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(54) Title: AN AQUATIC MANAGEMENT SYSTEM

(57) Abstract: Disclosed is an aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising: a powered vehicle capable of moving within the body of water; a task implementing system connected to the powered vehicle capable of performing a plurality of tasks pertaining to the management of the aquatic ecosystem; a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water for the task implementing system to implement a management task with respect to the aquatic ecosystem. The task implementing system is capable of performing tasks to obtain information about the ecosystem and, based on that information, cause another task to be performed.
AN AQUATIC MANAGEMENT SYSTEM

Technical Field

5 Disclosed is an aquatic management system for managing an aquatic ecosystem.

Background

The ecosystem of water bodies such as ponds or lakes may be monitored and/or managed for various purposes. For example, aquatic animals that are stocked or naturally reside in water bodies can be commercially farmed, or monitored for research purposes or informing fisheries management for implementation of actions and policies. In the example of commercial prawn farming, it may be desirable for the prawns to be fed according to a regular schedule or other criteria.

Traditional methods of feeding aquatic animals such as prawns include simply throwing, blowing or otherwise projecting feed out onto the pond from land or other boundary surrounding or adjacent the pond. However, this method is limited by the distance that the feed can be projected into the pond from the land. For a pond having a surface area of one hectare these traditional methods result in feed being dispersed to only 20 - 30% or less of the pond area in a thin strip or band adjacent the land. Thus, for a pond having a surface area of 10 hectares these traditional methods result in feed being dispersed to as little as 10% or less of the pond area.

An alternative traditional method in some parts of the world, such as South America, is to throw feed out onto the pond from a canoe or raft. Although a greater area of reach may be achieved compared to distributing feed from the land, this method is highly labour intensive, as well as potentially hazardous for the workers.

Similarly, monitoring aquatic organisms in a body of water, or monitoring various conditions in or of the water body, is traditionally carried out by personnel swimming, snorkelling or diving to make observations. This activity is labour intensive and potentially hazardous.
Summary of Disclosure

In a first aspect there is provided an aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:

- a powered vehicle capable of moving within the body of water;
- a task implementing system connected to the powered vehicle capable of providing information on one or both of:
  - (a) a behavioural activity of an aquatic animal; and
  - (b) a detrimental environmental condition in the aquatic ecosystem;

and implementing a task to enhance the well-being of the aquatic animal, or treat the detrimental condition, based on the information; and,

- a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water for the task implementing system to implement a management task with respect to the aquatic ecosystem.

The task implementing system may comprise an aquatic animal detector configured to detect one or more of the following behavioural activities of aquatic animals: feeding; feed seeking behaviour; movement; and interaction with other aquatic animals.

The task implementing system may comprise an aquatic animal detector is configured to detect a quantity of aquatic animals within a defined region in the body of water.

The aquatic animal detector may further be configured to estimate biomass of the aquatic animals detected.

The aquatic animal detector may comprise one, or a combination of two or more, of: an infrared camera; a video camera; an acoustic sensor with passive SONAR capability; an acoustic sensor with active SONAR capability.

The task implementing system may comprise a monitoring system comprising at least one sensor apparatus for monitoring the body of water for detrimental environmental conditions.
The sensor apparatus may be capable of detecting one or more of the following: (a) dissolved oxygen level in the body of water, (b) pH or dissolved carbon dioxide level in the body of water (c) water temperature, (d) salinity (e) turbidity, (f) level of one or more pollutants or toxic compounds in the body of water, (g) a level and/or distribution of uneaten feed in the body of water, and (h) a level and/or distribution of organic waste; (h) detritus; and (i) an anaerobic state.

The sensor apparatus may comprise any one of: a dissolved oxygen sensor; a dissolved CO$_2$ sensor; (c) a thermometer; (d) an acoustic sensor with active SONAR capability for detecting an amount of organic matter on a surface within the body of water.

The powered vehicle may be configured to float on the body of water and the task implementing system is located on-board the powered vehicle.

The powered vehicle may be an unmanned powered vehicle.

The task implementing system may comprise a feeder supported by or associated with the powered vehicle and capable of distributing feed to aquatic animals residing in the body of water.

The feeder may comprise a feed dispenser and a storage container capable of supplying feed to the feed dispenser.

The aquatic management system may comprise a control system in communication with the task implementing system such that when certain behavioural activity of an aquatic animal is detected, wherein the control system is arranged to instruct the feeder to distribute or to cease to distribute feed.

The task implementing system may comprise a detector capable of detecting physiological characteristics of aquatic animals. A component of the detector may be in a form capable of being implanted into a sentinel aquatic animal and communicating with another component of the detector. The component of the detector may be an RFID tag implantable into the sentinel aquatic animal. The physiological characteristics may be indicative of the health including stress.
levels of aquatic animals.

The aquatic management system may comprise a control system in communication with the task implementing system such that when a certain detrimental environmental conditions is detected, the control system is arranged to instruct the feeder to distribute or cease to distribute.

The task implementing system may comprise a harvesting system which facilitates partial or complete harvesting of aquatic animals.

The task implementing system may comprise a further detector for detecting a predator of aquatic animals. The further detector may trigger means for deterring the predator of aquatic animals.

The task implementing system may comprise means for administering one or more from the following group to treat the ecosystem when a detrimental environmental condition is present: nutrients; medications; water conditioners; lime; fertilisers; probiotics; and other substances.

The task implementing system may comprise a sample collecting mechanism for collecting samples of water or aquatic animals in the body of water.

