

TITLE

Resonant frequency detection for algae control system

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No.
5 63/548,564, filed February 1, 2024, and hereby incorporated by reference.

BACKGROUND

[0002] 1. Field of Invention

[0003] This invention pertains to a system for determining the resonant
frequency for waterborne algae and other bio-organisms. More particularly, this
10 invention pertains to detecting a resonant frequency of algae and bio-organisms in
order to control the proliferation of the algae and bio-organisms in a body of water.

[0004] 2. Description of the Related Art

[0005] An algae control system emits ultrasonic sound pressure frequency
waves at frequencies that are lethal to bio-organisms and is averse to colonization
15 of some microorganisms, such as biofilm. The ultrasonic frequencies are emitted at
frequencies matching or close to matching the structural resonance of key
components within algae such as the vacuole, internal cell structures, and mobility
components such as flagella, thereby killing the organisms or incapacitating them.
To achieve critical structural resonance, an exacting frequency is needed to be
20 applied to a variety of species of algae and, therefore, a spectrum of frequencies, for
example 20kHz to 120kHz, is created in discrete frequencies such as every 100Hz
between 20kHz and 120kHz resulting in 1000 discrete frequencies. If each discrete
frequency is produced once per second, 1000 seconds is needed before the pattern
of frequency production is repeated. It may be that only one of the 1000 frequencies
25 is effective in achieving critical structural resonance. Generally, not all of the
organisms in a harmful algal bloom (HAB) or colony will be disabled during a single
sweep. If the sweeps are too far apart, the HAB or colony will survive and grow
enough to reestablish the losses occurring during a single sweep. Increasing the
number of frequencies produced per second will subject the HAB or colony to
30 enough killing or incapacitating events to prevent the HAB or colony from
surviving.

[0006] It is advantageous to emit ultrasonic waves at a frequency matching the natural critical structural frequency of the organisms, their internal structure, and mobility mechanisms, such as their flagella and vacuoles, that are targeted in the body of water. Accordingly, the resonant frequency detection system determines
5 the natural critical structural frequency of the bio-organisms in the water. After the resonant frequency is detected, the algae control system is adjusted to emit ultrasonic waves at the frequency determined to match the natural critical structural frequency.

BRIEF SUMMARY

10 **[0007]** According to one embodiment of the present invention, an algae control system that includes a system for resonant frequency detection of waterborne algae is provided. In one such embodiment, the system includes an ultrasonic transducer assembly and a remote sensor. In another such embodiment,
15 the system includes an ultrasonic transducer assembly and a local sensor positioned near the transducer. The transducer emits ultrasonic waves that are received by the sensor, either directly or by reflection. When the frequency of the emitted ultrasonic wave matches the natural critical structural frequency of the bio-organisms in the water, the energy in the ultrasonic wave is absorbed by the bio-organisms. The energy absorption at resonance results in a dip in the
20 amplitude of the ultrasonic waves received by the sensor, compared to the amplitude at other frequencies.

[0008] In one embodiment, the resonance detection system includes at least one local controller, a transducer assembly, and a sensor assembly. The transducer assembly includes one or more ultrasonic transducers configured to emit
25 ultrasonic waves at various frequencies into the body of water. The sensor assembly includes one or more sensors responsive to ultrasonic waves. In one embodiment, multiple sensors are positioned to provide 360 degree coverage in a plane parallel to the surface of the body of water. In this way, the sensors provide direction information in addition to detection of the resonant frequency of bio-
30 organisms in the body of water. In another embodiment, a single sensor having a cylindrical configuration provides 360 degree coverage under water. In such an embodiment, direction information is determined from identifying the transducer emitting the ultrasonic waves being detected by the sensor. The local controller

includes a processor that executes the steps for a method of determining the natural resonant frequency of bio-organisms in the water.

[0009] In one embodiment, the resonance detection system includes a global positioning system (GPS) receiver that is aligned with the sonic head. The GPS provides location and direction information that allows for the location of detected algae blooms to be mapped. An algae bloom is detected when resonance is detected in the water. The sonic head includes multiple transducers and/or sensors that provide directional information relative to the sonic head. The GPS uses that directional information to provide geolocation information of the data corresponding to the information from the transducers and/or sensors.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0010] The above-mentioned features will become more clearly understood from the following detailed description read together with the drawings in which:

[0011] FIG. 1 is a symbolic view of one embodiment of an algae control system including a resonance detection system with a remote sensor.

[0012] FIG. 2 is a symbolic view of another embodiment of an algae control system including a resonance detection system with a local sensor.

[0013] FIG. 3 is a frequency response graph showing an example of algae resonance.

[0014] FIG. 4 is a functional block diagram of one embodiment of an algae control system including a resonance detection system.

[0015] FIG. 5 is a functional block diagram of another embodiment of an algae control system including a resonance detection system.

[0016] FIG. 6 is a side view of the sensor in the first embodiment shown in FIG. 7.

[0017] FIG. 7 is an isometric view of one embodiment of a sonic head that includes one embodiment of an ultrasonic transducer assembly and one embodiment of a sensor assembly.

[0018] FIG. 8 is an isometric view of a second embodiment of a sonic head that includes a second embodiment of an ultrasonic transducer assembly and a second embodiment of a sensor assembly.

5 [0019] FIG. 9 is a cross-sectional view of the sensor in the third embodiment shown in FIG. 8.

[0020] FIG. 10 is an isometric view of a third embodiment of a sonic head that includes a third embodiment of an ultrasonic transducer assembly and a second embodiment of a sensor assembly.

10 [0021] FIG. 11 is a flow diagram showing one embodiment of the steps for detecting alga resonance.

[0022] FIG. 12 is a flow diagram showing one embodiment of the steps for detecting and using resonance to control micro-organisms.

DETAILED DESCRIPTION

15 [0023] Apparatus for an algae control system **10** including a resonance detection system **100** is disclosed. The algae control system is generally indicated as **10**, with particular embodiments and variations shown in the figures and described below having an alphabetic suffix, for example, **10-A**, **10-B**, **10-1**, **10-2**. The resonance detection system is generally indicated as **100**, with particular embodiments and variations shown in the figures and described below having an alphabetic suffix, for example, **100-A**, **100-B**. Various components are illustrated
20 both generically and specifically in the figures and in the following description. For example, the sonic head **102-1**, **102-2**, **102-A** are discussed individually and separately to ensure clarity when describing the configuration and function of each sonic head **102-1**, **102-2**, **102-A**, **102-B**, **102-C**. The sonic head **102**, when
25 referred to collectively, is referenced without the alphanumeric suffix.

[0024] Positional references, such as top and bottom and horizontal and vertical, refer to the configuration of the resonance detection system **100** as it is deployed for use. For example, vertical is considered to be perpendicular to the surface **112** of the body of water **114** and horizontal is parallel to the surface **112**
30 when the resonance detection system **100** is deployed in the water **114**.

