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Application Number	Not Yet Assigned
Filing Date	Concurrently Herewith
First Named Inventor	Matthew Jordan ODLIN
Title	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE
Art Unit	N/A
Examiner Name	Not Yet Assigned
Attorney Docket Number	RUNN-002/01US 331356-2009

SIGNATURE of Applicant or Patent Practitioner

Signature	/Michael D. Winternitz/	Date (Optional)	September 15, 2020
Name	Michael Winternitz	Registration Number	73,102
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)	Running Tide Technologies, Inc.		

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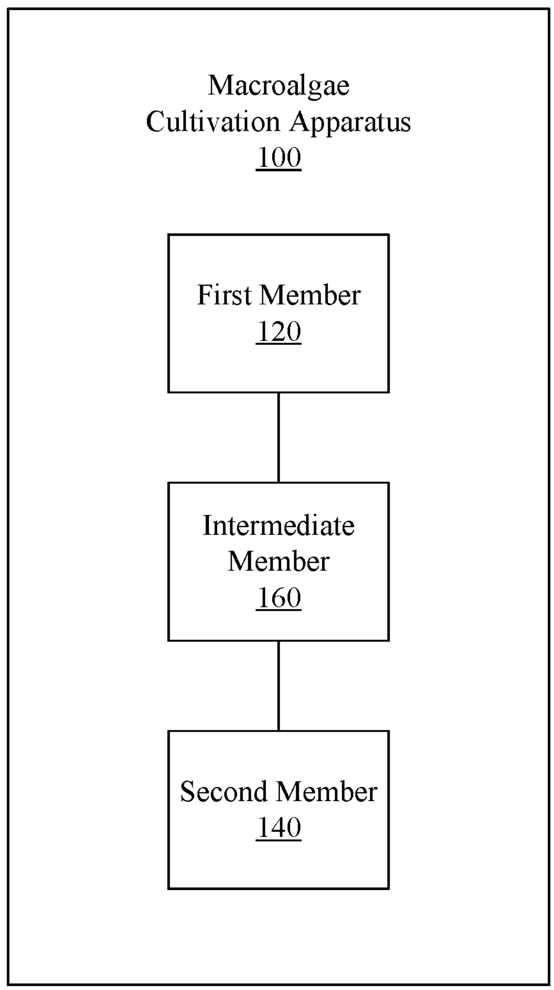
Macroalgae
Cultivation Apparatus
100
First Member
120
Intermediate
Member
160
Second Member
140