In another aspect, there is provided an aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:

- a powered vehicle movable on or within the body of water;
- a task implementing system comprising a sensor capable of detecting feeding or feed seeking behaviour of an aquatic animal, and a feeder mounted on the powered vehicle and in communication with the sensor such that the feeder is arranged to dispense feed when feeding or feed seeking behaviour is detected by the sensor; and
- a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water.

In yet another aspect, there is provided an aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:
a powered vehicle movable on or within the body of water;
a task implementing system comprising a monitoring system arranged to
monitor the body of water for one or more detrimental environmental conditions, and a treatment system in communication with the monitoring system, the
treatment system being arranged to administer one or more substances to treat the body of water when the monitoring system detects a detrimental environment condition; and
a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water.

The term "ecosystem" as used herein is understood to include biological organisms (i.e. plants and animals) and their surrounding physical environment. It follows that the term "aquatic ecosystem" includes the aquatic animals and other organisms living in an aquatic environment, as well as the aquatic environment itself.

Brief Description of Drawings

Figure 1 is a perspective view of an embodiment of the disclosed aquatic management system in use on a pond;

Figure 2 is a perspective view of the embodiment of the aquatic management system shown in Figure 1;

Figure 2a is a side view of an embodiment of the aquatic management system; and

Figure 3 is a schematic diagram showing components of the aquatic management system shown in Figure 1.

Detailed Description

Figure 1 shows an aquatic management system 10 for managing an aquatic ecosystem having a body of water 12 harbouring aquatic animals. The aquatic animals may have been stocked or naturally residing in the body of water 12. The system 10 comprises a powered vehicle 14, a task implementing system 16 connected to the powered vehicle 14 and a navigation system 18. The task
implementing system 16 is capable of performing one or more tasks pertaining to the management of the aquatic ecosystem. The navigation system 18 is capable of guiding the powered 14 vehicle to any location or along any path on the body of water 12 for the task implementing system 16 to implement a management task with respect to the aquatic ecosystem.

The body of water 12 may for example be a man-made water body such as a man-made pond or tank of considerable size, or natural pre-existing water body such as a river, pond or lake, or a netted or fenced volume of water in a larger water body including the sea. In a non-limiting example the body of water may have a surface area of 0.5 to 1 hectare. In some instances the body of water 12 may have an area up to 10 hectares or greater. For ease of reference only in the following description, the body of water 12 will hereinafter be referred to as "pond 12".

In order to provide context, the aquatic management system 10 will now be generally described according to a specific example with reference to Figure 1. The system 10 comprises a powered vehicle 14 arranged to float or otherwise move on or within the pond 12. The task implementing system 16 comprises a feeder 20 capable of distributing feed to aquatic animals such as prawns or fish residing in the pond 12. The feeder 20 is supported by the powered vehicle 14. The management task to be implemented by the task implementing system 16 is therefore to feed the aquatic animals. Further, the navigation system 18 can navigate the powered vehicle 14 along any route or path 22 within the pond 12. The path 22 can be a pre-selected path programmed into the navigation system 18, or dynamically variable either via remote control or dependant on measured or sensed environmental parameters and/or characteristics (e.g. feeding activity, feed seeking activity or other behaviour of aquatic animals being cultured in the pond 12).

The feeder 20 can distribute feed to aquatic animals in the pond 12 during its journey or at an end of its journey along the path 22. Thus, the aquatic management system 10 in this example is capable of implementing a task (distributing feed) throughout the whole pond area and not just in the vicinity of a boundary of the pond 12. The aquatic management system 10 can be implemented automatically so that a management task such as feeding aquatic animals can largely be done without the need of human operators.
Generally speaking, various components of the aquatic management system may be selected to operate in a fully automatic mode, semi-automatic mode or manual mode. For example, in a fully automatic mode, the powered vehicle (with the aid of the navigation system) can be an unmanned powered vehicle, without the need for on-board personnel to operate the vehicle. In some forms, the unmanned powered vehicle can move around the pond autonomously or via remote control. Further, the task implementing system is required in the management of the ecosystem. However, it is contemplated that a user can nevertheless override various automatic functions. In the semi-automatic mode, a component of the aquatic management system may operate automatically, apart from some inputs required from an operator. In another example, one component such as the task implementing system may operate automatically, whilst another component such as the vehicle is operated manually, or vice versa.

**Powered vehicle**

With reference to Figures 2 and 2a, the powered vehicle in one embodiment is arranged to float by virtue of a platform or deck supported by a buoyancy system. The buoyancy system in this embodiment is in the form of two floats. The floats have respective elongate inflated bodies and are positioned substantially parallel to each other underneath the deck. However, it will be appreciated that the vehicle may be configured in any suitable form, for example, the vehicle may have more than two floats made of material having a specific gravity less than that of water, or may be a mono-hull vessel, or a flat-bottomed barge. The deck supports other components or systems of the aquatic management system. In one example, the floats are suitable to support 2.5 tonnes of feed. In another embodiment, floatation may be provided by a hull, such as a flat-bottomed barge-type hull.

In another embodiment, the vehicle is a submersible or semi-submersible vehicle. In one example of a submersible vehicle, the vehicle is capable of travelling on the bottom of the pond or otherwise underwater. In another example of a semi-submersible, some components of the aquatic management system may operate underwater while other components float or remain
substantially above water level. Thus, the system 10 may operate partially underwater. For instance, the vehicle 14 may float on the water while a feed dispenser is disposed in the water body and towed by the vehicle 14 or attached to the vehicle by a boom or tether, but in any case connected or otherwise associated with the vehicle 14. In another example, a feed dispenser and on-board controls may be located above water, while say the buoyancy of floats of the vehicle 14 may be selectively modified to vary the buoyancy of the vehicle 14.

