rate of deflation of the buoy bladder **30** may be controlled so that the apparatus **10** sinks slowly in a controlled manner to maintain stability.

[0037] As shown in Figs. **3-5**, the compressed gas source **50** is preferably secured to a floating barge **52** or similar floating structure floating on the water surface **72**. The barge **52** may be moved to service multiple aquaculture apparatuses **10** in an area by connecting and disconnecting the compressed air source **50** to and from separate manifolds **60** for each apparatus **10** to be moved between the floating, suspended, or submerged positions. Alternatively, a separate gas source manifold may be used to connect a plurality of primary fluid supply lines **54** to a plurality of manifolds **60** for each aquaculture apparatus **10** so that the compressed gas source **50** may service multiple apparatuses **10** without the need to move the compressed gas source **50**. In this case, the compressed gas source **50** may optionally be secured to a dock or other stationary structure. The compressed gas source **50** is preferably a pressurized air tank or an air compressor.

[0038] The length of the buoy bladder fluid supply line **58** and the lift vessel fluid supply lines **56** may be varied depending on the depth of water **70** in which the aquaculture apparatus **10** is being deployed. A spooling device may optionally be utilized to manage lengths of air supply lines so that the lines may be spooled when moving the apparatus to the floating position and unspooled when moving the apparatus to the submerged position. The manifold **60** is preferably kept above the water surface and may be secured to a separate floating structure, which may additionally function as a marking buoy to mark the location of a submerged apparatus. By utilizing a lift vessel **12** in combination with a buoy bladder **30** retained in a centered position of the apparatus, the present aquaculture apparatus may be utilized in relatively deep bodies of water **70** while providing stable movement between three different modes of operation and through the entire water column. The floating position is generally used for air desiccation of shellfish **28**, as well as various aquaculture activities, such as harvesting shellfish, and the submerged position is generally used for growing shellfish. The suspended position may be utilized simply as a stable transition stage between the floating and submerged positions, or may additionally be used for shellfish growth near the water surface. The apparatus **10** may optionally be attached to an anchor with an anchor line to limit movement of the apparatus on the water surface when in the floating or suspended positions.

[0039] In an alternative embodiment, the lift vessel **12** may comprise an inflatable lift bladder **12a**, as shown in Figs. **6** and **7**, and preferably two lift bladders **12a** positioned at opposing ends of the apparatus and spanning the width of the apparatus. Each lift bladder **12a** is preferably disposed within a rigid cage **66** to protect the lift bladder **12a** to retain it in a fixed location. In this embodiment, air may simply be evacuated from each lift bladder **12a**, thereby causing each lift bladder **12a** to collapse into a flattened state. Fig. **6** shows each lift bladder **12a** inflated so the bladders push against an interior of each cage **66**, and Fig. **7** shows each lift bladder **12a** partially deflated, though the bladders may be further deflated when the apparatus is in the suspended or submerged position. Thus, to move the apparatus from the floating position in which each lift bladder **12a** is inflated to the suspended position, air may be evacuated from each lift bladder **12a** by relieving pressure on each lift bladder **12a** so that each lift bladder **12a** deflates and collapses. When inflating the lift bladders **12a** to float the apparatus to the floating position, air may be supplied to both lift bladders **12a** simultaneously or may be supplied sequentially to cause one end of the apparatus to rise before the opposing end.

[0040] Fig. **8** illustrates an alternative embodiment in which the apparatus **10** further comprises a second buoy **80** tethered to the apparatus by a flexible tether line **84**, the length of which may be varied to control the depth of the apparatus in the water column. The tether line **84** is preferably secured to the frame **32** at a generally centered position of the apparatus. In this embodiment, the apparatus **10** is in the submerged position with the buoy bladder **30** deflated and air evacuated from the lift tanks **12**, but the apparatus is not resting on the water bottom **74**. Instead, the second buoy **80** is inflated so that it is floating on the water surface **72**, thereby causing the tether line **84** to hold the lift tanks **12** in a position off the water bottom at a desired depth in the water column. The second buoy **80** may optionally be connected to the manifold **60** by a second buoy fluid supply line **82** so that the second buoy **80** can be inflated using the compressed gas source **50**. Gas flow to the second buoy **80** may be controlled by a second buoy fluid supply valve **86** on the manifold **60**. To move the apparatus from a mid-water column position to the water bottom **74**, the second buoy **80** may simply be deflated so that the second buoy **80** loses buoyancy and sinks. Alternatively, the second buoy **80** may not be connected to the manifold, in which case, to move the apparatus from a mid-water column position to the water bottom **74**, the apparatus can be raised to the floating position and the tether line **84** detached from the apparatus before then moving the apparatus back to the submerged position as shown in Fig. **5**.

