

SIEVING APPARATUSES FOR PUPAE SEPARATION

BACKGROUND

[0001] Generally, a sieve can be formed of a wire or plastic mesh held in a frame. The sieve can be used for straining solids from liquid or for separating coarser objects from finer objects.

[0002] Among those objects that can be separated are insects. Other devices have been designed to separate insects such as a device that includes parallel glass plates. The reasons for separating insects are various. For example, as part of a Sterile Insect Technique (SIT) program, male insects may be separated from female insects. Depending on the program, separation may be performed at one or more stages of insect development. For example, insects having an aqueous pupal stage may be separated while in the pupal stage.

[0003] Use of conventional mesh screens to separate pupae may create challenges given the physiological structures of the pupae. Additionally, use of devices including parallel glass plates may create challenges given their difficulty to operate and required user interaction. These challenges may result in prohibitively low throughput and similarly low yield.

SUMMARY

[0004] Various examples are described relating to sieving devices, systems including the sieving devices, methods for using the sieving devices, and methods for forming the sieving devices.

[0005] In an example, an apparatus is described. The apparatus includes a frame, a sieving device, a basin, and an actuation system. The sieving device includes a sieve surface including a first side and a second side and defining a set of openings to define a set of pathways extending between the first side and the second side. Individual openings of the set of openings are defined by a length dimension measured along a longitudinal axis of the respective opening, and a width dimension measured along a transverse axis of the respective opening. The width dimension corresponds to a cross-sectional cephalothorax width of a representative insect of a predetermined insect type (e.g., mosquitoes or other insects). The length dimension is greater than the width dimension. The sieving device also includes a sieve rim including a first wall defining a volume. The sieve surface is attached to a lower portion of an interior surface of the sieve rim and one side of the sieve surface is exposed

within the volume. The basin is attached to the frame and includes a wall and a bottom. The wall is attached to the bottom so as to define an opening opposite the bottom. The basin is sized to receive the sieving device and to retain a liquid. The actuation system is attached to the frame and the sieving device. The actuation system is configured to move the sieving device along a substantially vertical lifting axis between a first position within the basin and a second position within the basin. The second position is different than the first position. Moving the sieving device along the substantially vertical lifting axis between the first and second position is configured to separate a population of insects within the liquid based on cephalothorax size.

[0006] In another example, an apparatus is described. The apparatus includes a frame, a sieving device, a basin, and an actuation system. The sieving device includes a sieve surface including a first side and a second side. A set of elongate openings is formed in the sieve surface. The sieving device also includes a sieve rim attached to the sieve surface. The sieve rim forms a wall portion of the sieving device, with the sieve surface forming a bottom portion of the sieving device. The basin is attached to the frame. The basin is sized to receive the sieving device and to retain a liquid. The actuation system is attached to the frame and the sieving device. The actuation system is configured to move the sieving device along a lifting axis between a first position within the basin and a second position within the basin. The first position is different than the second position. Moving the sieving device along the lifting axis between the first position and the second position separates a population of insects present in the liquid based on cephalothorax width.

[0007] In yet another example, a computer-implemented method is described. The method includes instructing addition of a population of insect pupae to a sieving device. The sieving device is at least partially submerged in a water held within a first basin. The method also includes causing a lifting actuator that is attached to the sieving device to cycle between a first elevation and a second elevation so as to cyclically submerge a sieve surface of the sieving device in the water held within the first basin. The population of insect pupae is separated into a first group of insect pupae and a second group of insect pupae based at least in part on the cycling. The method also includes causing a valve to open to drain the water from the first basin. The first group of insect pupae is disposed in the water. The method also includes causing a lateral actuator that is attached to the sieving device to move the sieving device from a first position adjacent to the first basin to a second position adjacent to a second basin. The second group of insect pupae is disposed in the sieving device. The method

also includes, when the sieving device is at the second position, causing a rotational actuator to rotate the sieving device about a rotational axis between a first orientation and a second orientation. The method also includes, when the sieving device is in the second orientation, instructing removal of the second group of insect pupae from the sieving device.

[0008] In yet another example, a computer-implemented method is described. The method includes causing an actuation system to cycle between a first elevation and a second elevation to cyclically submerge a sieve surface of a sieving device in a liquid held within a basin. A population of insects present in the liquid is separated into a first group of insects and a second group of insects as a result of the cycling. The method also includes causing a valve to open to drain the liquid from the basin. The first group of insects is disposed in the liquid. The method also includes causing the actuation system to move the sieving device from a first position over the basin to a second position other than over the basin. The second group of insects is disposed in the sieving device.

[0009] In yet another example, a system is described. The system includes a separation station, a rinse station, and an actuation system. The separation station includes a sieving device, a first basin, and a fill nozzle. The sieving device includes a sieve surface including a first side and a second side. A set of elongate openings is formed in the sieve surface. The sieving device also includes a sieve rim attached to the sieve surface and forming a wall portion of the sieving device. The sieve surface forms a bottom portion of the sieving device. The first basin is sized to receive the sieving device and to retain a volume of liquid. The fill nozzle is disposed adjacent to the first basin and controllable to add first liquid to the first basin. The rinse station includes a second basin sized to receive the sieving device. The rinse station includes a spray nozzle disposed adjacent to the second basin and controllable to spray second liquid toward the second basin. The actuation system is attached to the sieving device. The actuation system is configured to move the sieving device between a first position within the first basin and a second position within the first basin. The actuation system is also configured to move the sieving device between a third position adjacent to the first basin and a fourth position adjacent to the second basin.

[0010] The illustrative examples are mentioned not to limit or define the scope of this disclosure, but rather to provide examples to aid understanding thereof. Illustrative examples are discussed in the Detailed Description, which provides further description. Advantages offered by various examples may be further understood by examining this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more certain examples and, together with the description of the example, serve to explain the principles and implementations of the certain examples.

[0012] Figure 1 illustrates a perspective view of a sieving apparatus, according to at least one example.

[0013] Figure 2 illustrates a perspective view of a sieving device for use in the sieving apparatus from Figure 1, according to at least one example.

[0014] Figure 3 illustrates a top view of a sieve surface, according to at least one example.

[0015] Figure 4 illustrates a detailed view of the sieve surface from Figure 3, according to at least one example.

[0016] Figure 5 illustrates a side view of an example mosquito pupa that can be separated using a sieving device as described herein, according to at least one example.

[0017] Figure 6 illustrates a profile view of an example mosquito pupa that can be separated using a sieving device as described herein, according to at least one example.

[0018] Figure 7 illustrates a profile view of an example mosquito pupa that can be separated using a sieving device as described herein, according to at least one example.

[0019] Figure 8 illustrates a side view of a mosquito pupa passing through an opening of a sieve surface, according to at least one example.

[0020] Figure 9 illustrates a mosquito pupa aligned in a first orientation with respect an opening, according to at least one example.

[0021] Figure 10 illustrates a mosquito pupa aligned in a second orientation with respect an opening, according to at least one example.

[0022] Figure 11 illustrates a mosquito pupa aligned in a first orientation with respect an opening, according to at least one example.

[0023] Figure 12 illustrates a mosquito pupa aligned in a second orientation with respect an opening, according to at least one example.

[0024] Figure 13 illustrates a detailed view of an example state of the sieving apparatus from Figure 1, according to at least one example.

[0025] Figure 14 illustrates a detailed view of an example state of the sieving apparatus from Figure 1, according to at least one example.

[0026] Figure 15 illustrates a detailed view of an example state of the sieving apparatus from Figure 1, according to at least one example.

[0027] Figure 16 illustrates a detailed view of an example state of the sieving apparatus from Figure 1, according to at least one example.

[0028] Figure 17 illustrates a detailed view of an example state of the sieving apparatus from Figure 1, according to at least one example.

[0029] Figure 18 illustrates an example process for separating a population of pupae based on size, according to at least one example.

[0030] Figure 19 illustrates an example process for separating a population of pupae based on size, according to at least one example.

[0031] Figure 20 illustrates an example computer system, according to at least one example.

DETAILED DESCRIPTION

[0032] Examples are described herein in the context of sieving apparatuses utilizing sieving devices for use in separation of mosquito pupae. Those of ordinary skill in the art will realize that the following description is illustrative only and is not intended to be in any way limiting. For example, the sieving apparatus described herein can be used to separate any insects having an aqueous pupal stage. The sieving apparatus may be used with sieving devices having different characteristics to enable separation of other organic and inorganic materials. Reference will now be made in detail to implementations of examples as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following description to refer to the same or like items.

[0033] In the interest of clarity, not all of the routine features of the examples described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another.