A propulsion system 28 enables the vehicle 14 to move on the pond 12. The propulsion system 28 can for example comprise a propeller (water or air propeller) or water jet and an associated driving motor. The motor may for example be a combustion motor or an electric motor. In one embodiment, a power supply 58 for the vehicle 14 is a hybrid power supply utilising an electrical power supply system and combustible fuel supply. In a further embodiment, the electrical power supply system comprises a battery and facility to enable recharging of the battery. This may include a cord enabling electrical connection to an off-board mains supply for recharging the battery, or a docking station 54 (as shown in Figure 3) with charging connections for auto-charging, re-fuelling, loading feed and other payloads. Alternatively or additionally, in another embodiment, the electrical power supply comprises renewable electrical energy generation systems such as on-board photovoltaic cells and/or a suitably sized wind turbine. The renewable electrical energy generation systems can either supply electrical energy directly to various devices or systems on the vehicle 14 or can supply electricity for recharging the battery, or both. The fuel component of the hybrid power supply may comprise ethanol or LPG. This is to reduce the risk of pollution to the pond or other water body 12. Additional back-up power supply 60 may be provided.

In another embodiment the vehicle 14 of the aquatic management system 10 may be largely propelled by currents on or in the water body. In this regard, aquaculture ponds may have aerators 62, such as paddlewheel aerators, to aerate the water by movement. These aerators 62 may create a current, such current usually being fairly circular. Thus, the vehicle 14 is configured to move across the pond 12 by harnessing the circular currents together with the propulsion system 28. In this manner, the vehicle 14 can move, for example, laterally across the pond, or along a circular pathway across the pond 12.
Alternatively, the vehicle 14 can maintain its position on the pond 12.

**Control System**

The aquatic management system 10 includes a control system 30. In one embodiment, the control system 30 is a distributed system comprising an on-board system 30a and an off-board system 30b. Each of the on-board and off-board systems 30a and 30b may comprise otherwise incorporate for example or one or more computers, microprocessors or PLCs and a transceiver. The transceivers enable communication between the on-board and off-board systems as well as communication with other components of the aquatic management system 10. The off-board system 30b may for example be at remotely located control centre.

In this specification reference to the "control system" or "control system 30", except where the context requires otherwise due to express language or necessary implication, is intended to be a reference to: the control system as a whole, namely both the on-board system 30a and the off-board system 30b; or either one of the on-board system 30a or the off-board system 30b.

The control system 30 is arranged to control and co-ordinate various functions and systems of the aquatic management system 10. Therefore, it is possible for all management tasks to be determined or processed on-board or off-board the vehicle 14 by the control system 30. These various functions and systems include but are not limited to:

- controlling a steering device 56 (for example a servo-motor) to steer the vehicle 14 to desired locations on the pond 12;
- operating or controlling one or more of the on-board systems including but not limited to the propulsion system 28, navigation system 18 and the task implementing system 16;
- transferring and receiving information between respective various on-board and off-board systems;
- transferring and receiving information between various on-board systems and on-board or off-board sensors and detectors;
- storing data (for example, data obtained from various sensors of the task implementing system) on a data storage unit;
- 10 -

- processing and analysing data from various on-board systems and on-board or off-board sensors and detectors, such as information relating to aquatic animal behaviour (e.g. resting or activity patterns, increased stress levels) and feeding or feed seeking activity, stock numbers, mortality, environmental parameters, and physiological data of aquatic animals and predators;
- operating the feeder;
- receiving and/or processing remotely sent control signals, for example, from command centre(s), for navigation and task implementation;

- sending diagnostic, operational, environmental and/or husbandry data to a remote location.

Multiple functions can be coordinated and executed simultaneously by the control system 30. The control and co-ordination of various functions and systems of the aquatic management system 10 by the on-board component 30a of the control system 30 may be done by utilising wired communication to other on-board devices, or wireless communication to on-board devices or remote devices. Data that is collected (e.g. by various detectors of the system 10) may be processed and/or stored on-board by the control system 30a, but is preferably transferred wirelessly to a remote command centre for processing and/or storing.

If data is to be processed on-board the vehicle 14, a data processing unit may be located on-board the vehicle 14 in communication with or otherwise within the on board control system 30a for processing data obtained by say detectors or monitoring systems of the task implementing system 16. The on board control system 30a may also include data storage units to store data collected by the system 10 and/or programs and/or algorithms for analysing the data and/or execution by components of the task implementing system 16.

Alternatively or additionally, data may be wirelessly transmitted by a transceiver of the on-board component 30a of the control system 30 to the off-board system 30b for processing with consequential instructions being sent back to the on board system 30a for implementation. In one embodiment the off board control system 30b could be implemented in by cloud computing service. Data generated or collected by the system 10 may be stored on board, off board, or both on and off board the vehicle 14.
Irrespective of where the data processing occurs the processing may be performed in real time to facilitate dynamic operation of the vehicle 14 and implementation of required tasks for example, but not limited to distributing feed or moving along a particular path.

The control system 30 may also be connected wirelessly to the internet, so that data may be transferred (e.g. through "real-time streaming"), analysed and accessed by users of computing systems anywhere in the world in real-time.

The control system 30 may also be arranged to enable direct human control or other intervention. For example a human operator at a remote location to the vehicle 14 may on a console coupled to the off board system 30b, input instructions and/or other commands for implementation by the task implementation system 16.

