PUPAE SINGULATOR

BACKGROUND OF THE INVENTION

[0001] Many Sterile Insect Technique (SIT) programs require visually classifying insects to separate male and female insects because male-only releases are more effective at introducing sterility into wild populations. Typically, sex-sorting batches of insects is an involved and human reliant process that involves a human visually inspecting each insect at an adult stage and sorting accordingly or limited purity mechanical sex-sorting methods based on sexually dimorphic traits such as body size in the pupal stage (e.g. sieving). Some other classifications, such as species, insect type, or size are similarly time and resource intensive and require human sorting of individual insects or mechanical separation with limited accuracy.

[0002] For some insects, the male and female pupae vary in size, and groups thereof may be sorted based on size or on at least some of the characteristics described above but with limited purity as many of these traits vary widely within sexes. Small females and large males, for example, can be misclassified in mechanical processes without time-consuming human inspection. Isolating and observing the pupae to differentiate males and females that overlap in body size or other sexually dimorphic traits, however, may prove difficult and time-consuming for human selection and sorting.

BRIEF SUMMARY OF THE INVENTION

[0003] A system of one or more computers that can be configured to perform particular operations including sorting insect pupae by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. ~~One general~~In a first aspect, ~~of the~~there is provided an insect pupae sorting system, which includes an isolation device having a ~~first~~ primary channel with an inlet and an outlet to deliver a first flow of liquid including insect pupae and a ~~second~~ first secondary channel that intersects the ~~first~~ primary channel at a first intersection between the inlet and the outlet to deliver a second flow of liquid into the ~~first~~ primary channel~~. The second flow of fluid intersecting the first flow~~ to generate~~s~~ a third flow of liquid and to separate~~s~~ adjacent insect pupae being transported through the ~~first~~ primary channel. The insect pupae sorting system also includes an optical sensor positioned proximate to the outlet of the isolation device to capture images of pupae from the

third flow of liquid, wherein the optical sensor is positioned between the first intersection and the outlet. ~~Downstream of the optical sensor, t~~The system also includes a storage unit system coupled to the outlet that includes a container into which insect pupae of a first type are directed based at least in part on the captured images.

[0004] In ~~another general aspect~~As disclosed, an insect pupae isolation device is described including: a body; a first channel formed in the body for transporting a first flow of fluid including insect pupae, the first channel having a first dimension corresponding to a size of the insect pupae and having an inlet at a first end of the first channel and an outlet at a second end of the first channel. The insect pupae isolation device also includes a second channel formed in the body, having a second dimension smaller than the first dimension, that meets the first channel at an intersection positioned between the inlet and the outlet to deliver a second flow of fluid into the first channel to generate a third flow of liquid and to separate adjacent insect pupae being transported through the first channel.

[0005] In ~~another general~~a second aspect, a method of sorting insect pupae is described, including providing, at an inlet of a primary channel of an insect isolation device, a flow of fluid with insect pupae ~~into a first channel of an insect isolation device. The isolation device has a first channel along which the insect pupae travel~~ in a first direction toward an outlet of the primary channel, the ~~first~~ primary channel having a dimension corresponding to a size of a representative pupa of the insect pupae. The method also includes providing, at a first intersection with the primary channel, a second flow of fluid~~,~~ through a ~~second~~ first secondary channel~~,~~ into the ~~first~~ primary channel. The method further includes determining that an individual pupa has passed the ~~second~~ first secondary channel and after the individual pupa has passed the first secondary channel: capturing an image of the individual pupa using an optical sensor positioned between the first intersection and the outlet. The method also includes determining a pupa type of the individual pupa based on the image and sorting the individual pupa based on the pupa type.

[0006] ~~In at least one example~~In a third aspect, an insect pupae sorting system is described, having an isolation device with a ~~first~~ priamry channel having an inlet and an outlet and a ~~second~~ first secondary channel intersecting the ~~first~~ primary channel between the inlet and the outlet at a first intersection. The insect pupae sorting system also includes a cover that encloses the ~~first~~ primary channel and the ~~second~~ first secondary channel into fully-enclosed passages. The system

includes an optical sensor positioned between the first intersection and the outlet to capture an image of an insect pupa in the isolation device. The insect pupae sorting system also has a storage system including at least one holding tank in fluid communication with the isolation device and a processor configured to determine the insect pupa has passed the ~~second~~ first secondary channel, receive an image of the insect pupa from the optical sensor,

determine a pupa characteristic based on the image, and cause the insect pupa to travel into holding tank of the storage system based at least in part on the pupa characteristic.