[0034] In an illustrative example, a sieving apparatus for separation of pupae is described. The sieving apparatus includes a support frame and a set of components attached to the support frame. These components include a funnel basin, a rinse basin, a sieving device, a drainage system connected to the funnel basin, and an actuation system attached to

the sieving device. The actuation system is configured to adjust the position and orientation of the sieving device with respect to the two basins as part of a process for separating pupae. The sieving device includes a sieve held within a rim. Together the sieve and the rim form a box-like structure, with the sieve forming the bottom of the box-like structure. The sieve includes a series of elongate openings. Each elongate opening is defined by a length corresponding to a longitudinal axis and a width corresponding to a transverse axis. A value of the width is selected to correspond to a smallest dimension of a cephalothorax of a representative pupa to be separated. For example, to separate male pupae from female pupae, a value of the width can be selected that is smaller than the cephalothoraxes of all females of a given population and larger than the cephalothoraxes of most, if not all, males of the same population. The elongate shape of the openings closely corresponds to how the pupae naturally orient in still water. When the water is flushed through the elongate openings, those pupae already in this natural orientation remain so and those that are not are oriented by the flowing water. Sizing the elongate openings to correspond to the size and natural orientation of the pupae can result in high separation rates. Additionally, high separation rates are possible because, unlike mesh sieves, the sieve surface is designed to include smooth transitions between the elongate openings. This results in fewer pupae becoming entangled, e.g., by their paddles or other physiological structures, with the openings.

[0035] To begin the separation process, water is added to the funnel basin and the actuation system is instructed to lower the sieving device into the water. The population including males and females are added to the water that is within the rim of the sieving device (e.g., within the box-like structure). The actuation system is instructed to vertically lower and raise the sieving device into and out of the water to draw the pupae down on to the sieve. In some examples, the water level is raised and lowered relative to the sieving device. Using this flushing action, most of the male pupae can pass through any one of the elongate openings, while most of the female pupae are prevented from passing because of their larger cephalothoraxes. Such flushing may be repeated, such as by oscillating or agitating movement of the sieve device or the water elevation, to perform a sieving action. Because the sieve rim is never fully submerged during the dunking, most female pupae remain within the rim and most male pupae move into the water outside the rim. After flushing, the actuation system is instructed to move the sieving device toward the rinse basin. At the rinse basin, the sieving device is rotated and the female pupae are flushed from the sieving device. Meanwhile, the water from the funnel basin is drained and the male pupae, which moved into

the water through the sieve during the sieving action, are removed from the drainage system through flushing. In some examples, because of the automation described herein, the sieving apparatus may enable separation of hundreds of thousands of pupae per hour.

[0036] This illustrative example is given to introduce the reader to the general subject matter discussed herein and the disclosure is not limited to this example. The following sections describe various additional non-limiting examples of sieving apparatuses including sieving devices.

[0037] Referring now to Figure 1, Figure 1 illustrates a perspective view of a sieving apparatus 1000, according to at least one example. The sieving apparatus 1000 includes a frame 1002, an actuation system 1004, a funnel basin system 1006, and a rinse basin system 1008. The sieving apparatus 1000 can be included as a single station within a process flow that includes upstream and downstream processes. The sieving apparatus 1000 along with the upstream and/or downstream processes can be automated using computer control such as by a computer system 1005. The computer system 1005 can be local to the sieving apparatus 1000, remote from the sieving apparatus 1000, and/or distributed between a remote location and the sieving apparatus 1000. For example, the computer system 1005 can be a remote computing device 1009 that computer interacts with a local control unit 1007 of the sieving apparatus 1000 via a network. In this manner, the remote computing device 1009 can provide instructions to the local control 1007 unit for execution. The computer system 1005 can also provide other instructions to other machines and devices located upstream and downstream from the sieving apparatus 1000. The remote computing device 1009 is described in detail with reference to Figure 20.

[0038] The local control unit 1007 may include a processing device such as a microprocessor, a digital signal processor (“DSP”), an application-specific integrated circuit (“ASIC”), field programmable gate arrays (“FPGAs”), state machines, or other processing means. Such processing means may further include programmable electronic devices such as PLCs, programmable interrupt controllers (“PICs”), programmable logic devices (“PLDs”), programmable read-only memories (“PROMs”), electronically programmable read-only memories (“EPROMs” or “EEPROMs”), or other similar devices.

[0039] The processing device may include, or may be in communication with, the memory. The memory includes computer-readable storage media, that may store instructions that, when executed by the processing device, cause the processing device to perform the functions described herein as carried out, or assisted, by the processing device. Examples of

computer-readable media may include, but are not limited to a memory chip, Read Only Memory (“ROM”), Random Access Memory (“RAM”), ASIC, or any other storage means from which a processing device can read or write information.

[0040] The components of each of the actuation system 1004, the funnel basin system 1006, and the rinse basin system 1008 are attached to and supported by the frame 1002. The frame 1002 may be formed in any suitable manner and from any suitable material so as to provide structural support for the systems 1004, 1006, and 1008. For example, the frame 1002 may be formed from metal tubing (e.g., steel, aluminum, etc.) that is welded, bolted, or otherwise attached together. In some examples, the systems 1004, 1006, and 1008 are not attached to the same frame 1002. For example, the funnel basin system 1006 and the rinse basin system 1008 can be disposed at adjacent stations in the process flow and the actuation system 1004 can move between the adjacent stations to perform the techniques described herein.

[0041] Beginning with the actuation system 1004, the actuation system 1004 in this example includes a sieving device 100, a rotational actuator 1010, a lifting actuator 1012, and a lateral actuator 1014. Together the rotational actuator 1010, the lifting actuator 1012, and the lateral actuator 1014 manipulate spatial position and orientation of the sieving device 100 with respect to the funnel basin system 1006 and the rinse basin system 1008. For example, as described in detail herein, the lifting actuator 1012 moves the sieving device 100 vertically, the lateral actuator 1014 moves the sieving device 100 horizontally, and the rotational actuator 1010 rotates the sieving device 100.

[0042] The funnel basin system 1006 includes a funnel basin 1016 and a drainage system 1018 that includes a first valve 1020a, a drain manifold 1022, and a second valve 1020b. The funnel basin 1016 can have any suitable shape and size other than the cylindrical shape shown. At a minimum, the funnel basin 1016 is sized to receive the sieving device 100 and hold a volume of liquid in which the sieving device 100 can be partially submerged. For example, the funnel basin 1016 can be filled with water and the lifting actuator 1012 can move the sieving device 100 vertically into and out of the funnel basin 1016 as part of a sieving action to separate a population of pupae.

[0043] In some examples, the funnel basin 1016 includes a bottom that slopes toward a drain disposed at the center of the bottom. The drain is the attachment point between the funnel basin 1016 and the drainage system 1018. The valves 1020 are controllable to selectively direct fluid from the funnel basin 1016. For example, with the second valve 1020b

closed, the first valve 1020a can be opened and fluid can be drained from the funnel basin 1016 via the drain manifold 1022. Because the drain manifold 1022 includes a perforated drain tube 1024, small debris such as pupae present in the liquid will be captured inside the perforated drain tube 1024. The second valve 1020b can then be opened to access the debris remaining in the perforated drain tube 1024. In some examples, a second volume of liquid is drained through the drainage system 1018 with both valves 1020 open. This second volume of liquid functions to flush the drainage system 1018, including any additional debris present in the perforated drain tube 1024.

[0044] The rinse basin system 1008 includes a rinse basin 1026, a rinse nozzle 1028, and a spill ramp 1030. The rinse basin 1026 can be any suitable basin having any suitable size. In some examples, the rinse basin 1026 includes a drain that empties to sewer system, a biological waste collection system, a specimen collection receptacle, or any other suitable location. When separating a population of pupae, the group of undesirable pupae can be rinsed off of the sieving device 100 and into the rinse basin 1026. This can be achieved by the lateral actuator 1014 moving the sieving device 100 from a position over the funnel basin 1016 to a position over the rinse basin 1026. At this point, the rotational actuator 1010 rotates the sieving device 100 and the rinse nozzle 1028 sprays a liquid such as water on the sieving device 100 to spray off the pupae. If a specimen collection receptacle is being used, these pupae can also be collected. The spill ramp 1030 helps to avoid contamination by directing any spilled water (e.g., that may drop out of sieving device 100) toward the rinse basin 1026.

[0045] The sieving apparatus 1000 can include any suitable sensors to manage the operation of the components of the sieving apparatus 1000. For example, position sensors, e.g. rotational encoders, variable resistors, etc., may be used to sense the position of the actuation system 1004. Ultrasonic sensors may be used to sense a water level in the funnel basin 1016. These sensors can provide sensor data (e.g., output) to the computer system 1005.