In one example, data (from say an aquatic animal detector of the task implementing system) can be transferred wirelessly and/or through the internet to a control centre located remotely of the control system 30 where the data can be processed, analysed and/or stored. Then, appropriate tasks may be determined at the control centre (either automatically by virtue of programs/algorithms or by a human operator), which tasks are then communicated wirelessly back to the control system 30 for implementing a task. Such a task may for example be commanding a feeder on-board the vehicle to dispense feed.

Therefore, the control system 30, or another system linked or in communication with the control system 30, may be configured with bespoke programs having specifically developed software programs and algorithms to determine and command various actions to be executed by the aquatic management system 10, for example, controlling the task implementing system 16. These actions include (but are not limited to): starting and stopping the distribution of feed; changing the feed delivery rate, navigating the vehicle 14 to an off-board recharging station; counting stock or otherwise determining biomass; deploying harvesting gear (such as suitably sized trawler nets); start electrofishing (e.g. by deploying electrodes into a desired position in the water where fish are detected); turning on sensors or detectors for monitoring environmental
parameters; deterring predators.

In one example, the aquatic management system 10 can estimate biomass by detecting and calculating the quantity of aquatic animals in a given area and linking this data with average size and/or weight data. For instance, the aquatic animals in a certain area may be counted using appropriate detection apparatus, such as a video camera, infrared camera and/or sound navigation and ranging (SONAR) technology, most likely whilst the animals are sedentary and/or not feeding. Certain video cameras, infrared cameras and acoustic generation and detection devices (such as SONAR) can also be used to determine size and weight data of the aquatic animals.

In another embodiment, biomass may be estimated by monitoring the frequency and/or distribution of a subset of the total population of aquatic animals in the pond that can be marked and identified by for example radio-frequency identification (RFID) tags, and the total population estimate calculated based on this data. The ability to estimate biomass may provide a significant management tool for aquaculture systems.

It is also envisioned that in one specific embodiment, the control system 30 is wholly located on-board the vehicle 14 so as to provide a standalone aquatic management system 10.

**Navigation System**

In some embodiments, the navigation system 18 may comprise one or more of: a global positioning system (GPS) on-board the vehicle 14; an inertial navigation system; and, a number of markers (e.g. electronic, magnetic and/or infrared markers) in or around the pond 12 and an interrogation unit on-board the vehicle. In one embodiment, the electronic markers 52 may be in the form of transponders or transmitters at known locations in or around the pond 12. The on-board interrogation unit is able to communicate with the markers and determine its position within the pond by for example triangulation.

The navigation system 18 provides positioning information to enable remote monitoring of the position of the vehicle 14 on the pond 12, and/or to control or assist in navigation of the vehicle 14 along a path 22. Navigational instructions
from the system 18 can be communicated to the steering device to direct the vehicle 14. In one example, navigation of the vehicle 14 may be controlled from the control centre that is remotely located. In this regard, the control centre may command the navigation system to direct the vehicle 14 along a path 22, which may be determined according to real-time data. The data may for example be from an aquatic animal detector of the task implementing system, which data is processed and analysed at the control centre. Based on the data, navigational instructions and other tasks can be determined using specifically designed software and algorithms, and be fed back wirelessly to the navigation system 18 to direct the vehicle 14. This provides the potential for fully automated sensing and navigation.

In another embodiment, the navigation system 18 may directly receive inputs corresponding to a path 22 or location on the pond 12, and communicate with the steering device to direct the vehicle 14 accordingly. Thus, for example, an operator or operating system (e.g. a computer system) may select a predetermined route or location or otherwise determine (for example, by programming or software) any path or location on the pond 12. Respective coordinates or other inputs may be entered into the navigation system 18. In one example, positioning and navigation instructions are communicated to the navigation system 18 by the off-board control system 30b and/or remotely located control centre.

The navigation system 18 can then communicate with the steering device to manoeuvre the vehicle 14 according to the selected route or path, or to the selected location. Further as described in greater detail below the navigation system 18 may be arranged to dynamically vary the path 22 on the basis of information received from on-board or off-board sensors. Alternatively or additionally the on-board navigation system 18 may be by-passed, or controlled, and the vehicle 14 be steered by remote control or otherwise from a remote location.

Task Implementing System

The task implementing system 16 may come in various forms depending on the task desired to be achieved, and multiple forms may be present at the same time. The various forms of the task implementing system 16 include but are not
limited to:

- a feeder for distributing or dispensing feed to aquatic animals while the vehicle 14 is on the pond 12;
- a detector capable of detecting a presence and/or a quantity of aquatic animals within a predefined area with respect to the detector;
- a detector capable of detecting activity, state and movement patterns of aquatic animals;
- a monitoring system capable of monitoring a preselected condition or quality of the body of water, including (a) dissolved oxygen level in the body of water, (b) pH or dissolved carbon dioxide level in the body of water, (c) water temperature, (d) salinity (e.g. via an electronic salinity probe), (e) turbidity, (f) level or concentrations of one or more pollutants in the body of water, for example ammonia or hydrogen sulphide (e.g. by deploying a sample collecting mechanism), (g) a level and/or distribution of uneaten feed in the body of water, (h) a level and/or distribution of organic waste; (g) benthic layers at the bottom of the pond or other body of water;
- a sample collecting mechanism;
- sensors or detectors 70 for detecting poachers and/or predators (such as birds, fish and crabs in prawn farms, and seals or sharks in fish farms) of aquatic animals;
- means 70 for deterring or warding off predators and/or poachers;
- means for administering substances for treatment of the aquatic animals and/or ecosystem, such as medication and/or substances for pond treatment (e.g. for managing algal bloom);
- means for monitoring sentinel animals.

Various forms or embodiments of the task implementing system 16 will now be discussed in more detail.