[0025] FIG. 1 illustrates a symbolic view of one embodiment of an algae control system **10-A** including a resonance detection system **100-A** with a remote sensor **106-2**. The algae control system **10-A** including the resonance detection system **100-A** is shown deployed in a body of water **114** that contains bio-organisms **116**. The resonance detection system **100-A** includes a pair of sonic heads **102-1**, **102-2** that are submerged in the body of water **114** below the surface **112**. The sonic heads **102-1**, **102-2** are each suspended from the surface **112** by a raft **110-1**, **110-2**. The raft **110** is a device that floats on the surface **112** of the body of water **114** and supports the sonic head **102** below the surface **112**. In the illustrated embodiment, each sonic head **102-1**, **102-2** includes a transmitting transducer **104-1**, **104-2** and a receiving sensor **106-1**, **106-2**. In one embodiment, the raft **110** also supports other equipment, such as a solar array and power supply **406** and/or a GPS receiver **408**.

[0026] The first sonic head **102-1** has a first transmitting transducer **104-1** that emits ultrasonic waves **108** into the water **114**. The ultrasonic waves **108** pass through the water **114** and the bio-organisms **116** in the water **114**. The second sonic head **102-2** has a second receiving sensor **106-2** that is responsive to the ultrasonic waves **108-i** that have passed through the water **114** and the bio-organisms **116**. The ultrasonic waves **108-i** received by the sensor **106-2** is attenuated by traveling through the water.

[0027] In one embodiment, the ultrasonic waves **108** emitted by the transducer **104-1** include a multitude of frequencies, each emitted one frequency at a time. For example, the transducer **104-1** emits individual frequencies in a bandwidth of 20 kHz to 200 kHz, with each frequency emitted for 5 milliseconds. As the ultrasonic waves **108** pass through the water **114** the intensity of the emitted waves **108** is attenuated. The attenuation of the wave **108** is due to several factors, including distance between the transducer **104-1** and the sensor **106-2**, debris and material in the water **114**, and any absorption by the bio-organisms **116**.

[0028] When the emitted frequency matches the natural critical structural frequency of the bio-organisms **116** in the water **114**, the energy in the waves **108-i** is absorbed by the bio-organisms **116**, resulting in a drop in the amplitude of the ultrasonic waves **108-i** received by the sensor **106-2**, compared to the amplitude detected by the sensor **106-2** at other frequencies.

[0029] FIG. 2 illustrates a symbolic view of another embodiment of an algae control system **10-B** including a resonance detection system **100-B** with a local sensor **106-1**. The algae control system **10-B** including the resonance detection system **100-B** is shown deployed in a body of water **114** that contains bio-organisms **116**. The resonance detection system **100-B** includes a single sonic head **102-1** that is submerged in the body of water **114** below the surface **112**. The sonic head **102-1** includes a transmitting transducer **104-1** and a receiving sensor **106-1**. The sensor **106-1** is located close to the transducer **104-1**. The sensor **106-1** is separated and isolated from the transducer **104-1** such that sensor **106-1** is not unduly influenced by the direct emissions from the transducer **104-1**.

[0030] The transducer **104-1** emits ultrasonic waves **108** into the water **114**. The ultrasonic waves **108** pass through the water **114**. A portion of the ultrasonic waves **108-i** is reflected by the bio-organisms **116** in the water **114** at frequencies outside of the resonance frequency. That is, the bio-organisms **116** reflect ultrasonic waves **108-i** except at the frequency where the ultrasonic waves **108** are absorbed by the bio-organisms **116**. The ultrasonic wave frequency where absorption occurs defines the resonant frequency. The reflected waves **108-i** are received by the sensor **106-1**. As with the system **100-A** shown in FIG. 1, the system **100-B** detects the natural critical structural frequency of the bio-organisms **116** in the water **114**.

[0031] FIG. 3 illustrates a frequency response graph **300** showing an example of algae resonance at a resonant frequency **302-5**. The graph **300** shows an x-axis **302** representing the frequency **f** of the emitted ultrasonic waves **108**. The graph **300** shows a y-axis **304** representing the amplitude **306** of the ultrasonic waves **108-i** received by the sensor **106**.

[0032] The graph **300** shows a plot of data **310** where the data **310** is amplitude **304** versus frequency **302**. That is, the graph **300** shows the amplitude **304** of a sensor signal **306** corresponding to the ultrasonic waves **108-i** received by the sensor **106** plotted for each frequency **302**. For a first ultrasonic wave **108**, the sensor signal **306-1** represents the amplitude **304** at a first frequency **302-1**. At various other frequencies **302-3**, **302-4**, **302-6**, **302-7** the sensor signal **306-3**, **306-4**, **306-6**, **306-7** has an amplitude **304** that is similar to the first sensor signal **306-1**. There is a slight difference in the amplitude **304** of the sensor signal **306-1**, **306-3**, **306-6**, **306-7**, which can be caused by debris or other materials in the water **116**.

[0033] The sensor signal **306** at each frequency **302** has a representative amplitude **304**. The sensor signal **306-1** represents the amplitude **304** at a frequency **302-1**. The sensor signal **306-5** has an amplitude **304** that is significantly less than the amplitude **304** of the sensor signals **306-1**, **306-3**, **306-6**, **306-7** at other frequencies **302**. The significant drop in amplitude **304** at the frequency **302-5** of the sensor signal **306-5** indicates that the energy of the ultrasonic waves **108** has been substantially absorbed by the bio-organisms **116** in the water **114**. The drop in amplitude **304** is an indication that the resonant frequency of the bio-organisms **116** in the water **114** is at frequency **302-5**.

[0034] The sensor signal **306-2** has an amplitude **304** that is slightly lower than the average amplitude **306-avg** of the sensor signals **306** at the frequencies **302**. If the drop in amplitude **304** is less than a threshold amount, then the frequency **302-2** corresponding to the second sensor signal **306-2** does not indicate a resonant frequency for the bio-organisms **116** in the water **114**. If the drop in amplitude **304** is greater than a threshold amount, then the frequency **302-2** corresponding to the second sensor signal **306-2** indicates a resonant frequency (resonant frequency data **310-rf**) for the bio-organisms **116** in the water **114**. In the illustrated example, second sensor signal **306-2** is only slightly below the average amplitude **306-avg** and does not indicate a resonant frequency.

[0035] In one embodiment, the threshold amount is defined as a percentage of the average amplitude **306-avg** of the amplitudes **306** at the emitted frequencies **302**. In another embodiment, the threshold amount is defined as a percentage of the average amplitude **306-avg** of the amplitudes **306** of the frequencies **302** surrounding the low amplitude **306-2**, **306-5** data **310**.

[0036] FIG. 4 illustrates a functional block diagram of one embodiment of algae control system **10-1** including a system **100-1**. The resonance detection system **100-1** includes a sonic head **102'**, a power supply **406**, a GPS **408**, and a remote controller **404**. The illustrated sonic head **102** includes a local controller **402**, a transducer **104**, and a sensor **106**. In one embodiment, the power supply, **406**, the GPS **408**, and any equipment enabling transmission to the remote controller **404** are located in the raft **110** supporting the sonic head **102'**.