[0041] The alternative embodiment shown in Fig. **8** provides the apparatus **10** with the capability to maintain and operate at any vertical position throughout the water column. This capability may allow the apparatus **10** to be used in the production of a variety of other aquatic species in pens or on lines suspended below the lift tanks **12**, such as cultured crustacea, finfish, or seaweeds. For instance, kelp may be supported by lines suspended below the apparatus and grown at various depths within the water column. In this case, the apparatus **10** may be utilized solely for producing non-shellfish species, or for producing more than one aquatic species simultaneously. In cases in which the apparatus **10** is utilized solely for growing non-shellfish species, the shellfish containers may optionally be removed from the apparatus. Controlling the position of the apparatus within the water column may accelerate growth of organisms such as kelp by moving kelp lines up and down within the water column diurnally for photosynthesis and respiration. This alternative configuration may also allow for quickly and easily sinking gear to the water bottom to avoid damaging storm waves. In addition, access to suspended gear at the surface would avoid the need for SCUBA divers or submersibles for aquaculture activities such as feeding, density reductions, harvest, gear maintenance and repair.

[0042] Figs. **9-19** illustrate another embodiment of an aquaculture apparatus **100** that may be utilized to control the depth of the apparatus **100** at any depth in the water **170** column, including a floating position, multiple suspended positions at different depths, and a completely submerged position in which the apparatus **100** is resting on the water bottom **174**. The aquaculture apparatus **100** comprises a lift vessel **112**, a container **126** for holding shellfish **128**, a floatation control tank **130**, and a compressed gas source **150** configured to independently supply gas to each of the lift vessel **112** and the floatation control tank **130**. The apparatus **100** further comprises a frame structure **132** attached to the lift vessel **112**. The frame structure **132** is designed to hold and secure shellfish **128** within the structure. Fig. **9** shows the apparatus **100** with the frame structure **132** attached to the lift vessel **112** and with the floatation control tank **130** and compressed gas source **150** both disconnected from the apparatus. In a preferred embodiment, the frame structure **132** comprises a plurality of rigid structural members **136**, **137** designed so that shellfish containers **126** can be inserted within the frame structure **132** and removably secured to the frame structure **132**, as best seen in Fig. **13**. The shellfish containers **126** are preferably mesh or wire containers that may be flexible, whereas the rigid frame structure **132** is suitable for providing structural support for other components of the apparatus **100**. Alternatively, the frame structure **132** may be designed with relatively small diameter openings so that the frame **132** itself be used to contain shellfish **128**. As best seen in Fig. **9**, the frame structure **132** may include a meshed flooring structure having small diameter openings for supporting the shellfish containers **126**, which may be secured directly to the floor or other structural members using suitable types of fasteners.

[0043] The lift vessel **112** has rigid walls and has an opening **124** on a bottom side of the lift vessel **112**, which can be seen in Fig. **10**, which shows the apparatus **100** in an inverted position to illustrate the bottom opening **124**. The opening **124** allows water to enter the interior of the lift vessel **112** to displace air in the lift vessel **112** when moving the apparatus **100** from the floating position to a suspended position. The opening **124** also provides a passageway through which air may displace water in the lift vessel **112** by forcing the water out through the opening **124** when moving the apparatus **100** from a suspended position to the floating position.

[0044] In a preferred embodiment, as best seen in Figs. **9-11**, the apparatus **100** comprises a plurality of lift vessels **112** that are spaced apart from each other and that each have at least a section having an elongated tubular shape. In this embodiment, the apparatus **100** further comprises a plurality of lift vessel fluid supply lines **156** each connecting a respective one of the plurality of lift vessels **112** to the compressed gas source **150**. Each lift vessel **112** has a first end **114** and a second end **116**. As shown in Fig. **11**, each lift vessel fluid supply line **156** is connected to a respective first end **114** of a lift vessel **112**, and each lift vessel **112** has an opening **124** located on the bottom side of the lift vessel **112** and positioned at the second end **116** of the lift vessel **112**, as shown in Fig. **10**. Each opening **124** is positioned at a low point of the lift vessel **112** when the apparatus **100** is in an upright position. Fig. **11** illustrates the apparatus **100** with two lift vessels **112**, though additional spaced lift vessels may be utilized to increase the capacity of the apparatus.