FIG. 1

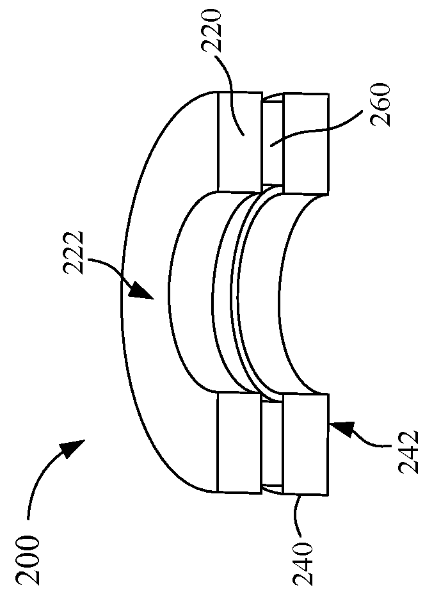

FIG. 3

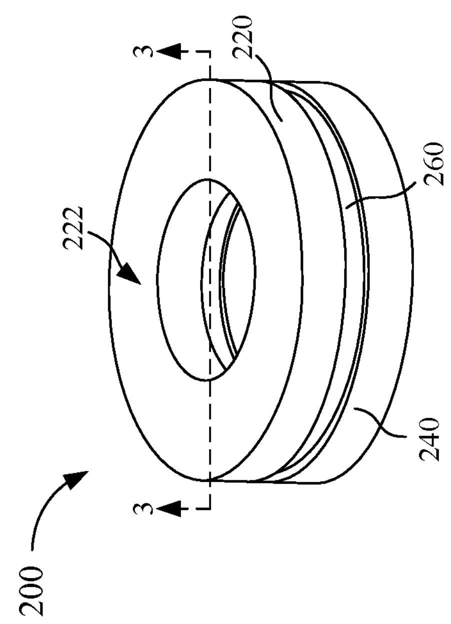

FIG. 2

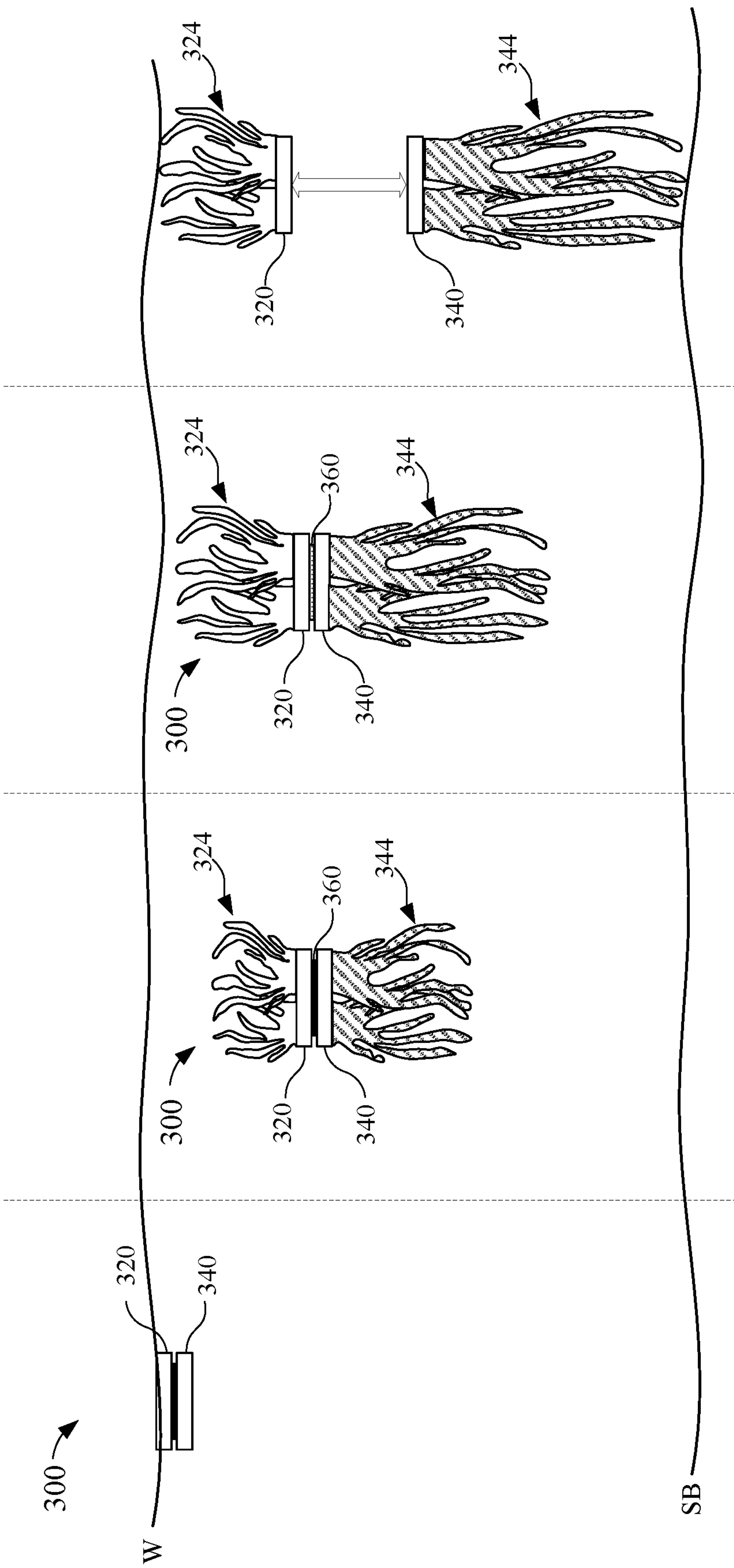

FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

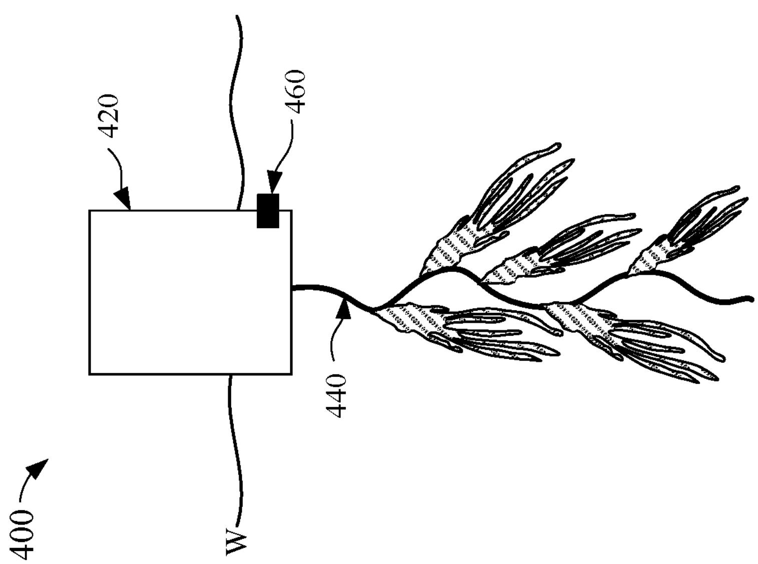

FIG. 5

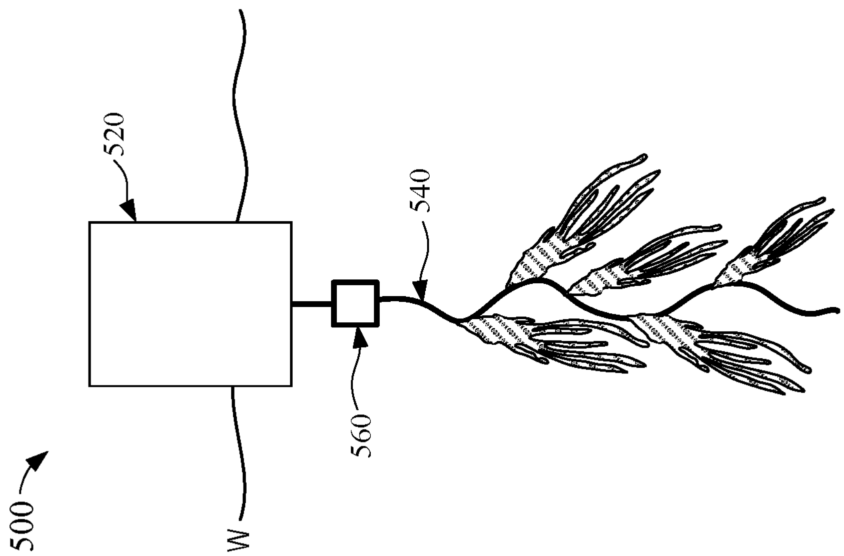

FIG. 6

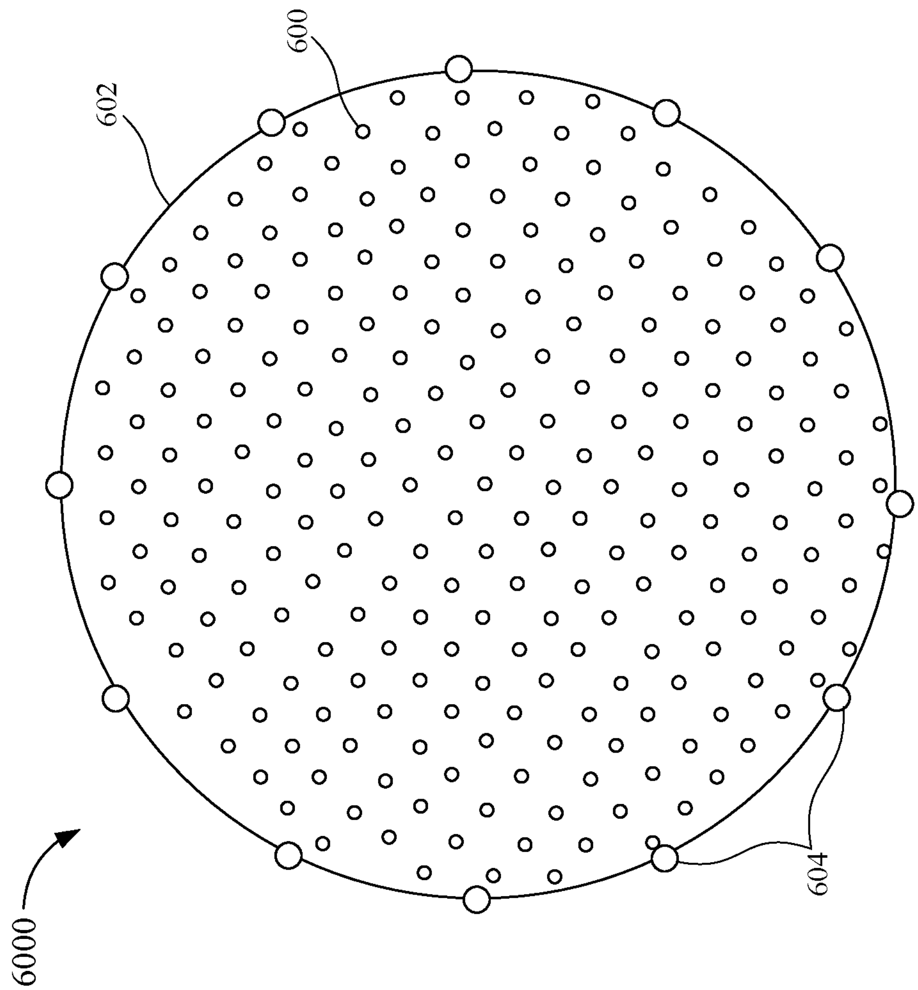

FIG. 7

SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE

Technical Field

[0001] This disclosure relates generally to the cultivation of macroalgae, and more particularly to systems and methods for cultivating different types of macroalgae for harvest and carbon sequestration.

Background

[0002] Cultivating algae such as macroalgae has become more important in recent years since macroalgae are considered as a promising resource for the future. Macroalgae are used for food or feed, as additives for food or feed, as raw materials for biofuels, as raw materials for pharmaceutical products, as raw materials for (bio) materials, etc. Cultivating algae has many advantages. Compared to the cultivation of plants on land, the cultivation of macroalgae leads to higher productivity. In addition, no scarce farmland or freshwater is needed and no additional nutrients are needed for the cultivation of macroalgae. Furthermore, macroalgae can make an important contribution to protecting or increasing the marine biodiversity and/or to mitigating harmful effects of anthropogenic greenhouse gas emissions. Accordingly, a need exists for improved systems and methods for cultivating macroalgae.

Summary

[0003] Systems and methods for cultivating macroalgae are described herein. In some embodiments, the system includes an apparatus for cultivating macroalgae having a first member seeded with a first species of macroalgae that becomes positively buoyant as it matures, a second member seeded with a second species of macroalgae that becomes negatively buoyant as it matures, and an intermediate member coupling the first to the second member, the intermediate member configured to degrade and decouple the first member from the second member.

Brief Description of the Drawings

[0004] FIG. 1 is a schematic illustration of a macroalgae cultivation apparatus, according to an embodiment.

[0005] FIG. 2 is a perspective view of a macroalgae cultivation apparatus, according to an embodiment.

[0006] FIG. 3 is a cross-sectional view the macroalgae cultivation apparatus of FIG. 2 taken along the line 3-3.