[0037] The power supply (PS) **406** provides power to the sonic head **102**. In various embodiments, the power supply **406** is a solar and/or a battery unit that is located on the raft **110** on the surface **112** or on land near the sonic head **102**. For example, the power supply **406** includes a solar panel that feeds a battery charger connected to a battery, all of which are located on or in the raft **110**.

[0038] The remote controller **404** is connected to the sonic head **102'** either by a wired connection or wirelessly. In one embodiment, the remote controller **404** is connected via the internet. The remote controller **404**, in various embodiments, includes a user interface, along with a processor or controller that provides for control of the sonic head **102** remotely.

[0039] The sonic head **102'** includes a local controller **402** that is operatively connected to the transducer **104** and the sensor **106**. In one embodiment of the system **100-A** with a remote sensor **102-2**, a first sonic head **102-1** includes a transducer **104-1** and a second sonic head **102-2** includes a sensor **106-2**. In such an embodiment, each sonic head **102-1**, **102-2** performs a single function, for example, emitting ultrasonic waves **108** and receiving an ultrasonic wave **108-i**.

[0040] The local controller **402** includes a computing device that executes programs and includes a processing unit, memory/storage unit, and input/output units for communicating with external devices, such as the remote controller **404**, the transducer **104**, and the sensor **106**. For example, the local controller **402** includes a system-on-a-chip (SOC) in which the processor contains various components that perform the major functions of the processor. In another embodiment, the local controller **402** includes is a specialized device, such as a micro-controller or an application-specific integrated circuit (ASIC) that, in conjunction with other components, that implement the functions of the system **100-1**.

[0041] In the illustrated embodiment, the GPS **408** is a global positioning system receiver. The GPS **408** is attached to the raft **110**. The sonic head **102** is attached to the raft **110** such that the sonic head **102** is held in a fixed position relative to the raft **110**. For example, in the embodiments illustrated in FIGS 5 and 6, two support cables, each attached to opposing holes in the upper bracket **522**, secure the sonic head **100** to the raft **110**. In this way, the GPS **408** determines the location and direction of both the raft **110** and the sonic head **102**.

[0042] In one embodiment, a pair of sonic heads **102-1**, **102-2** operate in tandem. The first sonic head **102-1** emits ultrasonic waves **108** that are received by a second sonic head **102-2**. In such an embodiment, the local controllers **402** of each sonic head **102-1**, **102-2** are in communication. The first local controller **402** controlling the frequency and power level of the emitted ultrasonic waves **108**. The second local controller **402** monitoring the amplitude of each received frequency of ultrasonic waves **108-i**. The received amplitude and frequency are stored and a trend analysis is performed to determine if the micro-organisms **116** in the water **114** are absorbing the energy of the ultrasonic waves **108**, thereby indicating the resonant frequency of the micro-organisms **116** in the water **114**. An example of a trend analysis is illustrated by the significant drop in amplitude of the signal **306-5** relative to the trend line defined by the amplitude of the signals **306** at adjacent frequencies **302**.

[0043] FIG. 5 illustrates functional block diagram of another embodiment of algae control system **10-2** including a system **100-2**. The resonance detection system **100-2** includes a sonic head **102"**, a power supply **406**, a GPS **408**, and a remote controller **404**. The illustrated sonic head **102"** includes an ultrasonic transducer assembly **504** and a sensor assembly **506**. The ultrasonic transducer assembly **504** and the sensor assembly **506** are connected via a cable **502**. In one embodiment, the power supply **406**, the GPS **408**, and any equipment enabling transmission to the remote controller **404** are located in the raft **110** supporting the sonic head **102"**.

[0044] The ultrasonic transducer assembly **504** includes a first local controller **402-1** operatively connected to the transducer **104**. The first local controller **402-1** communicates with the devices external to the sonic head **102"**, such as the remote controller **404**, the power supply **406**, and the GPS **408**.

[0045] The sensor assembly **506** includes a second local controller **402-2** operatively connected to the sensor **106**. The second local controller **402-2** communicates with the first local controller **402-1** whereby data **310** from the sensor **106** is shared with the second local controller **402-1**. In one embodiment, the two controllers **402-1**, **402-2** each execute software programs independently with the transducer local controller **402-1** receiving data **310** from the sensor controller **402-2** for execution of software programs.

[0046] FIG. **6** illustrates a side view of the sensor **106-A**, such as the sensors **106-A**, **106-B** illustrated in the embodiments shown in FIGS. **7** & **10**. The sensor **106-A** includes a piezoelectric element **608** electrically connected to a cable or conductors **602**. The sensor **106-A** is sensitive to ultrasonic waves **108-i** directed toward the forward face **610** of the sensor **106-A**. The piezoelectric element **608** is configured to be deployed in water **114**. In one embodiment, the piezoelectric element **608** is encapsulated in a protective covering such that the piezoelectric element **608** is isolated from the water **114**.

[0047] The sensor **106-A** includes a sealing washer **606** and a plug **604**. The sealing washer **606** and the plug **604** provide a seal between the sensor **106-A** and the housing **516-A**, **526-C** from which the sensor **106-A** protrudes. In one embodiment, the sealing washer **606** and the plug **604** are formed of a resilient elastomeric material that provides a water-tight seal between the piezoelectric element **608** and the disc **516** or the housing **516-A**, **526-C**.

[0048] The sensor **106-A** is isolated from mechanical vibrations originating in the sonic head **102**. In one embodiment, the washer **606** and plug **604** are made from an elastomeric material that attenuates the mechanical vibrations from the sonic head **102**. In this way, the sensor **106-A** is primarily responsive to ultrasonic waves **108-i** directed toward the forward face **610** of the sensor **106-A**.

[0049] In one embodiment, the sealing washer **606** is adhered to the outside surface of the housing **516-A**, **526-C** such that the sensor **106-A** is secured to the housing **516-A**, **526-C** and the opening into the housing **516-A**, **526-C** is sealed from water intrusion. In another embodiment, the plug **604** has an external thread configured to receive a nut, which, when tightened, compresses the sealing washer **606** between piezoelectric element **608** and the housing **516-A**, **526-C**.

[0050] FIG. 7 illustrates an isometric view of one embodiment of a sonic head **102-A** that includes one embodiment of an ultrasonic transducer assembly **504-A** and one embodiment of a sensor assembly **506-A**. In the illustrated embodiment, the sensor assembly **506-A** is secured above the transducer assembly **504-A**. The two assemblies **506-A**, **504-A** are electrically connected with a cable **502** and mechanically connected together.