Turning back to Figures 2 and 2a, the task implementing system may comprise the feeder 20 previously mentioned. The feeder 20 according to one embodiment comprises a feed dispenser 32 and a storage container 34 on-board the vehicle 14. The container 34 is capable of holding a volume of feed and supplying the feed to the feed dispenser 32. The container 34 in this embodiment is in the form of an inverted cone hopper, but may be any suitable
container. The dispenser 32 may for example be: a rotary dispenser relying on centrifugal force; a chute; or a pneumatic dispenser using a stream of air or water, to propel the feed into the pond 12.

In a specific, non-limiting example, the dispenser may be provided with or otherwise be in the form of a rotating disc feeder capable of distributing feed pellets to aquatic animals in the pond 12. The rate of dispensing feed may be controlled by controlling the flow of feed from the container 34 to the dispenser 32 and/or controlling; for a centrifugal dispenser the speed of rotation disc of a disc feeder; and for a pneumatic dispenser air pressure and flow rate (e.g. cubic feet per minute (CFM)).

Varying the rate of dispensing the feed may also be controlled, for example, by employing a control valve (e.g. a knife or gate valve) movable between an open and closed position. The amount of feed quantity dispensed (or remaining in the container) can also be monitored, for example, using weigh cells or other scales under the feed hopper, or infrared level sensors.

Irrespective of their nature and form the dispenser 32 and container 34 are controlled by the control system 30. This enables feed to be only dispensed upon prescribed conditions being met. In order to monitor whether said conditions are met, sensors or other detecting components of the aquatic management system 10 may be used. The information detected by sensors or other components of the aquatic management system 10 can be processed or calculated on- or off-board the vehicle 14 (e.g. at a remotely located control centre) to determine whether a particular condition, or a set of conditions, is/are met. Similarly, quantities of feed dispensed relative to spatial distribution may also be determined by certain conditions or sets of conditions.

Thus, in one example, if the vehicle 14 is navigating along a certain path 22 the control system 30 can be programmed to send a signal to the dispenser 32 to distribute feed at regular time intervals, for predetermined amount of time (e.g. using a timer), or continuously at a pre-defined rate. In another example, after navigating the vehicle 14 to a desired location, the control system 30 may instruct the dispenser 32 to disperse feed at that particular location.

In yet another example the control system 30 can intelligently, dynamically
and/or continuously adjust the amount of feed delivered while the vehicle 14 is travelling according to sensed conditions in the ecosystem. For example, while the vehicle 14 is travelling on the body of water, the presence of aquatic animals may be detected by an aquatic animal detector of the task implementing system 16, and the control system 30 can then instruct the feeder 20 to dispense an amount of feed. Furthermore, if the aquatic animal detector is capable of providing biomass information, the amount of feed dispensed can be tailored to that specific quantity, thus avoiding unnecessarily large amounts of feed being dispensed. Other conditions that may be monitored for the purposes of controlling the amount of feed dispensed include feed seeking activity or other recognisable behavioural patterns, benthic conditions, and dissolved oxygen levels in the pond 12.

Furthermore, historical data from the same body of water 12 can be used by the control system 30 to determine the appropriate amount of feed when a certain condition being present. The condition may for example be time of day, surrounding environmental conditions (such as temperature, salinity), meteorological conditions (such as barometric pressure, cloud cover), certain characteristics of aquatic animals (such as species, size class, age).

With reference to Figure 3 and as previously mentioned with respect to various embodiments, in addition to or instead of the feeder 20, the task implementing system 16 comprises an aquatic animal detector 40. The detector 40 may for example be an acoustic sensor, a digital video camera, acoustic propagation and receiving devices (e.g. active SONAR) or an infrared camera/sensor. Thus, the task to be implemented may be detecting the presence and/or quantity of aquatic animals in the pond 12. In another example, the task may be identifying a particular movement and/or behaviour of certain aquatic animals. In another example, the task may be identifying a particular movement and/or behaviour of certain aquatic animals. The information or data gathered by the detector 40 can be used to determine where and how much feed to distribute, thus increasing feed efficiency. The detector 40 can thus assist in estimating stock numbers and biomass for feed calculations or other husbandry and management decisions, such as deployment of additional aerators and planning allocation of harvesting and processing resources, and sales planning.

For example, the detector 40 may be a video camera capable of capturing
images of animals in a determined area and sending the image data to the control system 30 that can process the data and use algorithms to estimate the count. More specifically, the detector 40 may utilise a digital camera of the type configured to capture images or video footage of the aquatic animals, and analyse the captured data (using specific algorithms) to count or at least estimate a number of aquatic animals. In another example, vision-grader technology can also be used to visually identify certain physical characteristics of subjects.

In another example, the sensor may be in the form of a marker or tag reader to detect a subset of the population that are marked or tagged. In one example the sensors may be RFID readers to read an RFID tagged subset of the aquatic animal population to estimate the total population. In yet another example, the detector 40 is an acoustic sensor having SONAR capabilities, and is able to generate sound from the vehicle 14 (or other component of the management system 10) to be reflected from the aquatic animals in the pond 12, and detecting the returning signals or acoustic reflections. The acoustic data may then be processed and analysed by the control system 30.

In one specific embodiment, monitoring of animal state, activity and behavior may be done using cameras (e.g. infrared or video cameras) and active SONAR, using a hydrophone and projector (in other words, underwater acoustic speakers), or a transducer, or a combination of both, in order to observe and/or locate, monitor, count, and calculate biomass.

According to various embodiments, once an estimate of the quantity of aquatic animals is obtained, by linking the quantity data with average weight or size data, biomass can be calculated.