[0046] Details of the sieving device 100 will now be described with reference to Figures 2-12. Referring first to Figure 2, Figure 2 illustrates a perspective view of the sieving device 100, according to at least one example. The sieving device 100 includes a sieve surface 102 held within a sieve rim 104. The sieve rim 104 includes a plurality of walls 104a-104d that together define a volume having a rectangular cross section. In some examples, the sieve rim 104 defines a non-rectangular perimeter (e.g., round, triangular, and any other suitable non-rectangular shape). Irrespective of the shape of the perimeter, the sieve rim 104 can function to funnel or otherwise direct a liquid (e.g., water) through the sieve surface 102.

As the sieving device 100 can be sized for manual use (e.g., 6" x 6" square) in some examples, the sieve rim 104 also provides an area whereby an operator can manually grasp and manipulate the sieving device 100. For example, the operator can use her hands to grasp the sieve rim 104 to manipulate the sieving device 100 (e.g., applying an agitating or oscillating motion with respect to an aqueous solution that pushes smaller pupae through the sieve surface 102 and separates larger pupae and/or debris that cannot pass through the sieve surface 102). The sieving device 100 can also be sized for automated use, which may be smaller, larger, or the same size as the manual size. The sieving device 100 can also include an attachment location 107. For example, the attachment location 107 can be used to attach the actuation system 1004 to the sieve rim 104 (e.g., via the rotational actuator 1010). The sieving device 100 also includes a set of feet 105. The feet 105 are attached to the sieve rim 104 and can function to space the sieve surface 102 off a bottom of a container or other surface. The sieve surface 102 also includes a series of openings 106 which are described in detail with reference to later figures.

[0047] Figure 3 illustrates a top view of the sieve surface 102, according to at least one example. As illustrated in Figure 3, the sieve surface 102 can be held within a sieve frame 108. The sieve frame 108 includes a plurality of members 108a-108d that together define a rectangular perimeter. In some examples, the sieve frame 108 has a non-rectangular perimeter. In any event, the cross section of the sieve rim 104 and the cross section of the sieve frame 108 can correspond to enable mounting of the sieve frame 108 within the sieve rim 104. The sieve frame 108 also provides rigidity to the sieve surface 102. In some examples, sieve frames 108 having different sieve surfaces 102 (e.g., different sized openings) can be detachably mounted to the same sieve rim 104, depending on the implementation. For example, a kit can include multiple sieve surfaces 102 having different sized openings 106 that can be independently detachably mounted to the sieve rim 104.

[0048] As illustrated in Figure 4, the openings 106 can be organized into a series of rows 110a-110n including a plurality of openings 106. A few of the rows are labeled (e.g., 110a and 110b). The openings 106 can be repeated within the rows 110 to form a row pattern. The rows 110 can be repeated within the sieve surface 102 to form a sieve surface pattern. The number and dimensions of the rows 110 can be a product of the dimensions of the openings 106, spacing between the openings 106, and the material used to form the sieve surface 102. In some examples, a single row 110 including a plurality of openings 106 is provided. In this example, the single row 110 can extend transversely between members 108b

and 108d. The openings 106 of this single row 110 can extend longitudinally between members 108a and 108c.

[0049] In some examples, the sieve surface 102 is formed by a plurality of elongate rods laid out between the members 110b and 110d. The ends of these rods can extend between the members 108a and 108c and be held in place by these members 108a and 108c. In this example, the openings 106 can be formed between individual ones of the plurality of elongate rods.

[0050] Figure 4 illustrates a detailed view of the sieve surface 102, according to at least one example. The sieve surface 102 can be defined as having the openings 106, a few of which are labeled. Each opening 106 can have a generally elongate cross section. For example, as illustrated with respect to opening 106a, the cross section can be defined by a length dimension 111 measured along a longitudinal axis 112a of the opening 106a and a width dimension 113 measured along a transverse axis 114a of the opening 106a. The length dimension 111 can be greater than the width dimension 113. As described in detail herein, a generally elongate cross section can enable selection of a smaller width dimension 113 corresponding to the smallest dimension of cephalothorax as compared to square mesh sieves, which are generally sized to the largest dimension of the cephalothorax.

[0051] A value of the width dimension 113 can be dependent on the goals of a separation program and characteristics of pupae to be separated. For example, populations of *Aedes aegypti* or *Aedes albopictus* mosquitoes can be separated. Other species of mosquitoes or other populations of insects having a pupae stage can be separated using the sieving device 100 described herein. For example, the sieving device 100, in particular the openings 106, a space dimension 118, and a row dimension 116 may be tailored to the specific insect species.

[0052] As described herein, the sieving device 100 can be used to separate any species of insect that has an aquatic pupal phase. In some examples, the value of the width dimension 113 may correspond to a cross-sectional cephalothorax width of a representative insect from a particular insect species. In some examples, the width dimension 113 may range from 800 microns to 1500 microns, which may be appropriate for separating some species of mosquitoes, such as *Aedes aegypti*. Values larger than 1500 microns and smaller than 800 microns may be appropriate for other insect species. In a particular example, the value of the width dimension 113 can be about 1200 microns. In some examples, a value of the length dimension 111 may correspond to a cross-sectional cephalothorax length of a representative insect from the particular insect species. In a particular example, the length dimension 111

may range from 2500 microns to many millimeters (e.g., 12 millimeters), which may be appropriate for separating some species of mosquitoes. Values larger than 12 millimeters and smaller than 2500 may also be appropriate for other insect species.

[0053] A value of the length dimension 111 can also be dependent on the goals of the separation program and characteristics of the pupae to be separated. For example, in the example illustrated in Figure 3, the value of the length dimension 111 is about 10 times greater than the value of the width dimension 113. In some examples, the value of the length dimension 111 can be arbitrarily selected so long as it is greater than a largest cross-sectional dimension (e.g., tip to tail) of a typical pupa which is expected to pass through the opening 106a. Because the width dimension 113 is sized to correspond to a different smaller dimension of the typical pupa, the length dimension 111 will be larger than the width dimension 113.

[0054] The rows 110 can be spaced in accordance with a row dimension 116. For example, row 110m including the openings 106a, 106b can be spaced apart from row 110n including the openings 106c, 106d by the row dimension 116. The openings 106 can be spaced in accordance with the space dimension 118. For example, the opening 106a can be spaced apart from the opening 106b by the space dimension 118.

[0055] A value of the row dimension 116 may correspond or otherwise be proportional to a cross-sectional cephalothorax dimension of a representative insect of a preselected insect type. For example, the row dimension 116 may have a value that corresponds to a cross-sectional cephalothorax width or length of the representative insect. In this manner, the row dimension 116 may be selected to avoid having material in the sieve surface 102 that could hook or otherwise catch pupae and thereby prevent them from rolling off. In some examples, the row dimension 116 may enable the pupae to roll off the sieve surface 102 (e.g., through the openings 106). In a particular example, the row dimension 116 may range from 1000 microns to 3000 microns. In some examples, the value of the row dimension 116 is greater than 3000 microns or smaller than 1000 microns.

[0056] A value of the space dimension 118 may correspond or otherwise be proportional to a cross-sectional cephalothorax dimension of a representative insect of a preselected insect type. For example, like the row dimension 116, the space dimension 118 may have a value that corresponds to a cross-sectional cephalothorax width or length of the representative insect. In this manner, the space dimension 118 may be selected to avoid having material in the sieve surface 102 that could hook or otherwise catch pupae and thereby

prevent them from rolling off. In some examples, the space dimension 118 may enable the pupae to roll off the sieve surface 102 (e.g., through the openings 106). In a particular example, the space dimension 118 may range from about 500 microns to 3000 microns. In some examples, the value of the space dimension 118 is greater than 3000 microns or smaller than 500 microns. Depending on the value of the row dimension 116, the value of the space dimension 118, the value of the length dimension 111, and the value of the width dimension 113, an example sieve surface 102 may have between 5-30 openings 106 per square inch. In some examples, the value of the row dimension 116, the value of the space dimension 118, the value of the length dimension 111, and the value of the width dimension 113 are selected to provide sufficient rigidity to the sieving device 100 and a suitable fraction of open area to solid structure (e.g., openings 106 compared to rigid portion of the sieve surface 102), while still preventing entanglement with the pupae.

[0057] In some examples, the values of the row dimension 116 and the space dimension 118 are selected to minimize a ratio of solid area to open area across the sieve surface 102. Thus, by placing the openings 106 close together (e.g., a small value of the space dimension 118) and placing the rows 110 close together (e.g., small value of the row dimension 116), a greater quantity of openings 106 and rows 110 can be formed in the sieve surface 102. This can provide for increased throughput and increased yield in a separation program.