[0051] The transducer assembly **506-A** includes a first transducer **104-A** and a second transducer **104-B**. The first transducer **104-A** emits ultrasonic waves **108-A1**, **108-A2** in two opposing directions. The second transducer **104-B** emits ultrasonic waves **108-B1**, **108-B2** in two opposing directions. In this way, the transducer assembly **504-A** emits ultrasonic waves **108** in 360 degrees around the vertical axis of the transducer assembly **504-A**.

[0052] In one embodiment, the transducers **104-A**, **104-B** each include a single, double-sided piezoelectric crystal that emits ultrasonic waves in opposing directions. In another embodiment, the transducers **104-A**, **104-B** each include a pair of piezoelectric crystals that each emits ultrasonic waves in an opposing direction relative to the other crystal.

[0053] The sensor assembly **506-A** includes a housing **516-A** with four sensors **106** that protrude from the housing **516** and are aligned in parallel with the axis of the ultrasonic waves **108** emitted from the transducers **104-A**, **104-B**. The housing **516-A** has a short, cylindrical shape. In the illustrated embodiment, the housing **516-A** is above the transducer assembly **504-A**. In one embodiment, the housing **516-A** includes an overmolded enclosure that seals the sensors **106-A**, **106-B** from the water environment. The sensors **106** and associated electronics encapsulated in the overmolded enclosure are electrically connected to the electronics in the transducer housing **526-A** of the transducer assembly **504-A**. The transducer housing **526-A** includes a connector **528** configured to attach to a cable that has an opposite end connected to the local controller **402**.

[0054] In the illustrated embodiment, the housing **516-A** has an upper mounting bracket **522** extending upward from the housing **516-A**. The lower mounting bracket **524** extends downward from the lower transducer **104-A**. The upper mounting bracket **522**, is configured to attach to a line suspended from the raft **110** and the lower mounting bracket **524** is configured to attach to a line leading to an anchor or other object that holds the sonic head **102-A** in vertical alignment.

[0055] In the illustrated embodiment, two sensors **106-A**, **106-B** of the four sensors **106** are illustrated. The first sensor **106-A** receives ultrasonic waves **108-A1i** that are in parallel alignment with the axis of the ultrasonic waves **108-A1** emitted from one side of the first transducer **104-A**. Another sensor (not illustrated) is on the opposite side of the housing **516-A** and receives ultrasonic waves **108-A2i** that are in parallel alignment with the axis of the ultrasonic waves **108-A2** emitted from the opposite side of the first transducer **104-A**.

[0056] The second sensor **106-B** receives ultrasonic waves **108-B1i** that are in parallel alignment with the axis of the ultrasonic waves **108-B1** emitted from one side of the second transducer **104-B**. Another sensor (not illustrated) is on the opposite side of the housing **516-A** and receives ultrasonic waves **108-B2i** that are in parallel alignment with the axis of the ultrasonic waves **108-B2** emitted from the opposite side of the second transducer **104-B**. In the illustrated embodiment, each sensor **106** is aligned with a corresponding transducer **104** that emits ultrasonic waves **108**. Those skilled in the art will recognize that having a sensor **106** for each transducer **104** can be used without departing from the spirit and scope of the present invention. For example, a sonic head having a single transducer **104** emitting ultrasonic waves in one direction can have a single sensor **106** in alignment with the single transducer **104** such that the single sensor **106** is responsive to reflected ultrasonic waves **108-i** originating from that single transducer **104**. In other examples, a sonic head having four or eight transducers **104** can have an equal number of sensors **106**, each sensor **106** responsive to reflected ultrasonic waves **108-i** originating from an associated transducer **104**.

[0057] The four sensors **106** in the sensor assembly **506-A** allows for 360 degree coverage, in 90 degree intervals, around the sensor assembly **506-A**. In this way, when the sensors **106** in the sensor assembly **506-A** are operated as a remote sensor **106-2** in a second sonic head **102-2**, at least one sensor **106** will be responsive to the ultrasonic waves **108-i** emitted from transducers **104-1** associated with a first sonic head **102-1**.

[0058] The sensors **106** are isolated in the sensor assembly **506-A** such that the sensors **106** do not respond to mechanical vibrations of the transducers **104**. In one embodiment, the sensors **106** are mounted and supported in the sensor assembly **506-A** with vibration dampeners, such as a isomeric washer or gasket.

[0059] FIG. **8** illustrates an isometric view of a second embodiment of a sonic head **102-B** that includes one embodiment of an ultrasonic transducer assembly **504-B** and a second embodiment of a sensor assembly **506-B**. In the illustrated embodiment, the sensor assembly **506-B** is positioned above the transducer assembly **504-B**. The two assemblies **506-B**, **504-B** are electrically connected with a cable **502** and mechanically connected by securing two brackets **522**, **532** together. The two brackets **522**, **532** maintain alignment of the sensor assembly **506-B** with the transducer assembly **504-B**.

[0060] The sensor assembly **506-B** includes a sensor housing **516-B** that supports the sensor **106'** and a sensor bracket **526**. The sensor housing **516-B** includes the components associated with the sensor **106'**, such as the sensor processor **402-2** and the connector for the cable **502** to the transducer assembly **504-B**. Extending upward from the sensor housing **516-B** is the sensor upper bracket **526**. The sensor upper bracket **526** includes multiple openings that receive one or more lines from the raft **110**. In one embodiment such as when the system **100** includes a GPS **408**, at least two lines extend from different openings in the upper bracket **526** to the raft **110**. In this way, the sonic head **102-B** is kept in spatial alignment with the raft **110** so that direction information obtained by the GPS **408** corresponds with a defined direction of the sonic head **102-B**.

[0061] The sensor **106'** in the illustrated embodiment has a ring shape. The sensor **106'** is responsive to ultrasonic waves **108** that impinge upon the sensor **106'** from any angle in a plane perpendicular to the central axis **912** of the sensor **106'**, which is coaxial with the central axis of the sonic head **102-B**. In particular, the sensor **106'** is responsive to ultrasonic waves **108-A1i**, **108-A2i**, **108-B1i**, **108-B2i**, that are parallel with emitted ultrasonic waves **108-A1**, **108-A2**, **108-B1**, **108-B2**, respectively.

[0062] FIG. **9** illustrates a cross-sectional view of the sensor **106'** in the second embodiment of the sonic head **102-B** shown in FIG. **8**. The sensor **106'** includes a sensor housing **516-B** that includes an enclosure **916** with a piezoelectric element **902** inside. The sensor **106'** has a central axis **912** that is vertical and defines the center of the ring-shape of the sensor **106'**.

[0063] The piezoelectric element **902** has a ring configuration with a rectangular cross-section. The sensor housing **916** has a hollow, cylindrical configuration with a hollow portion defining a cavity **906**. The cavity **906** is defined by an upper wall, a cylindrical inner wall, and a concentric outer wall. The piezoelectric element **902** is secured inside the cavity **906**. The piezoelectric element **902** is supported with an upper support **904-1** and a lower support **904-2**. The supports **904** are configured to receive the upper and lower ends of the piezoelectric element **902**. In this way the piezoelectric element **902** is held in place without allowing vertical displacement nor lateral displacement in the cavity **906**.