In one embodiment, the detector 40 is capable of monitoring physical conditions or physiological characteristics of aquatic animals, such as detecting parasites (e.g. sea lice on salmon), monitoring ventilatory behaviour, heart rates, signs of stress, mortality and the general health and well-being of the animals. In one embodiment the detector 40 is capable of identifying and counting mortalities. Monitoring of animal behaviour, feeding activity, mortalities and monitoring stock physiological data can also be achieved using on- or off-board sensors.
For example, the detector 40 may be capable of providing high quality visuals of aquatic animals to monitor for parasites. In another example, the detector 40 may comprise a component that is in a form which can be embedded or inserted into sentinel aquatic animals for monitoring heart rate and other physiological data. In this way, diseases or other conditions spreading among the aquatic animals may be detected. It is also contemplated that such detector 40 within the aquatic animals is capable of wirelessly transmitting the physiological data monitored. Other behavioural activity that may be detected by the detector 40 according to various embodiments discussed above includes: detecting while animals are stationary or moving (e.g. walking, swimming), movement speed, movement patterns (e.g. circular swimming patterns), depth within the water body, directional changes, frequency, sedentary behaviour, movement of particular body parts, interaction with other aquatic animals (e.g. competitive or aggressive behaviour). Different behaviours may be recognised based on known behavioural movement or other patterns and software designed to match detected movements with known patterns.

In one embodiment the aquatic animal detector 40 comprises an acoustic sensor capable of detecting the sound of aquatic animal activity, for instance, the sound of aquatic animals eating in the pond 12. In one example, the acoustic sensor may utilise passive SONAR. In another example, the acoustic sensor comprises a hydrophone in communication with the control system 30. Thus, once the sound of animals feeding is detected, the task implementing system may communicate with the feeder to trigger an amount of feed to be dispensed.

In another embodiment, the aquatic animal detector is a light sensor capable of detecting light reflected from aquatic animal bodies, such as light reflected from prawn eyes. In yet another embodiment, the sensor may be a motion sensor capable of detecting aquatic animals within a certain radius of detection.

According to various embodiments, a sensing element of the detectors 40 may be submerged in pond water and communicate with the control system 30. This communication may be by wireless transmission, such as but not limited to one or more of air pressure waves, radio, infrared or visible light transmission, magnetic loop transmission. Alternatively or additionally such or other
sensors/detectors may be on-board the vehicle 14. In turn, the on-board control system 30a may also wirelessly transmit the information detected to an off-board control or command centre and/or the internet for data management (i.e. processing, analysing and/or storing). In one embodiment where the task implementing system 16 also comprises the feeder 20, the control system 30 is capable of enabling or disabling the dispensing of feed when aquatic animals are detected or not detected, respectively. In other words, feed efficiency can be improved and wastage minimized since the control system 30 can enable or disable the dispensing depending on whether or not aquatic animals (or their feeding behaviours) are detected. For example, the aquatic management system 10 is capable of feeding animals only when they are hungry and will eat the feed, for instance when the system has identified feed-seeking activity and/or detected feeding activity, leading to greater performance efficiencies and cost-savings in aquaculture.

In one example, the task implementing system (including a feeder 20 and detector 40) may be configured and programmed to dispense a test ration of feed initially, then shortly afterwards, the area of the pond 12 in which the test ration is distributed is monitored for feeding activity by the detector 40. If feeding activity is detected, more feed is distributed; but if feeding activity is not detected, the vehicle 14 moves on to another location. In another embodiment the detectors 40 are towed along by booms on the vehicle 14.

In another embodiment utilising the detector 40, the task implementing system 16 may further comprise a harvesting system 72 to assist or facilitate harvesting of aquatic animals. In a specific embodiment, the harvesting system 72 comprises a capturing system that allows a capturing device to be deployed into the pond 12 if aquatic animals are detected by the detector 40. The capturing device may be any suitable device, such as a net or electrofishing electrodes. Alternatively or additionally, the harvesting system 72 comprises an aquatic animal guiding or herding system that facilitates partial or complete harvesting of aquatic animals in the pond 12. The herding system may utilise electrical currents, acoustic signals, lights or other means of stimulating movement of the aquatic animals towards a harvesting area or capturing device such as a net. In some embodiments, the aquatic animals may be attracted towards a harvesting area for example by the use of acoustic transmitters, light emitting devices (e.g. a particular light wavelength and intensity), the strategic
deployment of feed, and/or releasing specific attractant dietary or other compounds (e.g. pheromones).

In another embodiment the detector 40 can also be in the form of a digital camera or infrared camera/sensor for monitoring the presence of predators and/or poachers of aquatic animals in the pond or other body of water 12. Furthermore, in response to any detection, the task implementing system 16 may also include for example light emitting devices or acoustic transmitters to deter or ward off predators and/or poachers using sounds, shapes, lights, reflectors and lasers.

In general, the data obtained by the detector(s) 40 pertaining to aquatic animal behavior, presence, location and numbers, can be sent to via the control system 30 to an on-board or off-board data analysis device, as described in various embodiments of the system 10. With the use of appropriate algorithms and programs, this data can be analyzed such that aquatic management the system 10 has the ability to learn the behavioural patterns and habits of the aquatic animals. This pattern information can then be fed back (e.g. wirelessly) to the control system 30 to implement action plans pertaining to the management of the ecosystem. For example, it is possible to predict where the aquatic animals are likely to be according to species, size, age of stock, time of day, and other environmental or ecosystem conditions, and thus the vehicle 14 can be autonomously driven to those locations at certain times of day to dispense feed. This may provide the advantage of achieving increased feeding efficiencies.