[0007] FIGS. 4A-4D are a schematic illustration of the life cycle of a macroalgae cultivation apparatus, according to an embodiment.

[0008] FIG. 5 is a schematic illustration of a macroalgae cultivation apparatus, according to an embodiment.

[0009] FIG. 6 is a schematic illustration of a macroalgae cultivation apparatus, according to an embodiment.

[0010] FIG. 7 is a top view of a macroalgae cultivation system, according to an embodiment.

Detailed Description

[0011] Systems and methods for cultivating macroalgae are described herein. In some embodiments, the system includes an apparatus for cultivating macroalgae having a first member seeded with a first species of macroalgae that becomes positively buoyant as it matures, a second member seeded with a second species of macroalgae that becomes negatively buoyant as it matures, and an intermediate member coupling the first to the second member, the intermediate member configured to degrade and decouple the first member from the second member. In some embodiments, the apparatus can be seeded with any number of positively buoyant and/or negatively buoyant species of macroalgae (e.g., two or more species having positive buoyancy and/or two or more species having negative buoyancy). In some embodiments, the apparatus can include one or more weights or the like that can create and/or supplement an amount of negative buoyancy allowing the apparatus to be sunk and/or submerged at a predetermined and/or desired depth and/or to otherwise offset the positive buoyancy associated with the first species.

[0012] The systems and methods described herein can be used in oceans, lakes, rivers, and/or any other suitable body of water. In some embodiments, the system includes at least one apparatus configured to receive and grow species of macroalgae gametophytes and/or sporophytes, which become positively or negatively buoyant as they mature, and that can be harvested and/or sequestered.

[0013] The abatement of harmful anthropogenic greenhouse gas emissions requires the development of technologies for carbon sequestration at the multi-gigaton scale in order to be atmospherically significant. Macroalgae has shown promise as a carbon sequestration technology as an estimated 11% of its biomass is naturally sequestered to the seafloor. Macroalgae cultivation has the potential to improve this sequestration rate significantly due to increased cultivation productivity relative to naturally-occurring macroalgae. Additionally, this technology may become increasingly desirable as prices in the global carbon credit market continue to climb. For example, in some implementations, an amount of carbon that can be sequestered per unit of macroalgae can be calculated and sold in a carbon credit market (or any other suitable market) as a credit tied to and/or otherwise associated with the calculated capacity of a unit of macroalgae to sequester that carbon.

[0014] Some known methods for growing and/or cultivating macroalgae use longlines, which need to be tendered after placing and harvested after the growth period is completed, resulting in prohibitively high labor costs. As such, a need exists for macroalgae cultivation systems and methods that do not require longlines, and thus little to no tending after placement, and that may be used solely for sequestration operations, for harvesting operations, and/or for both sequestration and harvesting, offering the potential to be a highly scalable solution from a manufacturing and operations standpoint for large scale carbon capture.

[0015] Referring now to the drawings, FIG. 1 is a schematic illustration of a macroalgae cultivation apparatus 100 according to an embodiment. The macroalgae cultivation apparatus 100 (also referred to herein as “cultivation apparatus” or “apparatus”) includes a first member 120 configured to receive a first species of macroalgae gametophytes and/or sporophytes, a second member 140 configured to receive a second species of macroalgae gametophytes and/or sporophytes, and an intermediate member 160 configured to reversibly couple the first member 120 to the second member 140. The first member 120 of the cultivation apparatus 100 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the first member 120 can be a ring-like shape, triangular shape, disc, sphere, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments, the first member 120 can be an irregular shape. In some embodiments, one or more portions of the first member 120 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, one or more portions of the first member 120 can be formed of a material relatively permeable to oxygen, carbon dioxide, water, and water-soluble nutrients to enable macroalgae growth. In some embodiments, one or more portions of the first member 120 can be formed of a relatively transparent material configured to allow absorption visible light.

[0016] The cultivation apparatus 100 can be used to seed species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. For example, in some instances, the first member 120 of the apparatus 100 can be seeded with macroalgae gametophytes and/or sporophytes species that become positively buoyant as they mature, and the second member 140 of the apparatus 100 can be seeded with macroalgae gametophytes and/or sporophytes species that become negatively buoyant as they mature. In some embodiments, the apparatus 100 can be first seeded with positively and negatively buoyant macroalgae gametophytes and/or sporophytes, and then deployed on oceans, lakes, rivers, and/or any other suitable body of water. The apparatus 100 can be further configured to be positively buoyant when initially deployed on oceans, lakes, rivers, and/or any other suitable body of water. In some embodiments, the apparatus 100 can be configured to float for a predetermined period of time after being deployed on oceans, lakes, rivers and/or any other body of water, and then gradually sink as the second member 140 seeded with negatively buoyant macroalgae grows and obtains biomass.

[0017] In some embodiments, the apparatus 100 can be further configured to sense, detect, and/or monitor macroalgae growth, biomass generation, and/or biomass yield upon being seeded with macroalgae gametophytes and/or sporophytes, deployed on oceans, lakes, rivers, and/or any other suitable body of water, and allowed to gradually sink as the apparatus 100 gains biomass. For example, in some embodiments the apparatus 100 can include one or more sensors configured to sense, detect, and/or monitor one or more characteristics associated with macroalgae growth. In some embodiments, the apparatus 100 can include underwater cameras or other imaging technologies configured to image, record, and/or monitor number of plants and/or heterokonts (e.g., kelp, macroalgae, etc.), number of fronds per heterokont, frond dimensions, and/or density associated to macroalgae growth. In some embodiments, the apparatus 100 can include one or more sensors configured to sense, detect, and/or measure water temperature, irradiance, dissolved oxygen concentration, concentration of nutrients, concentration of dissolved carbon, salinity, and/or other characteristics related to macroalgae growth. The plant size, plant density, water temperature, irradiance, dissolved oxygen concentration, concentration of nutrients, concentration of dissolved carbon, salinity and/or other characteristics related to macroalgae growth can be sensed and/or detected by the one or more sensors and data associated with an output of the sensor(s) can be analyzed (e.g., by the control system, an analysis unit, and/or other compute device) to determine macroalgae growth, quantify biomass production, and/or biomass yield. In other words, data output by the one or more sensors can be analyzed to determine macroalgae growth, biomass production, carbon capture and/or sequestration rates, quantities, or capacities, and/or the like.

[0018] In some embodiments, the apparatus 100 can include pressure-release depth sensors configured to measure, record, and/or transmit the sinking rate of the apparatus 100 as a function of time after the apparatus is seeded with macroalgae gametophytes and/or sporophytes, and deployed on oceans, lakes, rivers, and/or any other suitable body of water. The pressure-release depth sensors can be configured to measure the sinking rate of the apparatus 100, decouple from the apparatus 100 once the apparatus 100 reaches a predetermined depth threshold, emit the sinking rate information recorded via satellite, and return to the surface. In some instances, the sinking rate of the apparatus 100 can be used to quantify the biomass and related carbon captured and/or sequestered. In some instances, the pressure-release depth sensors can be used to determine whether the apparatus 100 has sunk below a predetermined depth or threshold associated with and/or suitable for the permanent sequestration carbon.