[0064] The piezoelectric element **902** is isolated from mechanical vibrations originating in the sonic head **102-B**. In the illustrated embodiment, the upper support **904-1** and the lower support **904-2** attenuate the mechanical vibrations from the sonic head **102-B**. In one such embodiment, the support **904-1** and the lower support **904-2** are made from an elastomeric material.

[0065] FIG. **10** illustrates an isometric view of one embodiment of a sonic head **102-C** that includes one embodiment of an ultrasonic transducer assembly **504-C** and one embodiment of a sensor assembly **506-C**. In the illustrated embodiment, the sensor assembly **506-C** is included in the housing **526-C** of the transducer assembly **504-C**. The housing **526-C** is sandwiched between the upper transducer **104-A** and the lower transducer **104-B**.

[0066] The transducer assembly **506-C** includes a first transducer **104-A** and a second transducer **104-B**, and a housing **526-C**. The first transducer **104-A** emits ultrasonic waves **108-A1**, **108-A2** in two opposing directions. The second transducer **104-B** emits ultrasonic waves **108-B1**, **108-B2** in two opposing
5 directions. In this way, the transducer assembly **504-C** emits ultrasonic waves **108** in 360 degrees around the vertical axis of the transducer assembly **504-C**.

[0067] The sensor assembly **506-C** is integrated with the housing **526-C** in the illustrated embodiment. The housing **526-C** includes a connector **528** configured to attach to a cable that has an opposite end connected to other
10 equipment, such as the power supply **406**, GPS **408**, communications equipment for remote controller **404**, or a second sonic head **102** supported by the same raft **110**. The sensor assembly **506-C** includes four sensors **106** aligned in parallel with each axis of the ultrasonic waves **108** emitted from the transducers **104-A**, **104-B**. The sensors **106** and associated electronics are in the housing **526-C**, along with
15 the electronics and wiring for the transducers **104-A**, **104-B**.

[0068] In the illustrated embodiment, the sonic head **102-C** includes an upper mounting bracket **522** extending upward from the second transducer **104-B**. The lower mounting bracket **524** extends downward from the lower transducer **104-A**. The upper mounting bracket **522**, is configured to attach to a line
20 suspended from the raft **110** and the lower mounting bracket **524** is configured to attach to a line leading to an anchor or other object that holds the sonic head **102-C** in vertical alignment. In one embodiment such as when the system **100** includes a GPS **408**, at least two lines extend from different openings in the upper bracket **522** to the raft **110**. In this way, the sonic head **102** is kept in spatial alignment
25 with the raft **110** so that direction information obtained by the GPS **408** corresponds with a defined direction of the sonic head **102**.

[0069] In the illustrated embodiment, two sensors **106-A**, **106-B** of the four sensors **106** are illustrated. The first sensor **106-A** receives ultrasonic waves **108-A1i** that are in parallel alignment with the axis of the ultrasonic waves **108-A1**
30 emitted from one side of the first transducer **104-A**. Another sensor (not illustrated) is on the opposite side of the sensor assembly **506-C** and receives ultrasonic waves **108-A2i** that are in parallel alignment with the axis of the ultrasonic waves **108-A2** emitted from the opposite side of the first transducer **104-A**.

[0070] The second sensor **106-B** receives ultrasonic waves **108-B1i** that are in parallel alignment with the axis of the ultrasonic waves **108-B1** emitted from one side of the second transducer **104-B**. Another sensor (not illustrated) is on the opposite side of the sensor assembly **506-C** and receives ultrasonic waves **108-B2i** that are in parallel alignment with the axis of the ultrasonic waves **108-B2** emitted from the opposite side of the second transducer **104-B**.

[0071] The four sensors **106** in the sensor assembly **506-C** allows for 360 degree coverage, in 90 degree intervals, around the sensor assembly **506-C**. In this way, when the sensors **106** in the sensor assembly **506-C** are operated as a remote sensor **106-2**, at least one sensor **106** will be responsive to the ultrasonic waves **108-i** emitted from transducers **104-1** associated with another sonic head **102-1**.

[0072] The sensors **106** are isolated in the sensor assembly **506-C** such that the sensors **106** do not respond to mechanical vibrations of the transducers **104**. In one embodiment, the sensors **106** are mounted and supported in the housing **526-C** with vibration dampeners, such as a isomeric washer or gasket **606**, **604**.

[0073] FIG. **11** illustrates a flow diagram showing one embodiment of the method **1100** for detecting bio-organism resonance. Bio-organism resonance is the resonant frequency **302-5** for a particular bio-organism. For the embodiment in which a single sonic head **102** includes both the transducer **104** and the receiving sensor **106**, the steps are performed by the local controller **402** in that sonic head **102**. For the embodiment in which multiple sonic heads **102** are used, such as one sonic head **102-1** emitting the ultrasonic waves **108** and at least one other sonic head **102-2** receiving ultrasonic waves **108-i**, the sonic heads **102-1**, **102-2** are in communication and the steps are performed by the appropriate local controller **402**.

[0074] The first step **1102** is to start the process **1100**. The next step **1104** is to initialize the process **1100**. The step **1104** of initializing the process **1100** is performed by the controller **402** associated with the transducer **104** with respect to preparing to emit the various frequencies. The step **1104** of initializing the process **1100** is performed by the controller **402** associated with the sensor **106** with respect to preparing to receive the ultrasonic waves **108-i** from the transducer **104**.

[0075] In one embodiment, the initialize step **1102** includes clearing all the resonant signature markers and initializing a Bandwidth Indexer to the first Bandwidth Table entry. The Bandwidth Indexer is a programmed function in the local controller **402**. The Bandwidth Indexer maintains the Bandwidth Table. The

5 Bandwidth Table contains data relating to at least the following fields: Bandwidth Index, Frequency, Gated Output or Duty Cycle, and Power Level. In one embodiment, the Bandwidth Index is a parameter, such as a number, that sequentially identifies information related to each pulse or gated output. Associated with each Bandwidth Index are the one or more Frequencies to be emitted during

10 the pulse or gated output. For example, one Bandwidth Index includes the Frequencies of 20,000 Hz, 20,005 Hz, 20,010 Hz, 20,015 Hz, and 20,020 Hz. The next Bandwidth Index includes the Frequencies of 33,000 Hz, 33,301 Hz, 33,302 Hz, and 33,303 Hz. Also associated with each Bandwidth Index is the Gated Output or Duty Cycle. For example, the Duty Cycle is 75% with a period of 2

15 seconds divided as 1.5 seconds of On Time and 0.5 seconds of Off Time. In one embodiment, a Power Level field is also associated with each Bandwidth Index. For example, a Power Level for a particular Bandwidth Index is specified as 10% of full power.