[0058] In some examples, the values of the row dimension 116 and the space dimension 118 depends on the material selected for the sieve surface 102 and the forming method. The sieve surface 102 can be formed from any suitable material such as metal, plastic, glass, ceramic, acrylic, and other materials having similar properties. The forming technique used to form the sieve surface 102 will depend on the material selected. Example forming techniques include, but are not limited to, laser cutting, water jet cutting, photochemical etching, punching, die cutting, milling, additive manufacturing (e.g., three-dimensional printing), molding, casting, stamping, and other similar techniques.

[0059] Figures 5, 6, and 7 respectively illustrate a side view, a first profile view, and a second profile view of an example mosquito pupa 400 that can be separated using the sieving device 100, according to various examples. The mosquito pupa 400 includes a cephalothorax 402 and an abdomen 404. When in the pupal stage, the mosquito pupa 400 uses its abdomen 404, including a distal portion 404a, as a flipper to move through water 408. The cephalothorax 402 also includes eyes 406, one of which is illustrated and labeled. In the

profile view illustrated in Figure 5, the mosquito pupa 400 can be defined by a cephalothorax width 410 and an overall length 412. In the profile view illustrated in Figure 6, the mosquito pupa 400 can also be defined by the cephalothorax height 414. Based on the physiological structures of the pupae (e.g., the mosquito pupa 400), the cephalothorax width 410 will be less than the overall length 412. In some examples, the cephalothorax height 414 is greater than the cephalothorax width 410. Thus, the cephalothorax width 410 can represent the narrowest dimension of the largest part (e.g., the cephalothorax 402) of the mosquito pupa 400.

[0060] As introduced herein, the value of the length dimension 111 of the openings 106 can be selected based on the overall length 412. For a given pupal population, a minimum value for the length dimension 111 should be greater than the overall length 412 of the largest pupa in the population. In some examples, a value of the length dimension 111 is much greater the overall length 412 of the largest pupa (e.g., an order of magnitude of 10 to 100 times greater).

[0061] As introduced herein, the value of the width dimension 113 of the openings 106 can be selected based on the cephalothorax width 410. For example, assume for a moment that a goal of a separation program is to separate male mosquito pupae from female mosquito pupae. In this example, if an example male population has an average cephalothorax width 410 of 1100 microns and an example female population has an average cephalothorax width 410 of 1400 microns. Given this difference of 300 microns between the average cephalothorax widths and given a difference of about 50 microns between a female mosquito with the smallest cephalothorax width 410 (e.g., 1250 microns) in the female population and a male mosquito pupa with the largest cephalothorax width 410 (e.g., 1200 microns) in the male population, a value for the width dimension 113 can be selected to give a high probability of separation. In this example, a value of 1200-1225 microns for the width dimension 113 can be suitable. Of course, other values would be appropriate for other populations of insects having cephalothoraxes of different sizes.

[0062] In the view illustrated in Figure 5, the mosquito pupa 400 is oriented in a natural orientation, one in which the mosquito pupa 400 will naturally orient when located within the water 408. In this orientation, the mosquito pupa 400 is able to obtain oxygen at the surface of the water 408 via respiratory trumpets (not shown) that extend from an upper portion of the cephalothorax 402 (e.g., near the upper surface of the water 408). This

orientation may be referred to as a “tail down orientation” because the distal portion 404a of the abdomen 404 (e.g., a tail) points down.

[0063] Figure 8 illustrates a side view of the mosquito pupa 400 passing through the opening 106 in the sieve surface 102, according to at least one example. In the example illustrated in Figure 8, the mosquito pupa 400 is oriented in the tail down orientation as the mosquito pupa 400 passes through the opening 106.

[0064] Figures 9 and 10 respectively illustrate a first mosquito pupa 400a in a first orientation and a second orientation with respect an opening 106, according to various examples. In particular, the first mosquito pupa 400a is shown passing through the opening 106. This is because the cephalothorax width 410 of a first cephalothorax 402a is less than a value of the width dimension 113. The first orientation of the first mosquito pupa 400a illustrated in Figure 9 is an example of the tail down orientation illustrated in Figures 5 and 9. The second orientation of the first mosquito pupa 400a illustrated in Figure 10 is an example of a tail up orientation. This may constitute a rotation of about 180 degrees.

[0065] Figures 11 and 12 respectively illustrate a second mosquito pupa 400b in a first orientation and a second orientation with respect an opening 106, according to various examples. In particular, the second mosquito pupa 400b is shown as being prevented from passing the opening 106. This is because the cephalothorax width 410 of a second cephalothorax 402b is greater than a value of the width dimension 113. The first orientation of the second mosquito pupa 400b illustrated in Figure 11 is an example of the tail down orientation illustrated in Figures 4 and 7. The second orientation of the second mosquito pupa 400b illustrated in Figure 12 is an example of the tail up orientation. This may constitute a rotation of about 180 degrees.

[0066] In some examples, the openings 106 of the sieve surface 102 are sized such that the first mosquito pupae 400a can pass through the openings 106 and the second mosquito pupa 400b are prevented from passing through the openings 106. For example, the first mosquito pupae 400a may be male pupae and the second mosquito pupae 400b may be female pupae. In some examples, the first mosquito pupae 400a is a first set of male (or female) pupae and the second mosquito pupae 400b is a second set of male (or female) pupae.

[0067] In some examples, the openings 106 of the sieve surface 102 are sized such that the first mosquito pupae 400a can pass through the openings 106 in any one of the tail down or tail up orientations and the second mosquito pupae 400b are prevented from passing

through in any orientation. In some examples, the openings 106 are sized such that the first mosquito pupae 400a may pass through in other orientations as well (e.g., head down or abdomen down).

[0068] Figures 13-17 illustrate example states of the sieving apparatus 1000 as the sieving apparatus performs an automated sieving process, according to various examples. Execution of the automated sieving process enables separation and downstream processing of a population of pupae such as mosquito pupae. The state changes of the components of the sieving apparatus 1000 illustrated in Figures 13-17 may be performed under the management of the computer system 1005.

[0069] Figure 13 illustrates a detailed view of an example state 1300 of the sieving apparatus 1000, according to at least one example. In the state 1300, the sieving device 100 is disposed vertically above the funnel basin 1016. The lifting actuator 1012 may include any suitable structure and controls to enable the vertical movement of the sieving device 100 described herein. For example, the lifting actuator 1012 may include a vertical carrier 1032 attached to the frame 1002 via a vertical rail 1034. The rotational actuator 1010 is disposed between and attaches to the vertical carrier 1032 and the sieving device 100. The vertical carrier 1032 can include an electric motor (e.g., servomotor) or other suitable actuator device (e.g., hydraulic actuators, pneumatic actuators, thermal actuators, etc.) configured to move the vertical carrier 1032 vertically along the vertical rail 1034. In particular, the lifting actuator 1012 may move the sieving device 100 into and out of the funnel basin 1016 as part of the sieving process, as illustrated by the vertical arrow 1036. Operation of the lifting actuator 1012 can be managed by the computer system 1005.

[0070] As illustrated in the state 1300, the sieving process may include filling the funnel basin 1016 with a liquid such as water. A fill nozzle may be disposed adjacent to the funnel basin 1016 in order to dispense the liquid. In some examples, the fill nozzle is a puck dispensing spout to enable adding fixed volumes of the liquid. Operation of the fill nozzle can be managed by the computer system 1005. After or before the funnel basin 1016 has been filled with water or while the funnel basin 1016 is being filled with water, the lifting actuator 1012 can be actuated to move the sieving device 100 down toward the funnel basin 1016 so as to submerge the sieve surface 102 in the water. A population of pupae may be added to the sieving device 100 (e.g., within the sieve rim 104). The population of pupae may include pupae of different sizes, of different sexes, of different species, and/or any combination of the foregoing. In some examples, the population of pupae includes males and females of the

same species. A conveyor system or other automated process may add the population of pupae to the sieving device 100. Addition of the population of pupae can be managed by the computer system 1005. Any suitable number of pupae may be added to the sieving device 100. For example, when the sieve rim 104 is about 8" x 8" square, around 6,000 mosquito pupae may be included in the population. In some examples, the population of pupae are treated with a larvicide prior to being added to the sieving device 100. This ensures any larvae still present in the population are dead prior to going through the sieving process.