In another embodiment, the task implementing system 16 comprises a monitoring system 42 to implement the task of monitoring a certain condition of the pond 12, such as water quality or benthic state. The monitoring system 42 may comprise sensor apparatus, such as a chemical sensor or electronic sensor. For example, a dissolved oxygen sensor that capable of providing a signal indicative of the level of dissolved oxygen concentration in the pond water may be used. Additionally or alternatively, the monitoring system 42 may comprise a dissolved carbon dioxide sensor, such as a pH probe, where there is a known relationship between water pH and dissolved carbon dioxide. In another embodiment, the monitoring system 42 is capable of monitoring the temperature of the pond water, for example, the system 42 may comprise a
digital water thermometer.

The information gathered by the monitoring system 42 can be processed through communication with the control system 30. Other management tasks can be initiated based on this information, such as activating aerators or adjusting water exchange rates. In one example, where the task implementing system 16 also comprises the feeder 20, if the dissolved oxygen level detected in the pond water is too low, the control system 30 may reduce the amount of feed distributed onto the pond 12.

In yet another embodiment, the monitoring system 42 may utilise SONAR for monitoring or detecting predetermined or certain unwanted conditions in or at the bottom of the pond 12. Once unwanted conditions are detected, remedial action can be instructed and undertaken by a component of the task implementing system 18 such as a waste management system 74. For example, SONAR can be used to detect a level and/or distribution of uneaten feed and/or organic waste such as detritus, or growth of benthic algae. More specifically, uneaten feed may be detected by active SONAR devices by recognising signals reflecting from say objects in pellet form, thus indicative of uneaten pellets. In another example, active SONAR signals may provide information as to whether the pond floor is soft (indicative of sludge build-up) or hard, by receiving different reflected signals based on the hardness of the ground.

Such benthic conditions, organic waste, detritus and the like can lead to anaerobic conditions and the formation of compounds toxic to aquatic animals, such as hydrogen sulphide. In this regard, organic or "sludge" build-up (i.e. benthic conditions) will often precede changes in water quality, but by the time the changes in water quality are detected, often the health of some aquatic animals (such as prawns) has already been affected detrimentally and mortalities have started to occur. Thus, monitoring the benthos and detecting and managing detritus, waste, sludge build-ups in aquaculture production systems can be very important, especially in prawn pond production systems since prawns and the like are benthic dwellers.

In further embodiments, the task implementing system can thus not only identify, but also assist in treating one or more of these detrimental conditions.
If such conditions are detected, the control system 30 may initiate tasks to prevent an excessive build-up of organic waste and detritus in those areas. For example, through using pumps 64, chaining and/or water thrusters, organic matter may be re-suspended or re-distributed before the affected area of pond 12 enters an anaerobic state. Further, the distribution of feed may be reduced or ceased depending on the predetermined pond conditions detected by the monitoring system 42. In another example, the SONAR capability of the monitoring system 42 may be utilised to monitor a degree of fouling on nets of aquaculture cages in freshwater bodies or in the ocean.

Information regarding uneaten feed obtained by the monitoring system 42 can also be sent back to the feeder 20 (e.g. via the control system 30) to change the amount of feed dispense and/or generally to learn about the efficacy of the current feed distribution.

It is also envisioned that the task implementing system 16 comprises a sample collecting mechanism capable of collecting samples of water or aquatic animals in the pond 12. For example, a smaller net may be deployed in response to the detector 40 detecting the presence of aquatic animals nearby. Once captured, the navigation system 18 can then direct the vehicle 14 to take the sample to a specified area of the pond 12. In another example, a tube may be deployed from the vehicle 14 into the pond 12, which is capable of pumping a water sample into a container (or array of containers) on-board the vehicle 14. This may be in response to the monitoring system 42 detecting certain pond conditions. The container may be tethered to the component of the system 10, so that once a sample has been collected, the container may be retrieved.

In another embodiment, the task implementing system 16 may comprise means for administering substances for treatment of the ecosystem. One or more non-feed substance containers 66 and dispensers 68 may be located on-board the vehicle 14. This can for example be in response to predetermined conditions in the pond 12. Therefore, the health, stability and well-being of aquatic animals and the ecosystem at large may be optimized. The substances administered into the pond 12 may be medication, probiotics, lime, fertilisers, nutrients and other substances for pond treatment (e.g. for managing algal bloom). In one embodiment, there comprises a tank, pump and a dosing mechanism for administering liquid substances into the pond. In another embodiment, there
comprises a hopper and distribution mechanism, for example similar to those of the feeder 20, for dispensing dry substances into the pond 12.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. For instance, the aquatic management system 10 may comprise multiple vehicles 14 and multiple docking stations (e.g. for re-fuelling, loading feed etc.) servicing the same water body or multiple water bodies. For example, it is envisioned that one prawn farm with 100 ponds can be serviced by 100 vehicles 14, one to each pond each pond optionally having its own docking station, all being controlled via the internet by one remotely located control system.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.
Claims

1. An aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:
   a powered vehicle capable of moving within the body of water;
   a task implementing system connected to the powered vehicle capable of providing information on one or both of:
      (c) a behavioural activity of an aquatic animal; and
      (d) a detrimental environmental condition in the aquatic ecosystem;
   and implementing a task to enhance the well-being of the aquatic animal, or treat the detrimental condition, based on the information; and,
   a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water for the task implementing system to implement a management task with respect to the aquatic ecosystem.

2. The aquatic management system according to claim 1, wherein the task implementing system comprises an aquatic animal detector configured to detect one or more of the following behavioural activities of aquatic animals: feeding; feed seeking behaviour; movement; and interaction with other aquatic animals.