[0006a] In a fourth aspect, an insect pupae sorting system is described, comprising a body; a first channel formed in the body to transport a first flow of fluid comprising insect pupae, the first channel having a first dimension corresponding to a size of the insect pupae and comprising: a pupae inlet at a first end of the first channel; a first liquid inlet at a second end of the first channel, the first liquid inlet configured to introduce a first liquid flow into the first channel to change a flow direction in the first channel; and a first liquid outlet at the second end of the first channel, the first liquid outlet configured to remove liquid from the first channel; a second channel formed in the body that intersects the first channel between the pupae inlet and the first liquid inlet and provides a conduit between the first channel and a third channel, wherein the third channel is formed in the body and provides a conduit between a first pupae outlet and a second pupae outlet, the third channel intersected by the second channel between the first pupae outlet and the second pupae outlet; a second liquid inlet adjacent the first pupae outlet; and a third liquid inlet adjacent the second pupae outlet, the second liquid inlet and third liquid inlet configured to selectively deliver a second and third liquid flow into the third channel.

[0006b] In a fifth aspect, a method of imaging and sorting insect pupae is described, comprising: providing a first flow of liquid comprising pupae into a first channel of an insect isolation device and through the first channel in a first direction, the first channel having a dimension corresponding to a size of a representative pupa of the pupae; adjusting the first flow of liquid by introducing a second flow of liquid via a second channel to position an individual pupa in an imaging portion of the first channel; capturing an image of the individual pupa using an optical sensor positioned between the second channel and a first and second pupae outlet; determining a pupa type of the individual pupa based on the image; and providing a third flow of liquid to sort the individual pupa into the first pupae outlet or the second pupae outlet based on the pupa type.

[0007] In another example, a method of imaging an individual insect pupa includes directing a flow of aqueous solution including insect pupae into a first channel having a dimension corresponding to a size of a representative insect pupa. The method includes providing a stream of fluid, through a second channel, into the first channel and closing an outlet of the first channel

after an individual insect pupa of the insect pupae has passed the second channel. The method also includes capturing an image of the individual insect pupa.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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.

[0009] FIG. 1 illustrates an isolation device for isolating individual insect pupae according to at least one example.

[0010] FIG. 2 illustrates a sorting system for insect pupae, according to at least one example.

[0011] FIG. 3 illustrates an example process for isolating individual insect pupae, according to at least one example.

[0012] FIG. 4 illustrates an example process for classifying and sorting individual insect pupae, according to at least one example.

[0013] FIG. 5 illustrates an example computing system for use with systems and processes described herein.

[0014] FIG. 6 illustrates an imaging and sorting system for insect pupae, according to at least one example.

[0015] FIG. 7 illustrates an isolation device of the imaging and sorting system of FIG. 6, according to at least one example.

WHAT IS CLAIMED IS:

1. An insect pupae sorting system, comprising:

an isolation device comprising:

a ~~first~~ primary channel to deliver a first flow of liquid including insect pupae, the ~~first~~ primary channel comprising an inlet and an outlet; and

a ~~second~~ first secondary channel that intersects the ~~first~~ primary channel at a first intersection between the inlet and the outlet to deliver a second flow of liquid into the ~~first~~ primary channel to generate a third flow of liquid and to separate adjacent insect pupae being transported through the ~~first~~ primary channel;

an optical sensor positioned proximate the outlet of the isolation device to capture images of pupae from the third flow of liquid, wherein the optical sensor is positioned between the first intersection and the outlet; and

a storage unit system coupled to the outlet that includes a container into which insect pupae of a first type are directed based at least in part on the captured images.

2. The insect pupae sorting system of claim 1, wherein the storage unit system comprises:

at least one container to support a volume of liquid and insect pupae; and

a valve positioned on a conduit between the isolation device and the at least one container, wherein ~~the~~ a single insect pupa that is separated from the adjacent insect pupae is directed into the at least one container by opening the valve.