[0045] As best seen in Fig. **9**, each of the lift vessels **112** may be fastened to the frame structure **132** with a plurality of U-bolts **134** sized to fit around each tubular lift vessel **112** having a circular cross-sectional shape. Each U-bolt **134** may be fastened to two opposing parallel longitudinal frame members **136** of the frame structure **132** using a fastening plate **135** and threaded fasteners. The opposing longitudinal frame members **136** are preferably positioned on opposing sides of each of the tubular lift vessels **112**. In a preferred embodiment, as best seen in Figs. **9** and **10**, the frame structure **132** further comprises a plurality of cross support frame members **137** each connected to two longitudinal frame members **136** to provide structural support between the lift vessels **112** and support for the shellfish containers **126** contained within the frame structure **132**.

[0046] In a preferred embodiment, as best seen in Figs. **11** and **13**, the first end **114** of each lift vessel **112** has an angled section **188** that is angled upwardly relative to the elongated tubular section. In this embodiment, each lift vessel fluid supply line **156** may be connected to an upwardly facing terminal end **115** of the first end **114** of each of the lift vessels **112**. Fig. **9** shows the terminal ends **115** of each lift vessel **112** with a nozzle **118** for connecting the lift vessel fluid supply lines **156** to each of the lift vessels **112**. The angled sections **188** of each lift vessel **112** may aid in breaking waves when towing the apparatus **100**. The angled sections **188** may also provide a high point of each vessel **112** to which air may be supplied to more effectively displace water inside the vessels **112** with air by forcing the water out of the bottom openings **124**, which are at a low point at an opposite end of each vessel **112**. To facilitate towing of the apparatus **100**, each lift vessel **112** may have a loop **122** installed at each end of the vessel **112** for securing a tow rope, chain, or similar type of tow line. Loops **122** at the first end **114** may be used for direct towing of the apparatus **100**, and loops **122** at the second end **116** may be used to attach one apparatus **100** to another apparatus for towing multiple apparatuses at the same time.

[0047] The floatation control tank **130** has a rigid tank wall and is attached to the frame structure **132** in a generally centered position of the apparatus **100**, as best seen in Figs. **11** and **13**. The floatation control tank **130** is disposed above both the shellfish containers **126** and the lift vessels **112** when the apparatus **100** is in an upright position for normal use, as best seen in Fig. **13**. In a preferred embodiment, the floatation control tank **130** is a cylindrical tank, which preferably has rounded heads at a top end and at a bottom end. When attached to the frame structure **132**, the tank **130** is preferably disposed in a generally vertical position such that the height of the tank **130** is greater than the width of the tank **130**. The apparatus **100** is preferably designed so that the height of the tank **130** is approximately equal to the distance between two opposing lift vessels **112** attached to each other by the frame structure **132** to which the tank **130** is also attached, which may prevent inadvertent overturning of the apparatus **100** when floating or sinking the apparatus. In a preferred embodiment, the floatation control tank **130** is removably attached to a top side of the frame structure **132**. To facilitate removable attachment of the floatation control tank **130** to the frame structure **132**, the tank **130** may preferably have a pair of opposing tabs **144** extending outwardly from the exterior shell of the tank **130** near the bottom head of the tank **130**, as best seen in Fig. **12**. In this embodiment, as best seen in Fig. **9**, the frame structure **132** may comprise a circular support structure **145** sized to receive the tank **130** within the structure **145**. The circular support structure **145** has an internal groove **146** into which the tabs **144** may be placed to lock the tank **130** onto the frame structure **132**. The circular support structure **145** may have two opposing slots positioned so that the two opposing tabs **144** may be placed downward into each respective one of the slots so that both tabs **144** enter the internal groove

**146**, and the tank **130** may then be rotated to slide the tabs **144** in the groove **146** away from the slots to securely attach the tank **130** to the circular support structure **145**.

[0048] In a preferred embodiment, to further secure the floatation control tank **130** to the frame structure **132** and support the tank **130** in a generally vertical position, a plurality of tensioned wires **142** may be utilized to further attach the tank **130** to the frame structure **132** at a plurality of attachment points, which are preferably located at four corners of the frame structure **132**, as best seen in Figs. **11** and **13**. The tank **130** may have a plurality of eyelets **140** located near the top head of the tank **130**, and the frame structure **132** may also have a plurality of eyelets **141** positioned at the attachment points. Each wire **142** may be connected to a tank eyelet **140** at one end of the wire and to a frame structure eyelet **141** at a second end of the wire to provide tensioned support for the tank **130**.