3. The aquatic management system according to claim 1, wherein the task implementing system comprises an aquatic animal detector is configured to detect a quantity of aquatic animals within a defined region in the body of water.

4. The aquatic management system of claim 3, wherein the aquatic animal detector is further configured to estimate biomass of the aquatic animals detected.

5. The aquatic management system according to any one of claims 1 to 3, wherein the aquatic animal detector comprises one, or a combination of two or more, of: an infrared camera; a video camera; an acoustic sensor with passive SONAR capability; an acoustic sensor with active SONAR capability.

6. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises a monitoring system comprising at least one sensor apparatus for monitoring the body of water for
detrimental environmental conditions.

7. The aquatic management system of claim 6, wherein the sensor apparatus is capable of detecting one or more of the following: (a) dissolved oxygen level in the body of water, (b) pH or dissolved carbon dioxide level in the body of water (c) water temperature, (d) salinity (e) turbidity, (f) level of one or more pollutants or toxic compounds in the body of water, (g) a level and/or distribution of uneaten feed in the body of water, and (h) a level and/or distribution of organic waste; (h) detritus; and (i) an anaerobic state.

8. The aquatic management system according to claim 7, wherein the sensor apparatus comprises any one of: a dissolved oxygen sensor; a dissolved CO₂ sensor; (c) a thermometer; (d) an acoustic sensor with active SONAR capability for detecting an amount of organic matter on a surface within the body of water.

9. The aquatic management system of any one of the preceding claims, wherein the powered vehicle is configured to float on the body of water and the task implementing system is located on-board the powered vehicle.

10. The aquatic management system of any one of the preceding claims, wherein the powered vehicle is an unmanned powered vehicle.

11. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises a feeder supported by or associated with the powered vehicle and capable of distributing feed to aquatic animals residing in the body of water.

12. The aquatic management system of claim 9, wherein the feeder comprises a feed dispenser and a storage container capable of supplying feed to the feed dispenser.

13. The aquatic management system of any one of claims 10 to 12 when dependent on claim 2, comprising a control system in communication with the task implementing system such that when certain behavioural activity of an aquatic animal is detected, the control system is arranged to instruct the feeder to distribute or to cease to distribute feed.
14. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises a detector capable of detecting physiological characteristics of aquatic animals.

15. The aquatic management system of claim 14, wherein a component of the detector is in a form capable of being implanted into a sentinel aquatic animal and communicating with another component of the detector.

16. The aquatic management system of claim 15, wherein the component of the detector is an RFID tag implantable into the sentinel aquatic animal.

17. The aquatic management system of any one of claims 14 to 16, wherein the physiological characteristics are indicative of the health including stress levels of aquatic animals.

18. The aquatic management system of any one of claims 10 to 12 when dependent on claim 4, comprising a control system in communication with the task implementing system such that when a certain detrimental environmental conditions is detected, the control system is arranged to instruct the feeder to distribute or cease to distribute.

19. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises a harvesting system which facilitates partial or complete harvesting of aquatic animals.

20. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises a further detector for detecting a predator of aquatic animals.

21. The aquatic management system of claim 18 wherein the further detector triggers means for deterring the predator of aquatic animals.

22. The aquatic management system of any one of the preceding claims, wherein the task implementing system comprises means for administering one or more from the following group to treat the ecosystem when a detrimental environmental condition is present: nutrients; medications; water conditioners;
lime; fertilisers; probiotics; and other substances.

23. The aquatic management system of any one of the preceding claims wherein the task implementing system comprises a sample collecting mechanism for collecting samples of water or aquatic animals in the body of water.

24. An aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:
   a powered vehicle movable on or within the body of water;
   a task implementing system comprising a sensor capable of detecting feeding or feed seeking behaviour of an aquatic animal, and a feeder mounted on the powered vehicle and in communication with the sensor such that the feeder is arranged to dispense feed when feeding or feed seeking behaviour is detected by the sensor; and
   a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water.

25. An aquatic management system for managing an aquatic ecosystem having a body of water harbouring aquatic animals, comprising:
   a powered vehicle movable on or within the body of water;
   a task implementing system comprising a monitoring system arranged to monitor the body of water for one or more detrimental environmental conditions, and a treatment system in communication with the monitoring system, the treatment system being arranged to administer one or more substances to treat the body of water when the monitoring system detects a detrimental environment condition; and
   a navigation system capable of guiding the powered vehicle to any location or along any path within the body of water.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

A01K 61/00 (2006.01) B63B 35/00 (2006.01) G06Q 50/02 (2012.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPIAP, TXTE: IPC/CPC = A01K61, B63B35, B63J99, B63B22 11, G06Q50/02; Keywords = AQUA, MARINE, ECOSYSTEM, AQUA CULTURE, VEHICLE, VESSEL, ANIMAL, FISH, PRAWN, BEHAVIOUR, ACTIVITY, ENVIRONMENT, CONDITION, IMPLEMENT, DETECT, SENSE, FEED and similar terms.

GOOGLE PATENTS: Keywords as above.

ESPACENET & AUSPAT: Applicant/Inventor's name searches; Keywords as above.

***Applicant/Inventor name searched in internal databases provided by IP Australia***

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Documents are listed in the continuation of Box C

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

'A' document defining the general state of the art which is not considered to be of particular relevance

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'X' document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search 14 September 2015

Date of mailing of the international search report 14 September 2015

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Form PCT/ISA/210 (fifth sheet) (July 2009)
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Form PCT/ISA/210 (Family Annex)(July 2009)
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