[0071] Once the mosquito pupae have been added, the lifting actuator 1012 can be actuated to perform a sieving action that causes separation of the population of pupae 1206. For example, the lifting actuator 1012 can be actuated between two vertical elevations, at one of which the sieve surface 102 is submerged in the water and at the other of which the sieve surface 102 is removed from the water. This sieving action of dunking the sieve surface 102 into and out of the water functions to force the pupae into two groups (e.g., a first group that will fit through the sieve surface 102 and remain in the water in the funnel basin 1016 and a second group that will not fit through the sieve surface 102 and remain in the sieving device 100). This action can be repeated any suitable number of cycles (e.g., predetermined, dynamic based on vision or weight, etc.). For example, an optical system including a camera can output image data as the sieving device 100 is moved. The computer system 1005 processes this image data to determine whether an expected number of pupae have been separated. In some examples, three cycles are performed. In some examples, a complete cycle may take about two seconds (e.g. one second down and one second up).

[0072] In some examples, instead of manipulating the elevation of the sieve surface 102 relative to the water, the water level within the funnel basin 1016 can be adjusted relative to the sieve surface 102. For example, a pump system may circulate the same water into and out of the funnel basin 1016. In other examples, the pump system may pump out dirty water and replace the dirty water with clean water. Operation of the pump(s) can be managed by the computer system 1005.

[0073] In some examples, the sieving action that causes separation of the population of pupae 1206 may include oscillating, agitating, shaking, and/or otherwise moving the sieving device 100 (e.g., rolling). Such movements may include raising and lowering an elevation of the sieving device 100, translating the sieving device 100 forward and backward, translating the sieving device side-to-side, rotating on one or more ends of the sieving device 100 with respect to other ends, rolling the sieving device 100, performing any combination of

the foregoing, and performing any other change to orientation and position of the sieving device 100. One or more of these actions can be performed simultaneously, in a predefined order, or in any other manner that causes separation of the population of pupae 1206.

[0074] The sieving device 100 can be oscillated, agitated, and/or shaken when at least some liquid is present within the sieve rim 104. In some examples, the sieving device 100 is oscillated, agitated, and/or shaken when little to no liquid is present in the sieve rim 104. For example, when a population of pupae is suspended in an aqueous solution in a pupae container, the sieving action may be performed as the population of pupae is transferred from the pupae container to the sieving device 100. In this example, the sieving device 100 may be oscillated, agitated, shaken, and/or otherwise moved in a manner that causes the population of pupae to move within the sieving device 100 and/or causes the aqueous solution in which the pupae are originally suspended or other aqueous solution to move. In this manner, the sieving action may cause separation of the population of pupae.

[0075] Continuing with the sieving process, as illustrated in the state 1300, the first valve 1020a can be opened after the sieving action has finished. The second valve 1020b remains closed. Operation of the valves 1020 can be managed by the computer system 1005. This results in the water from the funnel basin 1016 emptying through the perforated drain tube 1024, into the drain manifold 1022, and out of a drain manifold opening 1038. The first group of pupae that remained in the water will remain in the perforated drain tube 1024. This is because openings in the perforated drain tube 1024 are sized smaller than the pupae (e.g., less than 900 microns). After the water has drained from the funnel basin 1016, a second volume of water is added to the funnel basin 1016 to continue to rinse the funnel basin 1016 and to further consolidate the first group of pupae into the perforated drain tube 1024. After this second volume of water has flushed through the funnel basin 1016 and the drainage system 1018, the second valve 1020b is opened to dispense the consolidated first group of pupae into a container for downstream processing. With both valves 1020 open, a third volume of water is added to the funnel basin 1016 to further flush the funnel basin 1016 and the drainage system 1018.

[0076] The valves 1020 can be any suitable inline valve such as a ball valve, a butterfly valve, a gate valve, and other similar inline valves. The valves 1020 may include actuators 1021 configured to open and close the valves 1020 in response to a signal (e.g., a control signal from the computer system 1005).

[0077] Figure 14 illustrates a detailed view of an example state 1400 of the sieving apparatus 1000, according to at least one example. Between the states 1300 and 1400, the sieving device 100 has been raised vertically out of the funnel basin 1016. For example, the lifting actuator 1012 has raised the sieving device 100. In the state 1400, the second group of pupae is disposed in the sieve device 100 (e.g., those that could not fit through the sieve surface 102). In the state 1400, the sieving apparatus 1000 is prepared to move the sieving device 100 from a position over the funnel basin 1016 to a position over the rinse basin 1026.

[0078] The lateral actuator 1014, for example, can be used to perform this change in position of the sieving device 100. The lateral actuator 1014 may include any suitable structure and controls to enable the lateral movement (e.g., sideways movement other than vertical which may include horizontal and/or angled) of the sieving device 100 described herein. For example, the lateral actuator 1014 may include a lateral carrier 1040 attached to the frame 1002 via a horizontal rail 1042. In some examples, the lateral carrier 1040 is attached to the vertical rail 1034 of the lifting actuator 1012. In this manner, the vertical rail 1034, the vertical carrier 1032, the rotational actuator 1010, and the sieving device 100 all translate laterally (e.g., horizontally) together when the lateral actuator 1014 is actuated. The lateral carrier 1040 can include an electric motor (e.g., servomotor) or other suitable actuator device (e.g., hydraulic actuators, pneumatic actuators, thermal actuators, etc.) configured to move the lateral carrier 1040 laterally along the horizontal rail 1042. In particular, the lateral actuator 1014 may move the sieving device 100 between the funnel basin 1016 and the rinse basin 1026 as part of the sieving process, as illustrated by the horizontal arrow 1044. Operation of the lateral actuator 1014 can be managed by the computer system 1005.

[0079] Figure 15 illustrates a detailed view of an example state 1500 of the sieving apparatus 1000, according to at least one example. Between the states 1400 and 1500, the sieving device 100 has been translated horizontally from a position over the funnel basin 1016 to a position over the rinse basin 1026. The lateral actuator 1014 causes the movement between the states 1400 and 1500.

[0080] Figure 16 illustrates a detailed view of an example state 1600 of the sieving apparatus 1000, according to at least one example. Between the states 1500 and 1600, the sieving device 100 has been rotated by the rotational actuator 1010.

[0081] For example, the rotational actuator 1010 can include a shaft by which the rotational actuator 1010 is attached to the sieving device 100. A rotational axis may extend through the shaft such that the rotational actuator 1010 can rotate the sieving device 100

about the rotational axis. The rotational actuator 1010 is attached to the vertical carrier 1032 and thereby moves vertically and horizontally as the lifting actuator 1012 and the lateral actuator 1014 are actuated. In some examples, the rotational actuator 1010 is offset laterally from the vertical rail 1034. The rotational actuator 1010 may include any suitable structure and controls to enable the rotational movement (e.g., rotation about the rotational axis) of the sieving device 100 described herein. For example, the rotational actuator 1010 may include an electric motor (e.g., servomotor) or other suitable actuator device (e.g., hydraulic actuators, pneumatic actuators, thermal actuators, etc.) configured to rotate the sieving device 100 relative to the frame 1002 as part of the sieving process, as illustrated by rotational arrows 1046. Operation of the rotational actuator 1010 can be managed by the computer system 1005.

[0082] Figure 17 illustrates a detailed view of an example state 1700 of the sieving apparatus 1000, according to at least one example. Between the states 1600 and 1700, the rinse nozzle 1028 has been actuated to begin rinsing the sieving device 100. For example, the rinse nozzle 1028 can include a valve and actuator assembly that is controlled by the computer system 1005. The rinse nozzle 1028 can emit high pressure liquid such as water in the direction of the sieving device 100. The water functions to rinse the second group of pupae off the sieving device 100. In particular, the water rinses the sieve surface 102 and the sieve rim 104. The rinsing can be performed for any suitable period time, which may be predetermined or dynamic. The pupae of the second group and the water drains into the rinse basin 1026 and out of drain 1048. In some examples, the second group of pupae can be transferred to a container after they pass through the drain 1048 for further downstream processing. In some examples, the second group of pupae are filtered from the rinse water and disposed of.

[0083] In some examples, the system sieving apparatus 1000 can be used for separating the first group of pupae and the second group of pupae into one or more subgroups. For example, sieving devices 100 having sieve surfaces 102 with differently sized openings 106 can be used in sequence to further refine the separation of the pupae. For example, the second group of pupae which did not pass through the first sieve surface 102 can be sieved again using a sieve surface with larger openings than the first surface 102. The sieving process can be repeated to sort precisely by size differential. This process can also be performed in reverse, where the largest sieve surface 102 is used first, and sequentially moving to smaller and smaller sieve surfaces 102. In some examples, an additional sieve

surface 102 can be used to separate out other materials, e.g., debris that might be present with the pupae. Any suitable number of sieving surfaces 102 can be used to separate a set of insects into any suitable number of groups.