[0019] In some embodiments, the apparatus 100 can include one or more tracking devices configured to produce, and/or transmit signals associated with the apparatus 100 relative position upon being seeded with macroalgae gametophytes and/or sporophytes and being deployed on oceans, lakes, rivers, and/or any other suitable body of water. The position and/or trajectory of the apparatus 100 can be transmitted, recorded and/or stored (e.g., by the control system, an analysis unit, and/or other compute device) and can be further employed by remote sensing devices to determine and/or quantify (directly or indirectly) macroalgae growth, biomass production, and/or carbon capture. For example, in some instances, the apparatus 100 can include a Global Positioning System (GPS) tracking device configured to determine, record, and/or transmit the apparatus 100 geographic location. In other instances, the apparatus 100 can include Radio-Frequency Identification (RFID) devices configured to determine, record, and/or transmit the apparatus 100 geographic location. The geographic location of the apparatus 100 can be further used by remote sensing techniques to determine macroalgae growth, and quantify biomass production, biomass yield, and carbon capture. For example, in some instances, remote sensing techniques such as near-infrared aerial photography, SPOT multispectral imagery, aerial digital multispectral imaging systems (DMSC) calibrated with ground truthing, and/or airborne hyperspectral systems can be used to quantify biomass production, biomass yield, and carbon capture. In some instances, trajectory data can be used to determine, calculate, and/or infer biomass growth by comparing surface or subsurface conditions (e.g., wind, current, etc.) with subsurface biomass motion and/or the like.

[0020] In some implementations, biomass production, biomass yield, macroalgae growth, carbon sequestration capacity per unit mass of macroalgae, and/or the like associated with a farm or system of any number of the seeded apparatus 100 can be calculated, determined, predicted, forecasted, estimated, and/or the like based on a relatively small sample. In some such implementations, such a method or process can include seeding, for example, the apparatus 100 with macroalgae, deploying the apparatus 100 on or in oceans, lakes, rivers, and/or any other suitable body of water, allowing the apparatus 100 to sink as the apparatus 100 gains biomass, and then retrieving the apparatus 100 after a predetermined amount of time to measure the weight and dimensions of macroalgae grown. For example, in some instances, the apparatus 100 can be retrieved after a predetermined amount of time after deployment on oceans, lakes, rivers, and/or any other suitable body of water, and the wet weight (i.e., the weight of macroalgae as it is retrieved from the apparatus 100), the dry weight (i.e., the weight of macroalgae after drying under predetermined conditions), and overall dimensions of the macroalgae grown can be measured and quantified.

[0021] In some instances, the wet weight, dry weight, dry-to-wet weight ratios, and/or dimensions of macroalgae can be used to quantify and/or determine macroalgae growth characteristics for a given set of environmental variables. In some such implementations, any of the sensors described above can be used, for example, during the growth phase, to sense, detect, and/or otherwise provide data that enables the calculation and/or determination of the set of environmental variables (e.g., water temperature, irradiance, dissolved oxygen concentration, concentration of nutrients, concentration of dissolved carbon, salinity, water current conditions, bacterial blooms, El Niño or La Niña oscillation phases, etc.). Moreover, in some instances, additional analysis can be performed to determine carbon content for the macroalgae, a percentage of carbon present per unit of mass of macroalgae, and/or the like. The percentage of carbon present per unit of mass of macroalgae can be further used to calculate the mass of carbon dioxide captured and/or sequestered by considering the atomic weight of carbon, the atomic weight of oxygen, and the mass of carbon present per unit of mass of macroalgae.

[0022] For example, in some instances, a percentage of carbon per unit mass of macroalgae (dry) can be between about 30% and 40%, about 33% and about 39%, and/or about 34% and about 38%. In some instances, the percentage of carbon per unit mass of macroalgae can be between 34.8% and about 37.4%. Thus, for 1 kg of dry macroalgae at 37.4% carbon content, the mass of sequestered carbon is 0.374 kg of carbon. Using the atomic masses of carbon and oxygen, it can be determined that the 0.374 kg mass of carbon corresponds to 1.37 kg of CO_2. The calculated dry-to-wet ratio of the macroalgae can then be used to determine a mass of CO_2 sequestered per unit mass of wet macroalgae. In some instances, such calculations further can be used to determine, for example, a mass of CO_2 sequestered per unit length of macroalgae, and/or any other suitable characteristic. These characteristics can, in turn, be associated with the sensed, determined, and/or detected environmental variables allowing growth and/or carbon sequestration performance to be correlated to environmental variables. Furthermore, based on the calculations, data, and/or performance of the sample, characteristics, performance, etc., of an entire farm (or portion thereof such as a microfarm, assembly of any number of apparatus 100, and/or the like) can be determined, inferred, modeled, etc.

[0023] In some instances, such calculations, derivations, correlations, and/or the like can lead to and/or produce a desired level of predictability, foreseeability, and/or the like. The ability to predict and/or forecast growth and/or performance characteristics of the apparatus 100 (and/or a farm including large numbers of the apparatus 100) and/or a capacity to sequester carbon or carbon dioxide can, for example, enable the capacity to be bought and/or sold as a commodity and/or the like. For example, determining a sequestration capacity per unit mass and/or length of macroalgae can allow that capacity to be sold as a carbon credit on a carbon credit market. In some instances, the macroalgae and/or the carbon sequestration capacity can be bought and sold, for example, on a commodities market, a futures market, and/or any other suitable market.

[0024] The first member 120 of the cultivation apparatus 100 can be configured to receive a first species of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, one or more portions of the first member 120 can include a growth substrate (not shown) configured to provide the nutrients required for macroalgae growth. In some embodiments, the first member 120 growth substrate can include an enriched seawater medium, pasteurized seawater, filtrated seawater, seawater mixed with buffer solutions including but not limited to sodium nitrate ($NaNO_3$) solution, potassium dihydrogen phosphate (KH_2PO_4) solution, and/or the like. In some embodiments, the first member 120 growth substrate can include a binder configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes to the growth substrate. In some embodiments, the first member 120 growth substrate can be formed of a fibrous material configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes to the first member 120. In some embodiments, the first member 120 growth substrate can include additives formulated to suppress contamination of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, the first member 120 growth substrate can include germanium dioxide (GeO_2).

[0025] The second member 140 of the cultivation apparatus 100 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the second member 140 can be a ring-like shape, triangular shape, disc, sphere, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments, the second member 140 can be an irregular shape. In some embodiments the shape of the second member 140 can be substantially similar to or the same as the shape of the first member 120. In some embodiments, one or more portions of the second member 140 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, one or more portions of the second member 140 can be formed of a material relatively permeable to oxygen, carbon dioxide, water, and water-soluble nutrients to enable macroalgae growth. In some embodiments, one or more portions of the second member 140 can be formed of a relatively transparent material configured to allow absorption visible light.

[0026] The second member 140 can be configured to receive a second species of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, one or more portions of the second member 140 can include a growth substrate (not shown) configured to provide the nutrients required for macroalgae growth. In some embodiments the composition of the second member 140 growth substrate can be substantially similar to or the same as the composition of the first member 120 growth substrate. Accordingly, the composition of the second member 140 growth substrate may not be described in further detail herein. In some embodiments, the second member 140 growth substrate can include a binder configured to facilitate attachment of the gametophytes and/or sporophytes to the growth substrate. In some embodiments, the second member 140 can be formed of a fibrous material configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes. In some embodiments, the second member 140 can include additives formulated to suppress contamination of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, the second member 140 can include germanium dioxide (GeO_2).

[0027] The intermediate member 160 of the cultivation apparatus 100 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the intermediate member 160 can be a ring-like shape, triangular shape, sphere, disc, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments the intermediate member 160 can be a shape and size substantially similar to or the same as the shape and size of the first member 120 and/or the second member 140. In some embodiments, the intermediate member 160 can be a band or strip-like shape. In some embodiments, the intermediate member 160 can be an irregular shape. In some embodiments, one or more portions of the intermediate member 160 can be formed of an adhesive, glue, paste, cement and/or the like configured to mechanically couple the first member 120 to the intermediate member 160. In some embodiments, one or more portions of the intermediate member 160 can be formed of an adhesive, glue, paste, cement and/or the like configured to mechanically couple the second member 140 to the intermediate member 160. In other words, the intermediate member 160 can be configured to mechanically couple the first member 120 to the second member 140.