[0049] As best seen in Fig. **12**, the floatation control tank **130** has an opening **148** located on a bottom side of the tank **130**. The tank **130** preferably has only a single opening **148** positioned at the center of the rounded bottom head of the tank **130** so that the opening **148** is positioned at a low point of the tank **130**. The tank **130** may have a nozzle **147** at the bottom, and the opening **148** may be defined by an aperture at a lower end of the nozzle **147**. Like openings **124** on the bottoms of the lift vessels **112**, opening **148** is preferably an aperture that remains open at all times. The opening **148** allows water to move into the tank **130** through the opening **148** when the water is displacing air in the tank **130**. The opening **148** also allows water to move out of the tank **130** through the opening **148** when air is being used to displace water in the tank **130**. A tank fluid supply line **158** connects the tank **130** to the compressed gas source **150**. As best seen in Figs. **11** and **13**, the tank fluid supply line **158** is preferably connected to a top side of the tank **130**, preferably at a centered position of the top head.

[0050] The apparatus **100** further comprises a suspension buoy **180** that is tethered to the apparatus **100** by a tether line **184**. As shown in Fig. **16**, the suspension buoy **180** allows the apparatus **100** to be suspended at a depth in the water column defined by the length of the tether line **184**. Thus, the suspension depth may be adjusted by adjusting the length of the tether **184**. In a preferred embodiment, the tether line **184** is a generally flexible line that is attached to a top end of the tank **130**. In a preferred embodiment, the tether **184** may be connected to a harness **185** that is connected to each of the eyelets **140** on the tank **130** to provide balanced support when suspending the apparatus **100** from the suspension buoy **180**. In an optional embodiment, the harness **185** may be connected to eyelets **141**. In one embodiment, the suspension buoy **180** is constructed of foam, plastic, or other suitable floatation material and is not inflatable. In an alternative embodiment, as shown in Fig. **17**, the suspension buoy **180** may be inflatable. In this embodiment, the apparatus **100** further comprises a suspension buoy fluid supply line **182** connecting the suspension buoy **180** to the compressed gas source **150**. To suspend the apparatus **100** with the suspension buoy **180** floating on the water surface **172**, gas may be supplied through the suspension buoy fluid supply line **182** to inflate the suspension buoy **180**. Fig. **17** shows the suspension buoy **180** in a deflated state, which optionally allows the apparatus **100** to sink all the way to the water bottom **174** and rest on the bottom **174**.

[0051] In a preferred embodiment, the apparatus **100** further comprises a manifold **160** configured to independently supply gas from the compressed gas source **150** to each of the lift vessels **112** and to the floatation control tank **130**, and optionally to the suspension buoy **180**. As best seen in Fig. **11**, the manifold **160** comprises a plurality of valves for controlling the gas flow. The manifold **160** is fluidly connected to the compressed gas source **150** through a primary fluid supply line **154** and has a primary gas supply valve **155** for controlling the flow of gas from the compressed gas source **150** into the manifold **160**. The manifold **160** is fluidly connected to the floatation control tank **130** through a tank fluid supply line **158**. The manifold has a floatation control valve **164** for supplying gas to the floatation control tank **130** in order to control the apparatus **100** in a suspended position in which the floatation control tank **130** is floating at the water surface **172**, as shown in Fig. **15**. The manifold **160** further comprises at least one lift valve **162** for supplying gas to one or more lift vessels **112** through at least one lift vessel fluid supply line **156**.

[0052] As shown in Figs. **14-17**, the compressed gas source **150** is preferably secured to a floating barge **152** or similar floating structure floating on the water surface **172**. The apparatus **100** may be deployed in at least three different positions, and optionally in four positions. Fig. **14** shows the apparatus **100** deployed in a floating position with the lift vessel **112** floating on the water surface **172**. In the floating position, the lift vessel **112** is filled with gas and is designed to lift the frame structure **132** to a position in which the frame structure **132** is positioned above the surface **172** of the water **170**. Fig. **15** shows the apparatus **100** deployed in a first suspended position with the floatation control tank **130** floating on the water surface