3. The insect pupae sorting system of claim 1, wherein:

the ~~first~~ primary channel has a first cross-sectional dimension corresponding to a size of the insect pupae; and

the ~~second~~ first secondary channel has a second cross-sectional dimension smaller than a dimension of the insect pupae.

4. The insect pupae sorting system of claim 1, further comprising a pupa detection system for detecting when ~~the~~ a single insect pupa passes ~~an~~ the first intersection of the ~~first~~ primary channel and the ~~second~~ first secondary channel.

5. The insect pupae sorting system of claim 4, wherein the outlet comprises a closing device for shutting the outlet when the single insect pupa passes the ~~second~~ first secondary channel.

6. The insect pupae sorting system of claim 4, wherein the optical sensor is configured to capture the image when the single insect pupa passes the ~~second~~ first secondary channel.

7. The insect pupae sorting system of claim 1, wherein the isolation device further comprises a ~~third~~ second secondary channel that intersects the ~~first~~ primary channel between the ~~inlet and the second channel for delivering a third flow of liquid into the first channel~~first intersection and the outlet at a second intersection to selectively deliver a fourth flow of liquid into the primary channel to augment the third flow of liquid and to further separate the adjacent insect pupae being transported through the primary channel, wherein the second flow of liquid and the fourth flow of liquid are independently and selectively deliverable into the primary channel.

8. A method of sorting insect pupae, comprising:

providing, at an inlet of a primary channel of an insect isolation device, a flow of fluid comprising pupae ~~into a first channel of an insect isolation device and through the first channel~~ in a first direction toward an outlet of the primary channel, the ~~first~~ primary channel having a dimension corresponding to a size of a representative pupa of the pupae;

providing, at a first intersection with the primary channel, a second flow of fluid~~,~~ through a ~~second~~ first secondary channel~~,~~ into the ~~first~~ primary channel;

determining that an individual pupa has passed the ~~second~~ first secondary channel; and

after the individual pupa has passed the ~~second~~ first secondary channel:

capturing an image of the individual pupa using an optical sensor positioned between the first intersection and the outlet;

determining a pupa type of the individual pupa based on the image; and

sorting the individual pupa based on the pupa type.

9. The method of claim 8, further comprising closing ~~an exit~~the outlet of the ~~first~~ primary channel after the individual pupa has passed the ~~second~~ first secondary channel, and wherein closing the ~~exit~~ outlet causes the flow of fluid to advance through the ~~first~~ primary channel in a second direction, different from the first direction.

10. The method of claim 8, wherein sorting the individual pupa based on the pupa type comprises opening a valve downstream of ~~an exit~~the outlet of the ~~first~~ primary channel to direct the individual pupa to a container system based on the pupa type.

11. The method of claim 8, further comprising determining a number of pupae sorted to each pupa type.

12. The method of claim 8, further comprising providing a third flow of fluid, through a ~~third~~ second secondary channel, into the ~~first~~ primary channel.

13. The method of claim 8, wherein determining that the~~-~~ individual pupa has passed the ~~second~~ first secondary channel comprises using a laser gate across the ~~first~~ priamry channel adjacent to the ~~second~~ first secondary channel.

14. The method of claim 8, wherein the pupa type is at least one of:

a male pupa;

a female pupa;

a larvae; or

debris.

15. An insect pupae sorting system, comprising:

an isolation device comprising:

a ~~first~~ primary channel having an inlet and an outlet;

a ~~second~~ first secondary channel intersecting the ~~first~~ primary channel between the inlet and the outlet at a first intersection; and

a cover that encloses the ~~first~~ primary channel and the ~~second~~ first secondary channel into fully-enclosed passages;

an optical sensor positioned between the first intersection and the outlet to capture an image of an insect pupa in the isolation device;

a storage system including at least one holding tank in fluid communication with the isolation device; and

a processor configured to execute processor executable instructions stored in a non-transitory computer-readable medium configured to cause the processor to:

determine the insect pupa has passed the ~~second~~ first secondary channel;

receive an image of the insect pupa from the optical sensor;

determine a pupa characteristic based on the image; and

cause the insect pupa to travel into holding tank of the storage system based at least in part on the pupa characteristic.

16. The insect pupae sorting system of claim 15, wherein the processor executable instructions are further configured to receive the image of the insect pupa when the insect pupa passes the ~~second~~ first secondary channel.