[0028] The intermediate member 160 (or portions thereof) can be configured to degrade and mechanically decouple the first member 120 from the second member 140. One or more portions of the intermediate member 160 can be formed of any suitable degradable material such as, for example, those described herein with respect to specific embodiments. It should be understood, however, that the intermediate member 160 can be formed of any suitable material and therefore, the material of the intermediate member 160 is not intended to be limited to those materials shown and described herein. For example, in some embodiments, one or more portions of the intermediate member 160 can be formed of polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate, or any other ocean compatible material. In other embodiments, one or more portions of the intermediate member 160 can be formed of ecoflex®, ecovio®, or any other compostable co-polyester. In some embodiments, the intermediate member 160 can be formed of cellulose-based materials.

[0029] In some embodiments, the intermediate member 160 can be configured to degrade after some minimum period of intended lifetime. For example, in some embodiments, the intermediate member 160 can be formed of an ocean compatible material designed to decompose and decouple the first member 120 from the second member 140 after some minimum intended period of macroalgae growth. In some embodiments, the intermediate member 160 can be configured to degrade after some minimum amount of biomass has accumulated on the first member 120 and the second member 140. In some embodiments, the intermediate member 160 can be configured to degrade under predetermined environmental conditions including but not limited to temperature, pressure, exposure to UV and/or visible light. In some embodiments, the intermediate member 160 can be configured to degrade and decouple the first member 120 from the second member 140 allowing the first member 120 to float due to the positively buoyant macroalgae, and the second member 140 to sink to the bottom of the seafloor, effectively sequestering the carbon associated with the negatively buoyant macroalgae. In some embodiments, the floating first member 120 facilitates harvesting operations.

[0030] FIGS. 2 and 3 illustrate a macroalgae cultivation apparatus 200 according to another embodiment. The macroalgae cultivation apparatus 200 (also referred to herein as “cultivation apparatus” or “apparatus”) can be similar in at least form and/or function to the cultivation apparatus 100 described above with reference to FIG. 1. For example, as described above with reference to the cultivation apparatus 100, the cultivation apparatus 200 can be used to seed species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. The macroalgae cultivation apparatus 200 includes a first member 220 configured to receive a first species of macroalgae gametophytes and/or sporophytes, a second member 240 configured to receive a second species of macroalgae gametophytes and/or sporophytes, and an intermediate member 260 configured to reversibly couple the first member 220 to the second member 240. In some embodiments, the cultivation apparatus 200 can be arranged in a modular configuration in which one or more portions of the first member 220, the second member 240 and/or the intermediate member actuator 260 can be mechanically coupled (e.g., by an end user) to collectively form the macroalgae cultivation apparatus 200. In other embodiments, the macroalgae cultivation apparatus 200 need not be modular. For example, in some embodiments, the macroalgae cultivation apparatus 200 can be pre-coupled during manufacturing and/or prior to being delivered to an end user.

[0031] The first member 220 of the cultivation apparatus 200 can be any suitable shape, size, and/or configuration. For example, as shown in FIGS. 2 and 3, the first member 220 can be a ring-like shape. In other embodiments, the first member 220 can be a disc, a triangular shape, a sphere, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments, one or more portions of the first member 220 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, one or more portions of the first member 220 can be formed of a material relatively permeable to oxygen, carbon dioxide, water, and water-soluble nutrients to enable macroalgae growth. In some embodiments, one or more portions of the first member 220 can be formed of a relatively transparent material configured to allow absorption visible light.

[0032] The cultivation apparatus 200 can be used to seed species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. For example, in some embodiments, the first member 220 of the apparatus 200 can be seeded with macroalgae gametophytes and/or sporophytes species that become positively buoyant as they mature, and the second member 240 of the apparatus 200 can be seeded with macroalgae gametophytes and/or sporophytes species that become negatively buoyant as they mature. In some embodiments, the apparatus 200 can be first seeded with positively and negatively buoyant macroalgae gametophytes and/or sporophytes, and then deployed on oceans, lakes, rivers, and/or any other suitable body of water. The apparatus 200 can be further configured to be positively buoyant when initially deployed on oceans, lakes, rivers, and/or any other suitable body of water. In some embodiments, the apparatus 200 can be configured to float for a predetermined period of time after being deployed on oceans, lakes, rivers and/or any other body of water, and then gradually sink as the second member 240 seeded with negatively buoyant macroalgae grows and obtains biomass.

[0033] As described herein, the first member 220 of the cultivation apparatus 200 can be configured to receive a first species of macroalgae gametophytes and/or sporophytes. In some embodiments, one or more portions of the first member 220 can include a growth substrate configured to provide the nutrients required for macroalgae growth. As shown, for example, in FIGS. 2 and 3, the first member 220 can include a surface 222, a portion of which is arranged and configured to form and/or define the growth substrate. In some embodiments, the first member 220 growth substrate can include an enriched seawater medium, pasteurized seawater, filtrated seawater, seawater mixed with buffer solutions including but not limited to sodium nitrate ($NaNO_3$) solution, potassium dihydrogen phosphate (KH_2PO_4) solution, and/or the like. In some embodiments, the first member 220 growth substrate can include a binder configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes to the growth substrate. In some embodiments, the first member 220 growth substrate can be formed of a fibrous material configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes to the first member 220. In some embodiments, the first member 220 growth substrate can include additives formulated to suppress contamination of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, the first member 220 growth substrate can include germanium dioxide (GeO_2).

[0034] The second member 240 of the cultivation apparatus 200 can be any suitable shape, size, and/or configuration. In some embodiments the shape and of the second member 240 can be substantially similar to or the same as the shape and of the first member 220. For example, as shown in FIGS 2 and 3, the second member 240 can be a ring-like shape similar to that of the first member 220. In other embodiments, the second member 240 can be a disc, a triangular shape, a sphere, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments, the second member 240 can be an irregular shape. In some embodiments, one or more portions of the second member 240 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, one or more portions of the second member 240 can be formed of a material relatively permeable to oxygen, carbon dioxide, water, and water-soluble nutrients to enable macroalgae growth. In some embodiments, one or more portions of the second member 240 can be formed of a relatively transparent material configured to allow absorption visible light. In some embodiments, the second member 240 can include an optional metallic ring weight (not shown) to provide additional negative buoyancy.

[0035] As described herein, the second member 240 can be configured to receive a second species of macroalgae gametophytes and/or sporophytes. In some embodiments, one or more portions of the second member 240 can include a growth substrate configured to provide the nutrients required for macroalgae growth. As shown, for example, in FIGS. 2 and 3, the second member 240 can include a surface 242, a portion of which is arranged and configured to form and/or define the growth substrate. In some embodiments the composition of the second member 240 growth substrate can be substantially similar to or the same as the composition of the first member 220 growth substrate. Accordingly, the composition of the second member 240 growth substrate may not be described in further detail herein. In some embodiments, the second member 240 growth substrate can include a binder configured to facilitate attachment of the gametophytes and/or sporophytes to the growth substrate. In some embodiments, the second member 240 can be formed of a fibrous material configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes. In some embodiments, the second member 240 can include additives formulated to suppress contamination of macroalgae gametophytes and/or sporophytes. For example, in some embodiments, the second member 240 can include germanium dioxide (GeO_2).

[0036] The intermediate member 260 of the cultivation apparatus 200 can be any suitable shape, size, and/or configuration. In some embodiments the shape and size of the intermediate member 260 can be substantially similar to or the same as the shape and size of the first member 220 and/or the second member 240. For example, as shown in FIGS 2 and 3, the intermediate member 260 can be a ring-like shape of smaller size than that of the first member 220 and the second member 240. In other embodiments, the intermediate member 260 can be a disc, a triangular shape, a sphere, cylinder, cone, toroid, cuboid, polyhedral or any other geometrical shape. In some embodiments, the intermediate member 260 can be an irregular shape. In some embodiments, the intermediate member 260 can be a band or strip-like shape. In some embodiments, one or more portions of the intermediate member 260 can be formed of an adhesive, glue, paste, cement and/or the like configured to mechanically couple the first member 220 to the intermediate member 260. In some embodiments, one or more portions of the intermediate member 260 can be formed of an adhesive, glue, paste, cement and/or the like configured to mechanically couple the second member 240 to the intermediate member 260. In other words, the intermediate member 260 can be configured to mechanically couple the first member 220 to the second member 240.