**172**. In the first suspended position, the floatation control tank **130** is designed to suspend the frame structure **132** below the water surface **172**. In the first suspended position, the tank **130** is filled with gas, and gas is evacuated from the lift vessel **112**. When gas is evacuated from the lift vessel **112**, water from the body of water **170** displaces the gas in the lift vessel **112** and fills the lift vessel **112** with water. Fig. **16** shows the apparatus **100** deployed in a second suspended position with the suspension buoy **180** floating on the water surface **172** and the apparatus **100** suspended in the water column at a depth defined by the length of the tether line **184**. In the second suspended position, the suspension buoy **180** is designed to suspend the frame structure **132** in a second position below the water surface **172**. In the second suspended position, the suspension buoy **180** is floating on the water surface **172**, and gas is evacuated from both the tank **130** and the lift vessel **112** so that both the tank **130** and lift vessel **112** fill with water. Fig. **17** shows an optional embodiment in which suspension buoy **180** is inflatable, which allows the apparatus **100** to be deployed in a completely submerged position with the lift vessel **112** resting on the water bottom **174**. In the submerged position, the suspension buoy **180** is deflated, and gas has been displaced by water in both the tank **130** and the lift vessel **112**.

[0053] A method of controlling floatation of the apparatus **100** is also provided. First, the apparatus **100** may be deployed in the floating position by substantially filling the lift vessels **112** with gas so that the lift vessels **112** are floating on the water surface **172** and supporting the frame structure **132** and any shellfish **128** contained therein above the water surface **172**. The apparatus **100** may then be submerged in the body of water **170** by evacuating gas from the lift vessels **112** and from the floatation control tank **130**, thereby allowing both the lift vessels **112** and the tank **130** to substantially fill with water so that the lift vessels **112** and tank **130** sink below the water surface **172**. This action will deploy the apparatus **100** in the second suspended position, as shown in Fig. **16**, with the suspension buoy **180** floating on the surface **172** and both the lift vessels **112** and tank **130** suspended in the water **170** at a depth below the suspension buoy **180**, or optionally in the completely submerged position, as shown in Fig. **17**. To move the apparatus **100** to the first suspended position, as shown in Fig. **15**, gas may be supplied from the compressed gas source **150** to the tank **130** to substantially fill the tank **130** with gas, thereby causing the tank **130** to rise to the surface **172** with the lift vessels **112** and the frame structure **132** suspended below the tank **130**. When gas is supplied to the tank **130**, the gas displaces water in the tank **130** by forcing the water out of the opening **148** located on the bottom of the tank **130**. To then move the apparatus **100** into the floating position, as shown in Fig. **14**, gas may be supplied from the compressed gas source **150** to the lift vessels **112**, thereby causing the apparatus **100** to float with the frame structure **132** being held above the surface **172**. When gas is supplied to the lift vessels **112**, the gas displaces water in the lift vessels **112** by forcing the water out of the openings **124** located on the bottom sides of the lift vessels **112**.

[0054] To submerge the apparatus **100**, pressure may be relieved from the lift vessels **112** and the tank **130**. First, pressure may be relieved from the lift vessels **112** to the atmosphere via the lift vessel fluid supply lines **156** to evacuate gas from the lift vessels **112** so that water displaces the gas in the lift vessels **112** via water entering each of the lift vessels **112** through the opening **124** located on the bottom side of each lift vessel **112**, thereby causing each lift vessel **112** to sink below the surface **172**. Next, pressure may be relieved from the tank **130** to the atmosphere via the tank fluid supply line **158** to evacuate gas from the tank **130** so that water displaces the gas in the tank **130** via water entering the tank **130** through the opening **148** located on the bottom side of the tank **130**, thereby causing the tank **130** to sink below the surface **172**.

[0055] In a preferred embodiment, the manifold **160** may be utilized for supplying gas and for relieving pressure. Gas may be supplied to the tank **130** from the compressed gas source **150** by opening the floatation control valve **164**, and gas may be supplied from the compressed gas source **150** to each lift vessel **112** by opening each of the lift valves **162** on the manifold **160**. Pressure may also be relieved from both the lift vessels **112** and the tank **130** to the atmosphere through the manifold **160** to allow water to displace gas in the lift vessels **112** and tank **130**. To submerge the apparatus **100**, pressure on the lift vessels **112** may first be relieved via the lift vessel fluid supply lines **156** by disconnecting the primary fluid supply line **154** from the primary gas supply valve **155** and opening the lift valves **162** and the primary gas supply valve **155**. As the pressure is relieved, gas will flow to the atmosphere through the manifold **160** and water will displace substantially all of the gas in the lift vessels **112**. At this point, the floatation control valve **164** should remain closed to maintain gas pressure inside the tank **130**. Pressure may then be relieved from the tank **130** via the tank fluid supply line **158** by opening valve **164** to allow water to displace gas in the tank **130**. In an alternative embodiment, the manifold **160** may have one or more separate designated pressure relief valves that may be opened individually for the purposes of relieving pressure on one or more lift vessels **112**, as well as the tank **130**, to the atmosphere without the need to disconnect the primary fluid supply line **154** from the manifold **160**.