[0076] In another embodiment, the initialize step **1102** includes writing the

20 current resonant frequency data to a Historical Table before includes clearing all the resonant signature markers and initializing a Bandwidth Indexer to the first Bandwidth Table entry. As illustrated in FIG. 12, after completion of the major step **1204** to sweep the frequencies to determine the resonant frequencies, the step **1212** to initialize the resonant sweep further includes analyzing the data in the

25 Historical Table and in the Bandwidth Table to identify any trends over time with respect to detected resonant frequencies. For example, historical data on a specific resonant frequency may indicate the presence of an algae bloom or that an algae bloom is decreasing in size and/or density. That trend over time information is available to adjust the parameters of major step **1206** to sweep the resonant

30 frequencies. For example, if the trend over time information indicates the continued existence of bio-organisms **116**, the step **1214** to emit the frequency includes emitting the frequency for a longer period and/or higher power. That is, the period that the frequency is emitted is extended over the previously used time and/or the power is increased over the previously used power level.

[0077] The next step **1106** after the initialize step **1104** is to emit the frequency corresponding to the current entry in the Bandwidth Table. The emitting step is **706** performed by the transducer **104** and its associated controller **402**. The emitting step **1106** includes reading the data from the Bandwidth Table and
5 causing the transducer **104** to emit a specific frequency at a specific power level.

[0078] The next step **1108** of measuring and recording data **310** is performed while step **1106** is being performed. The measuring and recording step **1108** is performed by the sensor **106** and its associated controller **402**. Step **1108** measures the amplitude **306** from the sensor **106** and records the data **310**, which
10 includes the detected amplitude for the detected frequency.

[0079] The next step **1110** after completing step **1108** of measuring and recording data **310** is to determine if more frequencies are to be measured. The frequencies completed step **1110** is performed by the controller **402** associated with the transducer **104**. In one embodiment, if the Bandwidth Table has
15 additional entries, the Bandwidth Indexer increments the Table to the next entry and the method **1100** loops back to step **1106** to emit the next frequency. If the Bandwidth Table is at the end, then all the frequencies have been measured and method **1100** moves on to the next step **1112**.

[0080] The next step **1112** is to perform a trend analysis of the recorded data
20 **310**. The analysis step **1112**, in one embodiment, is performed by the local controller **402**. In another embodiment, the analysis step **1112** is performed by the remote controller **404**, which is in communication with the local controller **402**. In one embodiment, trend analysis step **1112** is performed by averaging the amplitude data points **306-1**, **306-2**, ... to determine an average amplitude **306-avg**.
25 **avg**. In one such embodiment, any outliers are not included in calculating the average amplitude. An outlier is an amplitude data point **306** that is below the average measured amplitude **306-avg** by a predetermined amount. For example, if the amplitude **306-5** shown in FIG. 3 is less than the average **30-avg** by a threshold amount, then the data point at the frequency **302-5** is an outlier. If that
30 data point is not an outlier, then the frequency **302-5** indicates a resonant frequency **302-5**.

[0081] The next step **1114** is to identify if a resonant frequency is present in the data **310**. The identification step **1114**, in one embodiment, is performed by the local controller **402**. In another embodiment, the identification step **1114** is performed by the remote controller **404**, which is in communication with the local controller **402**. In one embodiment, identifying the resonant frequency **302-5** is performed by identifying amplitude data points **306-5** that are below the amplitude value determined in step **1112** by a predetermined amount such as illustrated in FIG. 3.

[0082] If a resonant frequency **302-5** is found in step **1114**, then step **1116** to record the resonant frequency data **310-rf** is performed. The resonant frequency data **310-rf** includes the resonant frequency **302-5** as determined in step **1114**. The record step **1116** is performed by the controller **402**. In one embodiment, the Bandwidth Table for the frequency **302-5** that is identified as being resonant is annotated with the direction of the sensor **104** and the date and time of the measurement. In the embodiment with a GPS **408**, a direction associated with the detection of the resonant frequency is also recorded in the Bandwidth Table. In one embodiment, the direction is determined by the location of the sensor **106** on the sensor assembly **506-A**, **506-C**. In another embodiment, the direction is determined by the location of the transducer **104** on the transducer assembly **504-A**, **504-B**, **504-C**.

[0083] The step **1116** to record the resonant frequency data **310-rf** is performed for each time a resonant frequency is determined during a sweep of frequencies by the method **1100**. That is, method **1100** includes steps **1106**, **1108**, **1110** to emit multiple frequencies and to measure and record data **310** for those multiple frequencies. If the body of water **114** includes multiple types of bio-organisms includes multiple types of bio-organisms **116** and each of those types of multiple types of bio-organisms **116** have their own resonant frequency, then step **1116** to record the resonant frequency data **310-rf** is performed for each resonant frequency **302-5** determined. In the case where multiple resonant frequencies are determined, the entries in the Bandwidth Table for the multiple resonant frequencies is annotated with data associated with the resonant frequency determination.

[0084] In one embodiment, the step **1116** to record the resonant frequency data **310-rf** includes recording the resonant frequency **302-5** of beneficial bio-organisms. Beneficial bio-organisms are water-borne organisms that serve a purpose that benefits either the environment or other life. For example, diatoms are a food source for shrimp, which are then harvested for consumption. If a beneficial bio-organism has a resonant frequency and that resonant frequency is determined during step **1114**, the step **1116** to record the resonant frequency data, in one embodiment, includes recording data indicating that the resonant frequency is for a beneficial bio-organism. In another embodiment, once a resonant frequency **302-5** is determined to be associated with a beneficial bio-organism either during step **114** or step **1116**, the resonant frequency is not recorded during step **1116** of recording the resonant frequency data **310-rf**. In this way, when the algae control system **10** emits ultrasonic waves to eradicate or control the growth of bio-organisms, the transducer **104** does not emit those resonant frequencies that correspond to beneficial bio-organisms.

[0085] The next step **1118** is to wait a time before looping back to the initialize system step **1104**. The wait step **1118** is performed by the local controller **402**. The wait step **1118** is performed after the recording step **1116** and if identification step **1114** does not determine that a resonant frequency is present in the data. The wait time, in one embodiment, is preselected. For example, if the method **1100** is to be run once every three hours, the wait time is equal to three hours minus the time to perform the loop of steps **1106** to **1110**. Another example is if the method **1100** is to be run continuously or without delay, the wait time is set to zero.

[0086] FIG. **12** illustrates a flow diagram showing one embodiment of the method **1200** for detecting and using resonance to control micro-organisms. The method **1200** has two major steps, the first step **1204** is to perform a frequency sweep and the second step **1206** is to perform targeted emissions at frequencies associated with the determined resonant frequencies.