[0037] The intermediate member 260 (or portions thereof) can be configured to degrade and mechanically decouple the first member 220 from the second member 240. One or more portions of the intermediate member 260 can be formed of any suitable degradable material, similar to and/or substantially the same as the degradable materials of the intermediate member 160 described above with reference to FIG 1. Accordingly, the materials forming the intermediate member 260 may not be described in further detail herein. The intermediate member 260 can be configured to degrade after some minimum period of intended lifetime. For example, in some embodiments, the intermediate member 260 can be formed of an ocean compatible material designed to decompose and decouple the first member 220 from the second member 240 after some minimum intended period of macroalgae growth. In some embodiments, the intermediate member 260 can be configured to degrade after some minimum amount of biomass has accumulated on the first member 220 and the second member 240. In some embodiments, the intermediate member 260 can be configured to degrade under predetermined environmental conditions including but not limited to temperature, pressure, exposure to UV and/or visible light.

[0038] FIGS. 4A-4D illustrate the life cycle of a macroalgae cultivation apparatus 300 according to an embodiment. The macroalgae cultivation apparatus 300 (also referred to herein as "cultivation apparatus" or "apparatus") can be similar in at least in form and/or function to the apparatus 100 and 200 described above. For example, the cultivation apparatus 300 can be seeded with species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. The macroalgae cultivation apparatus 300 includes a first member 320 configured to receive a first species of macroalgae 324 gametophytes and/or sporophytes, a second member 340 configured to receive a second species of macroalgae 344 gametophytes and/or sporophytes, and an intermediate member 360 configured to reversibly couple the first member 320 to the second member 340. As shown in FIG. 4A, the cultivation apparatus 300 is seeded with positively and negatively buoyant macroalgae gametophytes and/or sporophytes, and deployed in a body of water (e.g., oceans, lakes, rivers, and/or any other suitable body of water). As shown, the apparatus 300 floats on or near the surface of the water line W when initially deployed. Moreover, the cultivation apparatus 300 can be configured such that after being deployed in the water the first member 320 faces the water line W, and the second member 340 faces the bottom of the body of water (i.e., the sea bottom SB).

[0039] Referring now to FIG.4B, after a first time period the second species of macroalgae 344 gametophytes and/or sporophytes begin to grow on the second member 340 and due to their negative buoyancy, draw the apparatus 300 down into the water column below the water line W. Similarly, after the first time period the first species of macroalgae 324 gametophytes and/or sporophytes species begin to grow on the first member 320 and due to their positive buoyancy, grow up from the first member 320 toward the water line W. In some embodiments, the apparatus 300 can be configured such that the rate of growth of the second species of macroalgae 344 exceeds the rate of growth of first species of macroalgae 324, causing the apparatus 300 to gradually sink and become submerged in the water as the second species of macroalgae 344 gains additional biomass. In some embodiments, the apparatus 300 can be configured so that the second species of macroalgae 344 starts growing during a first portion of the first time period and the first species of macroalgae 324 starts growing during a second portion of the first time period. In other words, the apparatus 300 can be configured so that the first species of macroalgae 324 does not start growing until the apparatus is at least partially submerged below the water line W. In some embodiments, the apparatus 300 can be configured such that the second species of macroalgae 344 is initially seeded on the second member 340 at a higher density than the first species of macroalgae 324 initially seeded on the first member 320. This higher seeding density can cause the second species of macroalgae 344 to grow at a faster rate and/or accumulate more biomass faster than the first species of macroalgae 324, thereby causing the apparatus 300 to gradually sink and become submerged as the macroalgae 324, 344 grows. In some embodiments, the first species of macroalgae 324 can naturally have a lower positive buoyancy in comparison with the natural negative buoyancy of the second species of macroalgae 344. In some embodiments, the second species of macroalgae 344 can be selected to have a faster growth rate than the first species of macroalgae 324.

[0040] Referring now to FIG. 4C, after a second time period the first species of macroalgae 324 and the second species of macroalgae 344 have continued to grow and have accumulated more biomass. As shown, the apparatus 300 is at a substantially similar position in the water column relative to the position in FIG. 4B. However, in some embodiments, the apparatus 300 can be higher or lower in the water column after the second time period depending on any of a number of factors including the relative buoyancy of the first species of macroalgae 324 and the second species of macroalgae 344, the relative biomass of the macroalgae 324, 344, fouling of the apparatus 300, etc. Also as shown in FIG. 4C, after the second time period the intermediate member 360 has begun to degrade to initiate the mechanical decoupling of the first member 320 from the second member 340. As described herein, the intermediate member 360 can be configured to degrade after a predetermined minimum period of intended lifetime. In some embodiments, the intermediate member 360 can be configured to degrade after a predetermined minimum amount of the first species of macroalgae 324 has accumulated on the first member 320, and/or some minimum amount of the second species of macroalgae 344 has accumulated on the second member 340. In some embodiments, the intermediate member 360 can be configured to degrade under predetermined environmental conditions including but not limited to temperature, pressure, exposure to UV and/or visible light, etc.

[0041] Referring now to FIG. 4D, after a third time period, the intermediate member 360 has degraded and the first member 320 is decoupled from the second member 340, effectively separating the first species of macroalgae 324 attached to the first member 340 from the second species of macroalgae 344 attached to the second member 340. In some embodiments, the first member 320 is configured to float and remain at the water line W after mechanically decoupling from the second member 340, facilitating harvesting operations of the first species of macroalgae 324. In some embodiments, the second member 340 is configured to sink to the sea bottom SB after mechanically decoupling from the first member 320, effectively sequestering the carbon associated with the biomass of the second species of macroalgae 344.

[0042] FIG. 5 illustrates a macroalgae cultivation apparatus 400 according to an embodiment. The macroalgae cultivation apparatus 400 (also referred to herein as "cultivation apparatus" or "apparatus") can be similar in function to the cultivation apparatus 100 described above with reference to FIG. 1. For example, as described above with reference to the cultivation apparatus 100, the cultivation apparatus 400 can be used to seed species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. The apparatus 400 can include a first member 420 (also referred to as a "buoy") configured to provide buoyancy to the various components of the apparatus 400, a second member 440 configured to receive one or more species of macroalgae gametophytes and/or sporophytes, and optionally, a sealing member 460 configured to seal the first member 420 from the external environment.

[0043] The first member 420 can be a flotation device of any suitable shape and/or size. In some embodiments, one or more portions of the first member 420 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, the first member 420 can be any type of buoy such as a navigation buoy, a mooring buoy, a shot buoy, a spar buoy, and the like. In some embodiments, the first member 420 can contain air and/or other gases. In some embodiments, the air and/or gas can be pressurized. In some embodiments, one or more portions of the first member 420 can be formed of a relatively transparent material configured to allow transmission of visible light, facilitating absorption of light by the macroalgae gametophytes and/or sporophytes. In some embodiments, the first member 420 can include various sensors configured to measure environmental and/or meteorological conditions including air temperature, water temperature, water salinity, barometric pressure, wind speed, and the like. In some embodiments, the entire first member 420 or portions thereof can be made of an ocean compatible material including but not limited to jute, sisal, cotton, hemp, polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate poly(lactic acid), poly(caprolactone), poly(orthoester), polycyanoacrylate, aluminum, carbon steel, stainless steel, galvanized steel, and/or brass.

[0044] In some embodiments, the first member 420 can be configured to degrade after some minimum period of intended lifetime, allowing the contained air and/or other gases to escape. For example, in some embodiments, the first member 420 can be formed of an ocean compatible material designed to decompose and sink after some minimum intended period of macroalgae growth. In some embodiments, the first member 420 can be an inflatable bladder or vesicle (not shown). In some embodiments, the bladder can include a mechanical or biological timer/valve configured to release gas contained in the bladder after a predetermined period of time or macroalgae growth, thereby causing it to lose buoyancy and sink to the sea bottom.