[0056] In one embodiment, the suspension buoy **180** is inflatable. In this embodiment, as shown in Fig. **17**, the manifold **160** may comprise an additional valve **186** for supply gas to the suspension buoy **180** and for relieving pressure from the buoy **180**, and the buoy **180** may be connected to the manifold **160** via a fluid supply line **182**. In this embodiment, pressure may be relieved from the suspension buoy **180** through the suspension buoy fluid supply line **182** by opening valve **186** to allow gas in the buoy **180** to flow to the atmosphere, thereby causing the buoy **180** to deflate, as shown in Fig. **17**. With the suspension buoy **180** deflated, the apparatus **100** may be deployed in the completely submerged position with the apparatus **100** resting on the water bottom **174**. In this embodiment, to deploy the apparatus **100** in the second suspended position with the suspension buoy **180** floating on the water surface **172**, valve **186** may be opened with the manifold **160** connected to the compressed gas source **150** to supply gas to the suspension buoy **180** to inflate the buoy **180**, thereby causing the suspension buoy **180** to float on the surface **172**.

[0057] In a preferred embodiment, as shown in Figs. **18** and **19**, the apparatus **100** further comprises a plurality of water distribution pipes **192** connected to a bottom of the tank **130**. Each of the water distribution pipes **192** extends into an interior of the frame structure **132**, and each of the pipes **192** has a plurality of openings **194** in a wall of the pipe **192**. The openings **194** extend along a length of each pipe **192**. The water distribution pipes **192** are fluidly connected to the floatation control tank **130**.

The pipes **192** may be connected to the tank **130** by a short length of pipe **190** or hose connected to the nozzle **147** located at the bottom of the tank **130**, preferably in a centered position on the bottom head of the tank **130**. Support members **197** are preferably utilized to attach the pipes **192** to structural members **136** or **137** to provide structural support to the pipes **192**. In a preferred embodiment, the support members **197** are vertically positioned and attach the pipes **192** to members of the frame structure **132** positioned above the pipes **192**. In this embodiment, when air is supplied to the tank **130** to displace water from the tank **130** in order to cause the floatation control tank **130** to rise in the water column, the water contained inside the tank **130** is pushed out of the plurality of openings **194** in the water distribution pipes **192**. The openings **194** are positioned on a bottom side of each of the pipes **192** so that water from the tank **130** is flushed in a downward direction from the openings **194** in the pipes **192**, which flushes water downward into the shellfish containers **126**. This flushing action utilizes the force of water being displaced from the tank **130** to help wash away dirt and debris from the shellfish **128** to produce a cleaner product. When using water to displace air from the tank **130** to submerge the apparatus **100**, the water may enter the tank **130** through the plurality of openings **194** in the pipes **192**. Thus, in this embodiment, the openings **194** in the pipes **192** may collectively function in the same manner as the opening **148** in the bottom of the tank **130**.

[0058] Fig. **19** shows a schematic view of a preferred embodiment of the water distribution piping **192**, which is generally disposed within the interior of frame structure **132** in a position below tank **130** and above the shellfish **128** contained within containers **126**. In a preferred embodiment, the apparatus **100** comprises two parallel water distribution pipes **192** that are disposed in a generally horizontal position above two rows of shellfish containers **126**. Additional pipes **192** in other configurations may be utilized depending on the size of the apparatus **100** and the number and configuration of shellfish containers **126**. The two parallel water distribution pipes **192** may be fluidly connected to each other by a connecting pipe **196** extending between the parallel pipes. Hose or pipe **190** may be connected to a nozzle **195** on the connecting pipe **196** to supply water from the tank **130** into both of the parallel water distribution pipes **192**.

[0059] It is understood that versions of the invention may come in different forms and embodiments. Additionally, it is understood that one of skill in the art would appreciate these various forms and embodiments as falling within the scope of the invention as disclosed herein.