[0087] In one embodiment, a Bandwidth Indexer is a programmed function in the processor **402**. The Bandwidth Indexer maintains the Bandwidth Table. The Bandwidth Table stores information on the multitude of frequencies emitted by the transducer **104**. The Bandwidth Table contains data relating to various fields, such as a Bandwidth Index, Frequency, Gated Output or Duty Cycle, Power Level, and Cavitation. The Bandwidth Table also stores data indicating if the Frequency is a resonant frequency, and in one embodiment, if there is a direction associated with the resonant frequency determination.

[0088] The first step **1202** is to start the process **1200**. The next step **1204** is to perform a frequency sweep. The major step **1204** includes the method **1100** described above with respect to FIG. 11 for determining the resonant frequency **302-5** of any bio-organisms **116** in the water **114**. In one embodiment, the step **1204** of performing the frequency sweep includes the controller **402** executing a software program that performs the function of the Bandwidth Indexer to identify frequencies to be emitted by the transducer **104**. As the frequencies in the Bandwidth Table are swept, the method **1100** determines and stores any resonant frequencies that are determined. In one embodiment, the step **1104** to initialize the resonance detection method **1100** includes resetting the Bandwidth Table to remove the data indicating previously determined resonant frequencies. In this way, the Bandwidth Table starts fresh and stores only the current state of resonant frequencies **302-5**.

[0089] The next major step **1206** is to sweep the resonant frequencies **302-5** determined during the step **1204** to perform the frequency sweep. The major step **1206** includes various steps **1212**, **1214**, **1216**, **1218** for sweeping the resonant frequencies identified in the Bandwidth Table.

[0090] The first step **1212** of major step **1206** is to initialize the resonant sweep. This step **1212** includes identifying the first resonant frequency **302-5** to be emitted by the transducer **104**. The step **1212** of initializing is performed by the controller **402**. The step **1212** of initializing includes preparing for the transducer **104** to emit the various frequencies that are determined to be resonant frequencies. In one embodiment, the frequencies to be emitted include a range or bandwidth of frequencies that include the resonant frequency.

[0091] The next step **1214** is to emit the frequencies associated with the resonant frequency **302-5**. The step **1214** is performed by the transducer **104** as directed by the controller **402**. In the embodiment where a range or bandwidth of frequencies that include the resonant frequency are to be emitted, the step **1214** to
5 emit includes sequentially emitting each of the frequencies within the range or bandwidth. In one embodiment, these frequencies are emitted for a pre-determined time. That is, the time is determined before the step **1206** is run. In another embodiment, these frequencies are emitted for a calculated time. In one such embodiment, historical trend data is used to calculate the time that these
10 frequencies are emitted. For example, if multiple runs of major step **1204** to perform a frequency sweep to determine resonant frequencies indicates the presence of a large algae bloom, then the time to emit these frequencies is set to be of a duration sufficient to have an impact on that bloom. Such multiple runs of major step **1204** are recorded in a Historical Table as described above with respect
15 to FIG. 11. In another example, if multiple runs of major step **1204** indicates that a once-large algae bloom has decreased, then the time to emit these frequencies is decreased.

[0092] The next step **1216** is to determine if there are more frequencies or bandwidths to emit. If the step **1216** determines that there are more resonant
20 frequencies to emit, then step **1218** to increment to the next frequency is performed. In one embodiment, step **1218** is performed by the controller **402** such that the Bandwidth Indexer selects the next Bandwidth Table entry that has a resonant frequency associated with it. The process then loops to step **1214** to emit the frequency or bandwidth.

25 [0093] If step **1216** determines that there are no more frequencies or bandwidths to emit, then the process **1200** loops to step **1204** to perform a frequency sweep. In this way, the process **1200** will determine if the resonant frequencies have changed, thereby indicating that the concentrations of various bio-organisms **116** in the water **114** have changed.

[0094] The resonance detection system **100** includes various functions. The function of determining the resonant frequency of a type of micro-organism **116** in a body of water **114** is implemented, in one embodiment, by a sensor **106** measuring the amplitude of ultrasonic waves **108-i** at various frequencies **302** emitted by a transducer **104** and determining which frequencies **302** indicate absorption by the micro-organisms at resonance.

[0095] The function of controlling bio-organisms **116** in a body of water **114** is implemented, in one embodiment, by a resonance detection system **100** that first, performs a step **1204** of detecting resonance of bio-organisms **116** by sweeping a multitude of frequencies and then performing a step **1206** of emitting the ultrasonic waves from a transducer **104** at the detected resonant frequencies or at a narrow bandwidth of frequencies above and below the resonant frequency.

[0096] From the foregoing description, it will be recognized by those skilled in the art that a system **100** for determining resonance of micro-organisms **116** in the water **114** has been provided. Each type of micro-organism **116** in a body of water **114** has a resonant frequency **306-5** at which the energy in the ultrasonic wave **108** is absorbed by the micro-organism **116**. A sensor **106** monitors the amplitude of the ultrasonic waves **108-i** over a range of emitted frequencies.

[0097] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

CLAIMS

What is claimed is:

1. An apparatus for determining resonance of bio-organisms (116) in a body of water (114), said apparatus comprising:

5 a transducer (104) configured to emit a plurality of ultrasonic waves (108) through the body of water (114), said plurality of ultrasonic waves (108) including a plurality of frequencies (302);

a sensor (106) responsive to said plurality of ultrasonic waves (108-i); and

10 a controller (402) operatively connected to said transducer (104), said sensor (106) providing data (310) to said controller (402); and whereby said controller (402) executes a first set of steps (1100) for detecting bio-organism resonance, and said controller (402) also executes a second set of steps (1206) to perform targeted emissions at frequencies associated with detected bio-organism resonance.

15 2. The apparatus of Claim 1 wherein said first set of steps (1100) for detecting bio-organism resonance includes said controller (402) causing said transducer (104) to emit said plurality of ultrasonic waves (108), said sensor (106) measuring data (310) corresponding to an amplitude of said plurality of ultrasonic waves (108), and said controller (402) determining a resonant frequency (302-5) from said data (310).

20 3. The apparatus of Claim 1 wherein said first set of steps (1100) for detecting bio-organism resonance includes a step (1106) of said transducer (104) emitting said plurality of ultrasonic waves (108) with each one of said plurality of ultrasonic waves (108) having a unique frequency (302); and said first set of steps (1100) includes a step (1108) of measuring and recording data (310) from said
25 sensor (106).

4. The apparatus of Claim 3 wherein said first set of steps (1100) for detecting bio-organism resonance includes a step (1112) to perform a trend analysis of said data (310) collected during said step (1108) of measuring and recording data (310) from said sensor (106); and said first set of steps (1100)
5 further includes a step (1114) to identify if a resonant frequency (302-5) is present in said data (310).

5. The apparatus of Claim 4 wherein said first set of steps (1100) for detecting bio-organism resonance includes determining said resonant frequency (302-5) by identifying a frequency (302-5) corresponding to an amplitude (306-5) in
10 said data (310) that is less than an average amplitude by a preselected amount.