[0045] In some embodiments, the first member 420 can be have a first portion made of a material that degrades at a first degradation rate, and a second portion made of a material that degrades at a second degradation rate. As the first portion degrades, water can enter the first member 420 causing it to lose buoyancy and sink to the sea bottom. After sinking to the sea bottom, the second portion of the first member 420 can degrade at the second degradation rate over a longer period of time. In some embodiments, the first member 420 can include an engineered "defect" that degrades at a faster rate than the rest of the first member 420. For example, the engineered defect can include a thinned portion of wall of the first member 420, or a stress fracture. The engineered defect can cause the first member 420 to lose buoyancy prior to degradation of the entire first member 420.

[0046] The second member 440 of the cultivation apparatus 400 can be any suitable shape, size, and/or configuration. The second member 440 can be any type of material suitable for attachment of macroalgae gametophytes and/or sporophytes. In some embodiments, the second member 440 can be formed of a fibrous material or seeding line configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes. In some embodiments, the second member 440 can include a binder configured to reinforce attachment of the gametophytes and/or sporophytes to the second member 440. The second member 440 can be mechanically coupled to the first member 420 to provide buoyancy to the macroalgae attached to the second member 440. In some embodiments, the second member 440 can be mechanically coupled to the first member 420 by means of tie knots, thimble kits, hooks, and/or similar anchor points devices. The second member 440 and/or the anchor point devices can be made of ocean compatible materials including jute, sisal, cotton, hemp, polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate poly(lactic acid), poly(caprolactone), poly(orthoester), polycyanoacrylate, aluminum, carbon steel, stainless steel, galvanized steel, brass and the like. As shown in FIG. 5, the second member 440 can include a single seeding line coupled to the first member 420. In some embodiments, the second member 440 can include a first seeding line coupled to the first member 420, and additional seeding lines (not shown) coupled to the first seeding line and/or to the first member 420 and configured to extend the amount of space available for attachment of macroalgae.

[0047] In some embodiments, the cultivation apparatus 400 can include a sealing member 460 coupled to and/or disposed in the first member 420. In some embodiments, the sealing member 460 can be a plug, stopper, cork, or the like, mechanically coupled to the first member 420, and configured to maintain a gas tight seal that prevents air and/or other gases contained in the first member 420 to escape. In some embodiments, the sealing member 460 can be mechanically coupled to the first member 420 by a pressure fitting, a screw-in sight, an expansion plug and the like. In some embodiments, the sealing member 460 can be an adhesive patch, glue, or paste, configured to seal an opening on the first member 420. In some embodiments, the sealing member 460 can be formed of an ocean compatible material configured to decompose after some minimum period of intended lifetime, allowing contained air and/or other gases to escape from the first member 420 and causing the cultivation apparatus 400 to sink.

[0048] As described above, the cultivation apparatus 400 can be used to seed species of macroalgae that may be utilized in carbon sequestration. In some embodiments, the cultivation apparatus 400 can be first seeded with negatively buoyant macroalgae gametophytes and/or sporophytes species, and then deployed on oceans, lakes, rivers, and/or any other suitable body of water. The apparatus 400 can be configured to float on or near the surface of the water line W when initially deployed on oceans, lakes, rivers and/or any other body of water, to facilitate absorption of UV light, O_2 and/or nutrients required for macroalgae growth. In some embodiments, the sealing member 460 can be configured to degrade after a minimum amount of macroalgae has accumulated on the second member 440, allowing air and/or other gases contained in the first member 420 to escape, causing the cultivation apparatus 400 to sink to the sea bottom, effectively sequestering carbon associated with the macroalgae biomass. In other embodiments, the first member 420 (or portions thereof) can be configured to degrade after a predetermined minimum amount of the macroalgae has accumulated on the second member 440, causing the apparatus 400 to sink and sequester carbon associated with the macroalgae biomass.

[0049] FIG. 6 illustrates a macroalgae cultivation apparatus 500 according to an embodiment. The macroalgae cultivation apparatus 500 (also referred to herein as “cultivation apparatus” or “apparatus”) can be similar in function to the cultivation apparatus 100 described above with reference to FIG. 1. For example, as described above with reference to the cultivation apparatus 100, the cultivation apparatus 500 can be used to seed species of macroalgae that may be utilized in harvesting operations and/or carbon sequestration. The apparatus 500 can include a first member 520 (also referred to as a “buoy”) configured to provide buoyancy to the various components of the apparatus 500, a second member 540 configured to receive one or more species of macroalgae gametophytes and/or sporophytes, and a link 560 configured to reversibly couple the first member 520 to the second member 540. In some embodiments, portions and/or aspects of the cultivation apparatus 500 can be similar to and/or substantially the same as portions and/or aspects of the cultivation apparatus 400 described above with reference to FIG. 5. Accordingly, such similar portions and/or aspects may not be described in further detail herein.

[0050] The first member 520 can be a flotation device of any suitable shape and/or size. In some embodiments, one or more portions of the first member 520 can be formed of a porous and/or hollow material configured to provide buoyancy. In some embodiments, the first member 520 can be any type of buoy such as a navigation buoy, a mooring buoy, a shot buoy, a spar buoy, and the like. In some embodiments, the first member 520 can contain air and/or other gases. In some embodiments, the air and/or gas can be pressurized. In some embodiments, one or more portions of the first member 520 can be formed of a relatively transparent material configured to allow transmission of visible light, facilitating absorption of light by the macroalgae gametophytes and/or sporophytes. In some embodiments, the first member 520 can include various sensors configured to measure environmental and/or meteorological conditions including air temperature, water temperature, water salinity, barometric pressure, wind speed, and the like. In some embodiments, the first member 520 can be made of ocean compatible materials including but not limited to, polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate poly(lactic acid), poly(caprolactone), poly(orthoester), polycyanoacrylate, aluminum, carbon steel, stainless steel, galvanized steel, and/or brass. In some embodiments, the first member 520 can be configured to degrade after some minimum period of intended lifetime, allowing the contained air and/or other gases to escape. The first member 520 can be substantially similar to the first member 420 described above with reference to FIG. 5, and thus is not described in further detail herein.

[0051] The second member 540 of the cultivation apparatus 500 can be any suitable shape, size, and/or configuration. The second member 540 can be any type of material suitable for attachment of macroalgae gametophytes and/or sporophytes. The second member 540 can be formed of a fibrous material or seeding line including a binder configured to facilitate attachment of the macroalgae gametophytes and/or sporophytes. The second member 540 can be mechanically coupled to the link 560 by means of tie knots, thimble kits, hooks, and/or similar anchoring points (not shown). The anchoring points can be made of ocean compatible materials including polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate poly(lactic acid), poly(caprolactone), poly(orthoester), polycyanoacrylate, aluminum, carbon steel, stainless steel, galvanized steel, brass and the like. As shown in FIG. 6, the second member 540 can include a single seeding line coupled to the link 560. In other embodiments, the second member 540 can include a first seeding line coupled to the link 560, and additional seeding lines (not shown) coupled to the first seeding line and/or to the link 560 and configured to extend the amount of space available for attachment of macroalgae.

[0052] The link 560 of the cultivation apparatus 500 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the link 560 can be a ring, shackle, swivel, joint or the like, configured to reversibly couple the first member 520 to the second member 540. In some embodiments, the first member 520 and the second member 540 can be coupled to the link 560 by means of tie knots, thimble kits, hooks, and/or similar anchor points. As described above, the anchor points can be made of ocean compatible materials including, for example, polyglycolide, polylactide, polyhydroxobutyrate, chitosan, hyaluronic acid, poly(lactic-co-glycolic), poly (caprolactone), polyhydroxyalkanoate poly(lactic acid), poly(caprolactone), poly(orthoester), polycyanoacrylate, aluminum, carbon steel, stainless steel, galvanized steel, brass and the like. The link 560 can also be formed of an ocean compatible material configured to decompose after some minimum period of intended lifetime, decoupling the first member 520 from the second member 540, therefore causing the second member 540 and the attached macroalgae to sink to the sea bottom. In some embodiments, the first member 520 can be configured to degrade and/or otherwise decompose on the surface of the water W. In some embodiments, the first member 520 can also be allowed to degrade and sink to the sea bottom. In some embodiments, the first member 520 can be configured to be retrieved and re-used.