CLAIMS

What is claimed is:

1.) An aquaculture apparatus, comprising:

a lift vessel;

a frame structure for holding shellfish therein, wherein the frame structure is attached to the lift vessel;

a floatation control tank having a rigid tank wall, wherein the tank is attached to the frame structure in a generally centered position of the apparatus, wherein the tank is disposed above the lift vessel when the apparatus is in an upright position;

a suspension buoy tethered to the apparatus;

a compressed gas source configured to independently supply gas to each of the lift vessel and the tank, respectively;

a lift vessel fluid supply line connecting the lift vessel to the compressed gas source; and

a tank fluid supply line connecting the tank to the compressed gas source,

wherein the lift vessel is designed to lift the frame structure to a position in which the frame structure is positioned above a water surface when the apparatus is in a floating position on the water surface in which the lift vessel is filled with gas, wherein the tank is designed to suspend the frame structure in a first position below the water surface when the apparatus is in a first suspended position in which the tank is filled with gas and in which gas is evacuated from the lift vessel, and

wherein the suspension buoy is designed to suspend the frame structure in a second position below the water surface when the apparatus is in a second suspended position in which the suspension buoy is floating on the water surface and gas is evacuated from both the tank and the lift vessel.

2.) The apparatus of claim 1, wherein the tank has an opening located on a bottom side of the tank.

3.) The apparatus of claim 1, wherein the tank is disposed in a generally vertical position such that a height of the tank is greater than a width of the tank.

4.) The apparatus of claim 1, wherein the tank is removably attached to the frame structure.

5.) The apparatus of claim 1, wherein the suspension buoy is tethered to the apparatus by a generally flexible line, wherein the line is attached to a top end of the tank.

6.) The apparatus of claim 1, wherein the suspension buoy is inflatable, wherein the apparatus further comprises a suspension buoy fluid supply line connecting the suspension buoy to the compressed gas source.

7.) The apparatus of claim 1, wherein the lift vessel has a rigid vessel wall, wherein the lift vessel has an opening located on a bottom side of the lift vessel.

8.) The apparatus of claim 1, wherein the apparatus comprises a plurality of lift vessels that are spaced apart from each other, wherein each of the plurality of lift vessels comprises an elongated tubular section, wherein the apparatus comprises a plurality of lift vessel fluid supply lines each connecting a respective one of the plurality of lift vessels to the compressed gas source, wherein each lift vessel has a first end and a second end, wherein each lift vessel fluid supply line is connected to a respective first end of a lift vessel, and wherein each lift vessel has an opening located on a bottom side of the lift vessel and positioned at the second end of the lift vessel.

9.) The apparatus of claim 8, wherein the first end of each of the plurality of lift vessels has an angled section that is angled upwardly relative to the elongated tubular section, wherein each lift vessel fluid supply line is connected to an upwardly facing terminal end of the first end of each respective one of the plurality of lift vessels.

10.) The apparatus of claim 1, further comprising a manifold fluidly connected to the compressed gas source through a primary fluid supply line, to the lift vessel through the lift vessel fluid supply line, and to the tank through the tank fluid supply line, wherein the compressed gas source is configured to independently supply gas to each of the lift vessel and the tank, respectively, through the manifold.

11.) The apparatus of claim 1, further comprising a plurality of water distribution pipes connected to a bottom of the tank, wherein each of the water distribution pipes extends into an interior of the frame structure, wherein each pipe of the plurality of water distribution pipes has a plurality of openings in a wall of the pipe.

12.) A method of controlling floatation of an aquaculture apparatus, said method comprising the steps of:

providing an aquaculture apparatus comprising:

a lift vessel,

a frame structure for holding shellfish therein, wherein the frame structure is attached to the lift vessel,

a floatation control tank having a rigid tank wall, wherein the tank is attached to the frame structure in a generally centered position of the apparatus, wherein the tank is disposed above the lift vessel when the apparatus is in an upright position,

a suspension buoy tethered to the apparatus,

a compressed gas source configured to independently supply gas to each of the lift vessel and the tank, respectively,

a lift vessel fluid supply line connecting the lift vessel to the compressed gas source, and

a tank fluid supply line connecting the tank to the compressed gas source,

wherein the lift vessel is designed to lift the frame structure to a position in which the frame structure is positioned above a water surface when the apparatus is in a floating position on the water surface in which the lift vessel is filled with gas,

wherein the tank is designed to suspend the frame structure in a first position below the water surface when the apparatus is in a first suspended position in which the tank is filled with gas and in which gas is evacuated from the lift vessel, and