6. The apparatus of Claim 4 wherein said first set of steps (1100) for detecting bio-organism resonance includes a step (1116) to record resonant frequency data (310-rf) when said resonant frequency (302-5) is present in said data (310) as determined by said step (1114) to identify if said resonant frequency
15 (302-5) is present in said data (310).

7. The apparatus of Claim 1 wherein said second set of steps (1206) to perform targeted emissions at frequencies associated with detected bio-organism resonance includes said controller (402) causing said transducer (104) to emit at least one ultrasonic wave (108) associated with a resonant frequency (302-5) where
20 said first set of steps (1204, 1100) for detecting bio-organism resonance identifies said resonant frequency (302-5).

8. The apparatus of Claim 1 wherein said second set of steps (1206) to perform targeted emissions at frequencies associated with detected bio-organism resonance includes a step (1214) to emit at least one frequency associated with a
25 resonant frequency (302-5) determined by said first set of set of steps (1204, 1100) for detecting bio-organism resonance.

9. The apparatus of Claim 1 wherein said transducer (104-1) is incorporated in a first sonic head (102-1); said sensor (106-2) is incorporated in a second sonic head (102-2); and said sensor (106-2) responsive to said plurality of ultrasonic waves (108-i) emitted from said transducer (104-1) in said first sonic
5 head (102-1).

10. The apparatus of Claim 1 wherein said transducer (104-1) is proximate said sensor (106-1); said sensor (106-1) being isolated from said transducer (104-1) such that said sensor (106-1) is responsive to said plurality of ultrasonic waves (108-i) received by said sensor (106-1) without interference from
10 mechanical vibrations of said transducer (104-1); and said sensor (106-1) responsive to said plurality of ultrasonic waves (108-i) reflected by the bio-organisms (116) in the body of water (114).

11. The apparatus of Claim 1 wherein said transducer (104-1) is one of a plurality of transducers (104) configured to emit said plurality of ultrasonic waves
15 (108) and said sensor (106) is one of a plurality of sensors (106) located proximate said plurality of transducers (104), and said plurality of transducers (104) and said plurality of sensors (106) incorporated in a sonic head (102).

12. The apparatus of Claim 1 further including a global positioning system receiver (408), and said global positioning receiver (408) detecting a position
20 of said sensor (106) in the body of water (114).

13. The apparatus of Claim 1 wherein said sensor (106') has a cylindrical shape, and said sensor (106') is responsive to said plurality of ultrasonic waves (108-A1i, 108-A2i, 108-B1i, 108-B2i) emitted by said transducer (104).

14. The apparatus of Claim 1 wherein said sensor (106') has a
25 piezoelectric element (902) with a ring configuration and a rectangular cross-section, and said sensor (106') is responsive to said plurality of ultrasonic waves (108-A1i, 108-A2i, 108-B1i, 108-B2i) from any angle in a plane perpendicular to a central axis (912) of said sensor (106').

15. An apparatus for determining resonance of bio-organisms (116) in a body of water (114), said apparatus comprising:

a transducer (104) configured to emit a plurality of ultrasonic waves (108) through a body of water (114), said plurality of ultrasonic waves (108) having a
5 plurality of frequencies (302);

a sensor (106) responsive to said plurality of ultrasonic waves (108-i), said sensor (106) detecting an amplitude of each of said plurality of frequencies (302) emitted from said transducer (104); and

a controller (402) operatively connected to said transducer (104) and said
10 controller (402) in communication with said sensor (106).

16. The apparatus of Claim 15 wherein said transducer (104-1) is incorporated in a first sonic head (102-1); said sensor (106-2) is incorporated in a second sonic head (102-2); and said sensor (106-2) responsive to said plurality of ultrasonic waves (108-i) emitted from said transducer (104-1) in said first sonic
15 head (102-1).

17. The apparatus of Claim 15 wherein said transducer (104-1) is one of a plurality of transducers (104) configured to emit said plurality of ultrasonic waves (108) and said sensor (106) is one of a plurality of sensors (106) located proximate said plurality of transducers (104), and said plurality of transducers (104) and said
20 plurality of sensors (106) incorporated in a sonic head (102).

18. The apparatus of Claim 15 wherein said transducer (104-1) is proximate said sensor (106-1); said sensor (106-1) being isolated from said transducer (104-1) such that said sensor (106-1) is responsive to said plurality of ultrasonic waves (108-i) received by said sensor (106-1) without interference from
25 mechanical vibrations of said transducer (104-1); and said sensor (106-1) responsive to said plurality of ultrasonic waves (108-i) reflected by the bio-organisms (116) in the water.

19. The apparatus of Claim 15 wherein said controller (402) causes said transducer (104) to emit said plurality of ultrasonic waves (108) with each one of said series of ultrasonic waves (108) having a specified frequency (302), and said controller (402) storing data related to measurements made by said sensor (106)
5 when receiving said plurality of ultrasonic waves (108).

20. The apparatus of Claim 19 further including said controller (402) performing a trend analysis of said stored data related to measurements made by said sensor (106).

21. The apparatus of Claim 19 further including said controller (402)
10 performing a trend analysis of said stored data related to measurements made by said sensor (106), said controller (402) identifying a resonant frequency from said trend analysis.

22. The apparatus of Claim 21 further including said controller (402) and said transducer (104) performing a sweep of resonant frequencies (1206) whereby
15 said resonant frequency is emitted by said transducer (104).

23. The apparatus of Claim 15 further including a global positioning system receiver (408), and said global positioning receiver (408) detecting a position of said sensor (106) in the body of water (114).

24. The apparatus of Claim 15 wherein said sensor (106') has a
20 cylindrical shape, and said sensor (106') is responsive to said plurality of ultrasonic waves (108-A1i, 108-A2i, 108-B1i, 108-B2i) emitted by said transducer (104).

25. An apparatus for determining resonance of bio-organisms (116) in a body of water (114), said apparatus comprising:

a raft (110) configured to float on the body of water (114);

a sonic head (102) suspended below said raft; said sonic head (102)
5 submerged in the body of water, said sonic head (102) including a transducer (104),
a controller (402), and a sensor (106),

said transducer (104) configured to emit a series of ultrasonic waves
(108) through the body of water (114), said series of ultrasonic waves (108) having a
plurality of frequencies (302); and

10 said controller (402) operatively connected to said transducer (104),
said controller (402) causing said transducer (104) to emit said series of ultrasonic
waves (108) with each one of said series of ultrasonic waves (108) being a specified
frequency (302); and

said sensor (106) responsive to said series of ultrasonic waves (108-i),
15 said sensor (106) providing data to said controller (402).

26. The apparatus of Claim 25 further including a global positioning
system receiver (408), and said global positioning receiver (408) detecting a
direction corresponding to an orientation of said sensor (106) in said sonic head
(102).

20 27. The apparatus of Claim 25 wherein said sensor (106') has a
cylindrical shape with a sensing surface perpendicular to a surface of the body of
water when said sonic head (102-B) is deployed in the body of water (114).