[0053] As described above for the apparatus 400, the cultivation apparatus 500 can be used to seed species of macroalgae that may be utilized in carbon sequestration operations. In some embodiments, the cultivation apparatus 500 can be first seeded with negatively buoyant macroalgae gametophytes and/or sporophytes species, and then deployed on oceans, lakes, rivers, and/or any other suitable body of water. The apparatus 500 can be configured to float near surface of the water line W to facilitate absorption of UV light, O_2 and/or nutrients required for macroalgae growth. The link 560 can be configured to degrade after a minimum period of intended lifetime and/or a minimum amount of macroalgae has accumulated on the second member 540, decoupling the first member 520 from the second member 540, causing the second member 540 and the attached macroalgae to sink to the sea bottom, effectively sequestering the carbon associated with the macroalgae biomass.

[0054] FIG. 7 illustrates a macroalgae cultivation system 6000, according to an embodiment. The macroalgae cultivation system 6000 (also referred to herein as "cultivation system") includes a plurality of cultivation apparatuses 600 that can be similar at least in form and/or function to the apparatus 100, 200 and/or 300 described above, thus are not described in further detail herein. For example, as described above with reference to the apparatus 100, 200 and 300, the cultivation system 6000 can be used to seed species of macroalgae that may be utilized in large scale harvesting operations and/or carbon sequestration. In addition to the plurality of cultivation apparatuses 600, the cultivation system 6000 includes a containment boom 602, and a plurality of buoys 604.

[0055] In some embodiments, the containment boom 602 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the containment boom 602 can be a circular shape or any other geometrical shape. In some embodiments, the containment boom 602 can include multiple flotation segments, a skirt, chain ballasts, tension cables, and/or end connectors. In some embodiments, the containment boom 602 can be formed of durable and reusable materials. For example, in some embodiments, the containment boom 602 can include flotation segments formed of durable encapsulated closed-cell polyethylene foam that can be sealed with high strength fabrics. In some embodiments, the containment boom 602 can include a skirt formed of highly resistant fabrics including PVC and/or nylon configured to provide a barrier enclosing the cultivation apparatuses. In some embodiments, the containment boom 602 can include galvanized chain ballasts configured to attach to the skirt and provide weight to maintain the skirt in vertical position. In some embodiments, the containment boom 602 can include stainless steel tension cables configured to carry axial loads imposed on the containment boom 602 by external forces including currents, winds, and/or towing. In some embodiments, the containment boom 602 can include high tensile strength aluminum end connectors.

[0056] In some embodiments, the buoys 604 can be any suitable shape, size, and/or configuration. For example, in some embodiments, the buoys 604 can be a disk shape, toroid, cone, sphere, skiff, spar or any other shape. In some embodiments, the buoys 604 can be configured to be anchored or free-floating. In some embodiments, the buoys 604 can be made of, or include, any of a number of materials including, for example, wood, steel, aluminum, and/or synthetic materials including, fiber glass, high density polyethylene, polystyrene, and polyurethane elastomers, and/or any other suitable material such as any of those described herein. In some embodiments, the buoys 604 can be configured to be reusable. In some embodiments, the buoys 604 can be configured to be capable of tracking and performing automated processes needed for macroalgae growth, harvesting operations, and/or carbon sequestration. In some embodiments, the buoys 604 can be placed within the containment boom 602 to provide information related to the weight of macroalgae biomass accumulated on the cultivation system 6000.

What is claimed:

1. An apparatus for cultivating macroalgae, comprising:

a first member seeded with a first species of macroalgae, the first species of macroalgae becoming positively buoyant as it matures;

a second member seeded with a second species of macroalgae, the second species of macroalgae becoming negatively buoyant as it matures; and

an intermediate member coupling the first member to the second member, the intermediate member configured to degrade and decouple the first member from the second member.

2. The apparatus of claim 1, wherein the intermediate member is configured to degrade over a predetermined time period.

3. The apparatus of claim 1, wherein the intermediate member is configured to degrade under predetermined environmental conditions.

4. A method, comprising:

seeding an apparatus with a species of macroalgae;

allowing the macroalgae to grow and accumulate biomass;

after the macroalgae accumulates at least a predetermined amount of biomass, allowing the macroalgae to sink to the seafloor;

calculating an amount of carbon sequestered by the sinking of the macroalgae; and

selling a carbon credit associated with the amount of carbon sequestered by the macroalgae.

Abstract

Systems and methods for cultivating macroalgae are described herein. In some embodiments, the system includes an apparatus for cultivating macroalgae having a first member seeded with a first species of macroalgae that becomes positively buoyant as it matures, a second member seeded with a second species of macroalgae that becomes negatively buoyant as it matures, and an intermediate member coupling the first to the second member, the intermediate member configured to degrade and decouple the first member from the second member.

Electronic Patent Application Fee Transmittal

Application Number:	
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Title of Invention:	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE
First Named Inventor/Applicant Name:	Matthew Jordan ODLIN
Filer:	Michael D. Winternitz/Jody Begley
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Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
PROVISIONAL APPLICATION FILING FEE	2005	1	140	140
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
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37 CFR 1.21 (Miscellaneous fees and charges)

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37 CFR 1.17 (Patent application and reexamination processing fees)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	RUNN-002-01US_ADS.pdf	1255697 5afa36680e688d2cd9a6a827872647da3d34bb52	no	8

Warnings:

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2	Power of Attorney	RUNN-002-01US_POA.pdf	1828181 f1b8bb4155a80ce0f1d795cc66f5d1fa91d00971	no	2

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Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
3	Drawings-only black and white line drawings	RUNN-002-01US_figs.pdf	1514392 323c4d7a27d3faed64b7044f6f25fd736a9dad4c	no	5

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
4		RUNN-002-01US_spec.pdf	226349 0f94e33deef50d358132283ee7d0e979a819ec6f	yes	25

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	23
Claims	24	24
Abstract	25	25

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
5	Fee Worksheet (SB06)	fee-info.pdf	30211 ffa1efbf3a538eb45468638d03cf5db7deda89cc	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	4854830

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	

Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Matthew	Jordan	ODLIN	

Residence Information (Select One) ● US Residency Non US Residency Active US Military Service

City	Freeport	State/Province	ME	Country of Residence	US

Mailing Address of Inventor:

Address 1	29 Crows Nest Drive		
Address 2			
City	Freeport	**State/Province**	ME
Postal Code	04032	**Country**	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	58249
Email Address	zIPPatentDocketingMailboxUS@Cooley.com Add Email Remove Email

Application Information:

Title of the Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE		
Attorney Docket Number	RUNN-002/01US 331356-2009	**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	**Suggested Figure for Publication (if any)**	

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	58249		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE	

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
● Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:	
If the Applicant is an Organization check here.	☒
Organization Name	Running Tide Technologies, Inc.

Mailing Address Information For Applicant:

Address 1	P.O. Box 10304		
Address 2			
City	Portland	**State/Province**	ME
Country	US	Postal Code	04104
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Michael D. Winternitz/			Date (YYYY-MM-DD)	2020-09-15
First Name	Michael	Last Name	Winternitz	Registration Number	73,102

Additional Signature may be generated within this form by selecting the Add button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	RUNN-002/01US 331356-2009
	Application Number	

Title of Invention	SYSTEMS AND METHODS FOR THE CULTIVATION OF MACROALGAE

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.