wherein the suspension buoy is designed to suspend the frame structure in a second position below the water surface when the apparatus is in a second suspended position in which the suspension buoy is floating on the water surface and gas is evacuated from both the tank and the lift vessel;

submerging the apparatus in a body of water by evacuating gas from the lift vessel and from the tank, thereby allowing both the lift vessel and the tank to substantially fill with water;

then supplying gas from the compressed gas source to the tank to substantially fill the tank with gas, thereby causing the tank to rise to the surface of the body of water with the lift vessel and the frame structure suspended in the body of water below the tank; and

then floating the apparatus by supplying gas from the compressed gas source to the lift vessel, thereby causing the apparatus to float with the frame structure being held above the surface of the water.

13.) The method of claim 12, further comprising the step of suspending the apparatus in the body of water by floating the suspension buoy on the surface of the water and evacuating gas from both the lift vessel and from the tank, thereby causing both the lift vessel and the tank to sink below the surface of the water and to be suspended in the body of water at a depth below the suspension buoy.

14.) The method of claim 13, wherein the suspension buoy is inflatable, wherein the apparatus further comprises a suspension buoy fluid supply line connecting the suspension buoy to the compressed gas source, wherein the step of suspending the apparatus in the body of water comprises supplying gas from the compressed gas source to the suspension buoy to inflate the suspension buoy, thereby causing the suspension buoy to float on the surface of the water.

15.) The method of claim 12, wherein the lift vessel has a rigid vessel wall, wherein the lift vessel has an opening located on a bottom side of the lift vessel, and wherein the tank has an opening located on a bottom side of the tank.

16.) The method of claim 15, wherein the step of submerging the apparatus comprises the steps of:

first relieving pressure from the lift vessel to the atmosphere via the lift vessel fluid supply line to evacuate gas from the lift vessel so that water displaces the gas in the lift vessel via water entering the lift vessel through the opening located on the bottom side of the lift vessel, thereby causing the lift vessel to sink below the surface of the water; and then

relieving pressure from the tank to the atmosphere via the tank fluid supply line to evacuate gas from the tank so that water displaces the gas in the tank via water entering the tank through the opening located on the bottom side of the tank, thereby causing the tank to sink below the surface of the water.

17.) The method of claim 15, wherein the step of supplying gas from the compressed gas source to the tank comprises supplying gas from the compressed gas source to the tank so that the gas displaces water in the tank by forcing the water out of the opening located on the bottom side of the tank.

18.) The method of claim 15, wherein the step of floating the apparatus comprises supplying gas from the compressed gas source to the lift vessel so that the gas displaces water in the lift vessel by forcing the water out of the opening located on the bottom side of the lift vessel.

19.) The method of claim 12, wherein the apparatus further comprises a manifold fluidly connected to the compressed gas source through a primary fluid supply line, to the lift vessel through the lift vessel fluid supply line, and to the tank through the tank fluid supply line, wherein the manifold is configured to independently supply gas to each of the lift vessel and the tank, respectively,

wherein the step of supplying gas to the tank comprises opening a float valve on the manifold, and

wherein the step of supplying gas to the lift vessel comprises opening a lift valve on the manifold.

20.) The method of claim 16, wherein the apparatus further comprises a manifold fluidly connected to the compressed gas source through a primary fluid supply line, to the lift vessel through the lift vessel fluid supply line, and to the tank through the tank fluid supply line, wherein the manifold is configured to independently supply gas to each of the lift vessel and the tank, respectively,

wherein the step of relieving pressure from the lift vessel to the atmosphere comprises relieving pressure through the manifold, and

wherein the step of relieving pressure from the tank to the atmosphere comprises relieving pressure through the manifold.

*PNEUMATICALLY CONTROLLED AQUACULTURE APPARATUS*

ABSTRACT OF THE DISCLOSURE

A pneumatically controlled aquaculture apparatus is provided. The apparatus has a lift vessel that lifts containers holding shellfish out of the water when the lift vessel is floating in order to allow air desiccation to prevent bio-fouling of the equipment and shellfish. The apparatus has a floatation control tank positioned above the containers holding shellfish in a centered position of the apparatus. The apparatus also has a suspension buoy for suspending the apparatus in the water column. The apparatus may be deployed in two different suspended positions with either the floatation control tank or the suspension buoy floating on the water surface and the containers holding shellfish suspended below the surface. The apparatus may also be deployed in a submerged position in which the apparatus is resting on the water bottom.