[0084] In some examples, a single sieving device 100 can include an adjustable sieve surface. The adjustable sieve surface can include two or more sieve surfaces 102 positioned on top of each other. The two or more sieve surfaces 102 may be held adjacent to each other via an alignment structure (e.g., a set of tongue and groove structures or other similar structure capable of aligning two surfaces 102 and enabling slidable movement of two planar surfaces). At least one of the sieve surfaces 102 is configured to slide with respect to the other sieve surface(s) 102 so as to expand and contract a value of the width dimension 113 of the openings 106. When openings 106 of the sieve surfaces 102 are aligned with each other, the value of the width dimension 113 is the greatest. When one of the sieve surfaces 102 is moved with respect to the other sieve surface(s) 102, the value of the width dimension 113 will get smaller. For example, a first sieve surface 102 may be configured to slide along the transverse axis 114a with respect to a second sieve surface 102 at least until a value of the width dimension 113—measured between openings in the first sieve surface 102 and openings in the second sieve surface 102—is about half the value of the width dimension 113 measured when the openings 106 of the first and second sieve surfaces 102 are aligned. In some examples, the first sieve surface 102 may be transversely moveable with respect to the second sieve surface 102 within some range that is less than the value of the width dimension 113 measured when the openings 106 of the first and second sieve surfaces 102 are aligned. In this manner, movement (e.g., sliding) of the first sieve surface 102 may contract the openings 106.

[0085] In some examples, the sieving device 100, including the adjustable sieve surface, may be used in a process for separating artifacts of various sizes (e.g., insects in various stages, insects of various species, random debris, any combination of the foregoing, etc.). In this example, the process may begin by translating a first sieve surface 102 with respect to a second sieve surface 102 into a first overlapping position. In the first overlapping position, values of the openings 106 may be the smallest and allow debris to pass through the openings 106, but prevent larvae and pupae from passing therethrough. From the first overlapping position, the first sieve surface 102 can be translated with respect to the second sieve surface 102 so as to widen the openings to a second overlapping position. In the second overlapping position, values of the openings 106 may be suitably sized to allow larvae to pass

through the openings 106, but prevent pupae from passing therethrough. From the second overlapping position, the first sieve surface 102 can be translated with respect to the second sieve surface 102 so as to widen the openings 106 to a third overlapping position. In the third overlapping position, values of the openings 106 may be suitably sized to allow male pupae to pass through the openings 106, but prevent female pupae from passing therethrough. From the third overlapping position, the first sieve surface 102 can be translated with respect to the second sieve surface 102 so as to widen the openings 106 to a fourth overlapping position. In the fourth overlapping position, values of the openings 106 may be suitably sized to allow female pupae to pass through the openings 106. In this manner, the openings 106 may be gradually widened so as to split up an initial population into any suitable number of sub-samples (e.g., debris, larvae, male pupae, and female pupae).

[0086] In some examples, a single sieving device 100 can include an adjustable sieve surface that includes two or more sieve surfaces 102 stacked on top of each other and held in a rotary relationship. Thus, instead of a first sieve surface 102 being configured to translate with respect to a second sieve surface 102, the first sieve surface 102 can be configured to rotate with respect to the second sieve surface 102 so as to adjust values of the width dimension of the openings 106. For example, such rotation may be achieved by connecting the two or more sieve surfaces 102 via a shaft that extends through a center point of the sieve surfaces 102.

[0087] A pattern of the openings 106 in the first sieve surface 102 can be the same as a pattern of the openings 106 in the second sieve surface 102. In some examples, the patterns on the two sieve surfaces 102 are different.

[0088] Figures 18 and 19 illustrate example flow diagrams showing respective processes 1800 and 1900, as described herein. These processes 1800 and 1900 are illustrated as logical flow diagrams, each operation of which represents a sequence of operations that can be implemented in hardware, computer instructions, or a combination thereof. In the context of computer instructions, the operations represent computer-executable instructions stored on one or more computer-readable storage media that, when executed by one or more processors, perform the recited operations. Generally, computer-executable instructions include routines, programs, objects, components, data structures, and the like that perform particular functions or implement particular data types. The order in which the operations are described is not intended to be construed as a limitation, and any number of the described operations can be omitted or combined in any order and/or in parallel to implement the

processes. The order in which the operations are described is not intended to be construed as a limitation, and any number of the described operations can be omitted or combined in any order and/or in parallel to implement the processes.

[0089] Additionally, some, any, or all of the processes may be performed under the control of one or more computer systems configured with executable instructions and may be implemented as code (e.g., executable instructions, one or more computer programs, or one or more applications) executing collectively on one or more processors, by hardware, or combinations thereof. As noted above, the code may be stored on a computer-readable storage medium, for example, in the form of a computer program including a plurality of instructions executable by one or more processors. The computer-readable storage medium is non-transitory.

[0090] Figure 18 illustrates an example flow diagram illustrating the example process 1800 for separating a population of pupae based on size, according to at least one example. The process 1800 can be performed using the sieving apparatus 1000 operating under the management of the computer system 1005.

[0091] The process 1800 begins at 1802 by instructing addition of a population of mosquito pupae to a sieving device. In some examples, the sieving device is at least partially submerged in water held within a first basin. In some examples, instructing addition of the population of mosquito pupae to the sieving device includes instructing a human operator to add the population of mosquito pupae or causing an automated device to add the population of mosquito pupae. In some examples, the sieving device includes a sieve rim to which the sieve surface is attached. The sieve rim can form a wall portion of the sieving device. The sieve surface can form a bottom portion of the sieving device opposite an open portion of the sieving device.

[0092] At 1804, the process 1800 causes a lifting actuator that is attached to the sieving device to cycle between a first elevation and a second elevation. Such cycling may cyclically submerge a sieve surface of the sieving device in the water held within the first basin. In some examples, the population of mosquito pupae is separated into a first group of mosquito pupae and a second group of mosquito pupae based at least in part on the cycling.

[0093] In some examples, the sieve surface includes a first side and a second side. A set of openings can be formed in the sieve surface so as to define a set of pathways extending between the first side and the second side. Individual openings of the set of openings can be defined by a length dimension and a width dimension. The length dimension can be measured

along a longitudinal axis of a respective opening. The width dimension can be measured along a transverse axis of the respective opening. In some examples, the width dimension of the individual openings corresponds to a cephalothorax width of a representative mosquito pupa of the population of mosquito pupae. The length dimension can be greater than the width dimension

[0094] At 1806, the process 1800 causes a valve to open to drain the water from the first basin. In some examples, the first group of mosquito pupae is disposed in the water in the first basin.

[0095] In some examples, the valve is a first valve in fluid communication with a second valve via a drain pipe. A portion of the drain pipe can include an opening extending into a manifold. The water can drain via the opening and through the manifold.

[0096] In some examples, the process 1800 further includes, after causing the first valve to open, causing a second valve to open to obtain access to the first group of mosquito pupae. In this example, the first group of mosquito pupae is prevented from passing through the opening.

[0097] At 1808, the process 1800 causes a lateral actuator that is attached to the sieving device to move the sieving device from a first position adjacent to the first basin to a second position adjacent to a second basin. In some examples, the second group of mosquito pupae is disposed in the sieving device.

[0098] At 1810, the process 1800 causes a rotational actuator to rotate the sieving device about a rotational axis from a first orientation to a second orientation. This may be performed when the sieving device is at the second position. In some examples, in the first orientation, a sieve surface of the sieving device is disposed below an opening of the sieving device. In some examples, in the second orientation, the sieve surface is disposed above the opening of the sieving device.

[0099] At 1812, the process 1800 instructs removal of the second group of mosquito pupae from the sieving device. This may be performed when the sieving device is in the second orientation. In some examples, instructing removal of the second group of mosquito pupae from the sieving device includes causing a rinse nozzle to spray the sieving device. The sieving device can be disposed between the rinse nozzle and the second basin when in the second position.

[00100] Figure 19 illustrates an example flow diagram illustrating the example process 1900 for separating a population of pupae based on size, according to at least one example.

The process 1900 can be performed using the sieving apparatus 1000 operating under the management of the computer system 1005.

[00101] The process 1900 begins at 1902 by causing an actuation system that is attached to a sieving device to cycle between a first elevation and a second elevation. In some examples, this may cyclically submerge a sieve surface of the sieving device in a liquid held within a basin. The basin can be disposed below the sieving device. In some examples, a population of pupae present in the liquid is separated into a first group of pupae and a second group of pupae as a result of the cycling.

[00102] At 1904, the process 1900 causes a valve to open to drain the liquid from the basin. In some examples, the first group of pupae is disposed in the liquid.

[00103] At 1906, the process 1900 causes the actuation system to move the sieving device from a first position over the basin to a second position other than over the basin. In some examples, the second group of pupae is disposed in the sieving device. In some examples, the basin is a first basin. In this example, the second position is a position over a second basin disposed adjacent to the first basin. In this example, when the sieving device is at the second position, the process 1900 further includes causing the actuation system to rotate the sieving device about a rotational axis from a first orientation to a second orientation. The process 1900 further includes, when the sieving device is in the second orientation, instructing removal of the second group of pupae from the sieving device. In some examples, instructing removal of the second group of pupae includes causing a spray nozzle to spray the sieving device to remove the second group of pupae.

[00104] In some examples, the process 1900 further includes causing a first valve to open to drain the liquid from the basin. The liquid may pass through a perforated drain tube disposed within a drain manifold prior to draining from the drain manifold. In some examples, the process 1900 further includes, after the liquid has drained from the drain manifold, causing a second valve disposed downstream from the perforated drain tube to open. In this example, the first group of pupae is located in the perforated drain tube. In some examples, the process 1900 further includes instructing flushing of the perforated drain tube to move the first group of pupae from the perforated drain tube into a container located downstream from the second valve. In some examples, instructing flushing of the perforated drain tube includes, when the second valve is open causing the first valve to open, and causing a fill nozzle to add a different volume of the liquid to the basin.

[00105] Figure 20 illustrates an example of the computer system 1005, in accordance with at least one example. The computer system 1005 includes the local control unit 1007 in communication with the remote computing device 1009 via communication link 2006. The remote computing device 1009 illustrated in Figure 20 includes a processor 2002 and a memory 2004.

[00106] The processor 2002 may be implemented as appropriate in hardware, computer-executable instructions, firmware, or combinations thereof. Computer-executable instruction or firmware implementations of the processor 2002 may include computer-executable or machine-executable instructions written in any suitable programming language to perform the various functions described.

[00107] In some examples, the processor 2002 may include a microprocessor, a DSP, an ASIC, FPGAs, state machines, or other processing means. Such processing means may further include programmable electronic devices such as PLCs, PICs, PLDs, PROMs, EPROMs, EEPROMs, or other similar devices.

[00108] The processor 2002 may include, or is in communication with, the memory 2004. The memory 2004 includes computer-readable storage media, that may store instructions that, when executed by the processor 2002, cause the processor 2002 to perform the functions described herein as carried out, or assisted, by the processor 202. Examples of computer-readable media of the memory 2004 may include, but are not limited to a memory chip, ROM, RAM, ASIC, or any other storage means from which a processing device can read or write information. The memory 2004 may store example modules.

[00109] The communication link 2006 may be a wireless communication link and may include wireless interfaces, such as IEEE 802.11, BlueTooth™, radio frequency identification (RFID), near-field communication (NFC), or radio interfaces for accessing cellular telephone networks (e.g., transceiver/antenna for accessing a CDMA, GSM, UMTS, or other mobile communications network). In some aspects, the communication link 2006 may be a wired communication link and may include interfaces, such as Ethernet, USB, IEEE 1394, fiber optic interface, voltage signal line, or current signal line. The local control unit 1007 can transmit data to the remote computing device 1009 via the communication link 2006. Likewise the remote computing device 1009 can transmit data to the local control unit 1007 via the communication link 2006. In this manner, the computer system 1005 manages the operation of the sieving apparatus 1000.

[00110] The foregoing description of some examples has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Numerous modifications and adaptations thereof will be apparent to those skilled in the art without departing from the spirit and scope of the disclosure.

[00111] Reference herein to an example or implementation means that a particular feature, structure, operation, or other characteristic described in connection with the example may be included in at least one implementation of the disclosure. The disclosure is not restricted to the particular examples or implementations described as such. The appearance of the phrases “in one example,” “in an example,” “in one implementation,” or “in an implementation,” or variations of the same in various places in the specification does not necessarily refer to the same example or implementation. Any particular feature, structure, operation, or other characteristic described in this specification in relation to one example or implementation may be combined with other features, structures, operations, or other characteristics described in respect of any other example or implementation.

[00112] Use herein of the word “or” is intended to cover inclusive and exclusive OR conditions. In other words, A or B or C includes any or all of the following alternative combinations as appropriate for a particular usage: A alone; B alone; C alone; A and B only; A and C only; B and C only; and all three of A and B and C.

WHAT IS CLAIMED IS:

- 1 1. An apparatus, comprising:
2 a frame;
3 a sieving device comprising:
4 a sieve surface comprising a first side and a second side and defining a
5 set of openings to define a set of pathways extending between the first side and the
6 second side, individual openings of the set of openings defined by:
7 a length dimension measured along a longitudinal axis of the
8 respective opening; and
9 a width dimension measured along a transverse axis of the
10 respective opening, the width dimension corresponding to a cross-sectional
11 cephalothorax width of a representative insect of a predetermined insect type,
12 and the length dimension greater than the width dimension; and
13 a sieve rim comprising a first wall defining a volume, the sieve surface
14 attached to a lower portion of an interior surface of the sieve rim and one side of the
15 sieve surface exposed within the volume;
16 a basin attached to the frame and comprising a wall and a bottom, the wall
17 attached to the bottom so as to define an opening opposite the bottom, the basin sized to
18 receive the sieving device and to retain a liquid; and
19 an actuation system attached to the frame and the sieving device, the actuation
20 system configured to move the sieving device along a substantially vertical lifting axis
21 between a first position within the basin and a second position within the basin, the second
22 position different than the first position,
23 wherein moving the sieving device along the substantially vertical lifting axis
24 between the first and second position is configured to separate a population of insects of the
25 predetermined insect type within the liquid based on cephalothorax size.
- 1 2. The apparatus of claim 1, wherein, when the sieve surface is
2 submerged in the liquid:

3 a first insect of the predetermined insect type having a first cephalothorax
4 width that is less than the width dimension is free to move through any one of the set of
5 pathways between the first side and the second side; and

6 a second insect of the predetermined insect type having a second
7 cephalothorax width that is greater than the width dimension is prevented from moving
8 between any one of the set of pathways between the first side and the second side.

1 3. The apparatus of claims 1 or 2, wherein moving the sieving device
2 along the substantial vertical lifting axis between the first position and the second position is
3 configured to cyclically submerge the sieve surface in the liquid, wherein an upper portion of
4 the sieve rim is not submerged in the liquid while the sieve surface is cyclically submerged.

1 4. The apparatus of any of claims 1-3, wherein the actuation system
2 comprises a lifting actuator that comprises:

3 a vertical rail extending in a vertical direction that corresponds to the
4 substantially vertical lifting axis;

5 a first carrier slidably attached to the vertical rail and attached to the sieving
6 device; and

7 a first actuator device configured to move the first carrier along the vertical
8 rail to cause the sieving device to move along the substantially vertical lifting axis.

1 5. The apparatus of claim 4, wherein the actuation system comprises a
2 lateral actuator that comprises:

3 a horizontal rail extending in a horizontal direction relative to the vertical rail;

4 a second carrier comprising a first carrier side and a second carrier side, the
5 first carrier side slidably attached to the horizontal rail and the second carrier side attached to
6 the vertical rail; and

7 a second actuator device configured to move the second carrier along the
8 horizontal rail to cause the sieving device to move along a lateral axis between:

9 a first lateral position at which the sieving device is disposed above the
10 basin; and

11 a second lateral position at which the sieving device is not disposed
12 above the basin.

1 6. The apparatus of claims 4 or 5, wherein the actuation system comprises
2 a rotational actuator that comprises:

3 a shaft attached to the sieving device and the first carrier, the shaft defining a
4 rotational axis; and

5 a third actuator device attached to the shaft and configured to rotate the
6 sieving device about the rotational axis between:

7 a first orientation in which the sieving device opens upward; and

8 a second orientation in which the sieving device opens downward.

1 7. The apparatus of any of claims 1-6, wherein:

2 the basin defines a drain opening in a bottom surface of the basin; and

3 the apparatus further comprises a first valve in fluid communication with the
4 drain opening.

1 8. The apparatus of claim 7, further comprising:

2 a second valve in fluid communication with the first valve via a drain pipe;

3 and

4 a manifold disposed between the first valve and the second valve and in fluid
5 communication with the first valve and the second valve via the drain pipe, at least a portion
6 of the drain pipe disposed within the manifold and comprising a plurality of openings sized
7 smaller than the width dimension.

1 9. The apparatus of claim 8, wherein:

2 opening of the first valve and closing of the second valve allows the liquid to
3 drain from the basin into the manifold via the plurality of openings and to trap separated
4 insects in the drain pipe; and

5 opening of the second valve after the liquid has drained into the manifold
6 allows dispensing of a portion of the population of insects.

1 10. The apparatus of any of claims 1-9, further comprising:
2 a rinse basin attached to the frame and disposed adjacent to the basin; and
3 a rinse head attached to the frame and disposed above the rinse basin, the rinse
4 head configured to rinse the sieving device when the sieving device is disposed between the
5 rinse head and the rinse basin.

1 11. The apparatus of any of claims 1-9, further comprising a computing
2 device in electrical communication with the apparatus, the computing device configured to
3 communicate with a remote computing device to manage operation of the apparatus.

1 12. An apparatus, comprising:
2 a frame;
3 a sieving device comprising:
4 a sieve surface comprising a first side and a second side, wherein a set
5 of elongate openings is formed in the sieve surface; and
6 a sieve rim attached to the sieve surface and forming a wall portion of
7 the sieving device, with the sieve surface forming a bottom portion of the sieving
8 device;
9 a basin attached to the frame, the basin sized to receive the sieving device and
10 to retain a liquid; and
11 an actuation system attached to the frame and the sieving device, the actuation
12 system configured to move the sieving device along a lifting axis between a first position
13 within the basin and a second position within the basin, the first position different than the
14 second position,
15 wherein moving the sieving device along the lifting axis between the first
16 position and the second position separates a population of insects present in the liquid based
17 on cephalothorax width.

1 13. The apparatus of claim 12, wherein individual elongate openings of the
2 set of elongate openings are defined by:

3 a length dimension measured along a longitudinal axis of a respective elongate
4 opening; and

5 a width dimension measured along a transverse axis of the respective elongate
6 opening, the width dimension corresponding to a representative cephalothorax width of a
7 representative insect of the population of insects.

1 14. The apparatus of claims 12 or 13, wherein, when the sieve surface is
2 submerged in the liquid:

3 a first insect is free to move through any one of the set of elongate openings,
4 the first insect having a first cephalothorax width that is less than a width dimension of the set
5 of elongate openings; and

6 a second insect is prevented from moving through any one of the set of
7 elongate openings, the second insect having a second cephalothorax width that is greater than
8 the width dimension of the set of elongate openings.

1 15. The apparatus of any of claims 12-14, wherein the actuation system
2 provides vertical translation of the sieving device, horizontal translation of the sieving device,
3 and rotation of the sieving device.

1 16. The apparatus of claim 15, wherein the vertical translation is provided
2 by a lifting actuator, the horizontal translation is provided by a lateral actuator, and the
3 rotation is provided by a rotational actuator.

1 17. The apparatus of any of claims 12-16, further comprising a sensing
2 device configured to sense a level of liquid in the basin.

1 18. A computer-implemented method, comprising:
2 instructing addition of a population of insect pupae to a sieving device, the
3 sieving device at least partially submerged in a water held within a first basin;
4 causing a lifting actuator that is attached to the sieving device to cycle
5 between a first elevation and a second elevation so as to cyclically submerge a sieve surface
6 of the sieving device in the water held within the first basin, wherein the population of insect

pupae is separated into a first group of insect pupae and a second group of insect pupae based at least in part on the cycling;

causing a valve to open to drain the water from the first basin, the first group of insect pupae disposed in the water;

causing a lateral actuator that is attached to the sieving device to move the sieving device from a first position adjacent to the first basin to a second position adjacent to a second basin, the second group of insect pupae disposed in the sieving device;

when the sieving device is at the second position, causing a rotational actuator to rotate the sieving device about a rotational axis between a first orientation and a second orientation; and

when the sieving device is in the second orientation, instructing removal of the second group of insect pupae from the sieving device.

19. The computer-implemented method of claim 18, wherein the sieve surface comprises a first side and a second side, wherein a set of openings is formed in the sieve surface so as to define a set of pathways extending between the first side and the second side, individual openings of the set of openings defined by:

a length dimension measured along a longitudinal axis of the respective opening; and

a width dimension measured along a transverse axis of a respective opening, the length dimension greater than the width dimension.

20. The computer-implemented method of claim 19, wherein a value of the width dimension of the individual openings is less than a cross-sectional cephalothorax width of a representative female insect pupa of the second group of insect pupae.

21. The computer-implemented method of any of claims 18-20, wherein instructing addition of the population of insect pupae to the sieving device comprises instructing a human operator to add the population of insect pupae or causing an automated device to add the population of insect pupae.

1 22. The computer-implemented method of any of claims 18-21, wherein
2 instructing removal of the second group of insect pupae from the sieving device comprises
3 causing a rinse nozzle to spray the sieving device, the sieving device disposed between the
4 rinse nozzle and the second basin when in the second position.

1 23. The computer-implemented method of any of claims 18-22, wherein:
2 the valve is a first valve in fluid communication with a second valve via a
3 drain pipe, a portion of the drain pipe comprising an opening extending into a manifold, the
4 water draining via the opening and through the manifold; and
5 the method further comprises, after causing the first valve to open, causing a
6 second valve to open to obtain access to the first group of insect pupae, the first group of
7 insect pupae prevented from passing through the opening.

1 24. The computer-implemented method of any of claims 18-23, wherein
2 the sieving device comprises a sieve rim to which the sieve surface is attached, the sieve rim
3 forming a wall portion of the sieving device, with the sieve surface forming a bottom portion
4 of the sieving device opposite an open portion of the sieving device.

1 25. The computer-implemented method of claim 24, wherein:
2 in the first orientation, the sieve surface is disposed below the open portion;
3 and
4 in the second orientation, the sieve surface is disposed above the open portion.

1 26. A computer-implemented method, comprising:
2 causing an actuation system to cycle between a first elevation and a second
3 elevation to cyclically submerge a sieve surface of a sieving device in a liquid held within a
4 basin, wherein a population of insects present in the liquid is separated into a first group of
5 insects and a second group of insects as a result of the cycling;
6 causing a valve to open to drain the liquid from the basin, the first group of
7 insects disposed in the liquid; and

causing the actuation system to move the sieving device from a first position over the basin to a second position other than over the basin, the second group of insects disposed in the sieving device.

27. The computer-implemented method of claim 26, wherein an upper portion of a sieve frame of the sieving device is not submerged in the liquid while the sieving surface is cyclically submerged in the liquid.

28. The computer-implemented method of claim of claim 27, wherein the second group of insects remain within the sieve frame while the sieving surface is cyclically submerged in the liquid.

29. The computer-implemented method of any of claims 26-28, wherein:
the basin is a first basin; and
the second position is a position over a second basin disposed adjacent to the first basin.

30. The computer-implemented method of claim 29, further comprising:
when the sieving device is at the second position, causing the actuation system to rotate the sieving device about a rotational axis from a first orientation to a second orientation; and
when the sieving device is in the second orientation, instructing removal of the second group of insects from the sieving device.

31. The computer-implemented method of claim 30, wherein instructing removal of the second group of insects comprises causing a spray nozzle to spray the sieving device to remove the second group of insects.

32. The computer-implemented method of claim any of claims 26-31, further comprising:
causing a first valve to open to drain the liquid from the basin, the liquid passing through a perforated drain tube disposed within a drain manifold prior to draining from the drain manifold;

6 after the liquid has drained from the drain manifold, causing a second valve
7 disposed downstream from the perforated drain tube to open, the first group of insects located
8 in the perforated drain tube; and

9 instructing flushing of the perforated drain tube to move the first group of
10 insects from the perforated drain tube and into a container located downstream from the
11 second valve.

1 33. The computer-implemented method of claim 32, wherein instructing
2 flushing of the perforated drain tube comprises, with the second valve open:

3 causing the first valve to open; and

4 causing a fill nozzle to add a different volume of the liquid to the basin.

1 34. A system, comprising:

2 a separation station comprising:

3 a sieving device comprising:

4 a sieve surface comprising a first side and a second side,
5 wherein a set of elongate openings is formed in the sieve surface; and

6 a sieve rim attached to the sieve surface and forming a wall
7 portion of the sieving device, with the sieve surface forming a bottom portion
8 of the sieving device;

9 a first basin sized to receive the sieving device and to retain a volume
10 of liquid; and

11 a fill nozzle disposed adjacent to the first basin and controllable to add
12 first liquid to the first basin;

13 a rinse station comprising:

14 a second basin sized to receive the sieving device; and

15 a spray nozzle disposed adjacent to the second basin and controllable
16 to spray second liquid toward the second basin; and

17 an actuation system attached to the sieving device, the actuation system
18 configured to:

19 move the sieving device between a first position within the first basin and a
20 second position within the first basin; and
21 move the sieving device between a third position adjacent to the first
22 basin and a fourth position adjacent to the second basin.

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