17. The insect pupae sorting system of claim 16, wherein the processor executable instructions are further configured to cause the processor to cause the outlet to close after determining the insect pupa has passed the ~~second~~ first secondary channel.

18. The insect pupae sorting system of claim 17, wherein the processor executable instructions are further configured to cause the processor to cause the outlet to open after capturing the image of the insect pupa.

19. The insect pupae sorting system of claim 15, wherein the pupa characteristic comprises at least one of:

male;

female;

larva; and

waste.

20. The insect pupae sorting system of claim 15, wherein the processor executable instructions are further configured to cause the processor to cause a fluid inlet to add fluid at the outlet when more than one insect pupa passes the ~~second~~ first secondary channel.

21. The insect pupae sorting system of claim 15, wherein the processor executable instructions are further configured to cause the processor to cause selective closure of the outlet to position the insect pupa for imaging.

22. An insect pupae sorting system, comprising:

a body;

a first channel formed in the body to transport a first flow of fluid comprising insect pupae, the first channel having a first dimension corresponding to a size of the insect pupae and comprising:

a pupae inlet at a first end of the first channel;

a first liquid inlet at a second end of the first channel, the first liquid inlet configured to introduce a first liquid flow into the first channel to change a flow direction in the first channel; and

a first liquid outlet at the second end of the first channel, the first liquid outlet configured to remove liquid from the first channel;

a second channel formed in the body that intersects the first channel between the pupae inlet and the first liquid inlet and provides a conduit between the first channel and a third channel, wherein the third channel is formed in the body and provides a conduit between a first pupae outlet and a second pupae outlet, the third channel intersected by the second channel between the first pupae outlet and the second pupae outlet;

a second liquid inlet adjacent the first pupae outlet; and

a third liquid inlet adjacent the second pupae outlet, the second liquid inlet and third liquid inlet configured to selectively deliver a second and third liquid flow into the third channel.

~~23. The insect pupae sorting system of claim 22, further comprising:~~

~~a second liquid inlet adjacent the first pupae outlet; and~~

~~a third liquid inlet adjacent the second pupae outlet, the second liquid inlet and third liquid inlet configured to selectively deliver a third and fourth liquid flow into the third channel.~~

~~24~~23. The insect pupae sorting system of claim 22, further comprising a fourth channel that intersects the first channel between the pupae inlet and the second channel, the fourth channel to deliver a ~~second~~ fourth flow of liquid into the first channel to generate a ~~third~~ fifth flow of liquid directable to the first liquid outlet, the first pupae outlet, or the second pupae outlet

~~25~~24. The insect pupae sorting system of claim 22, wherein the first channel comprises a tapered funnel section to guide insect pupae from the pupae inlet into the first channel.

~~26~~25. The insect pupae sorting system of claim 22, wherein the first channel comprises:

a first portion having a first cross-sectional dimension; and

a second portion having a second cross-sectional dimension, wherein:

the second cross-sectional dimension is smaller than the first cross-sectional dimension; and

the first cross-sectional dimension enables the pupae to change direction within the first channel.

~~27~~26. The insect pupae sorting system of claim ~~26~~25, wherein the first portion has a first width and the first channel comprises a third portion having a second width, the second width smaller than the first width.

~~28~~27. The insect pupae sorting system of claim 27, wherein the second portion is adjacent and in between each of the first portion and the third portion.

~~29~~28. A method of imaging and sorting insect pupae, comprising:

providing a first flow of liquid comprising pupae into a first channel of an insect isolation device and through the first channel in a first direction, the first channel having a dimension corresponding to a size of a representative pupa of the pupae;

adjusting the first flow of liquid by introducing a second flow of liquid via a second channel to position an individual pupa in an imaging portion of the first channel;

capturing an image of the individual pupa using an optical sensor positioned between the second channel and a first and second pupae outlet;

determining a pupa type of the individual pupa based on the image; and

providing a ~~second~~ third flow of ~~fluid~~ liquid to sort the individual pupa into ~~a~~ the first pupae outlet or ~~a~~ the second pupae outlet based on the pupa type.

~~30~~29. The method of claim ~~29~~28, further comprising determining a number of pupae sorted into the first pupae outlet or the second pupae outlet.

~~31~~30. The method of claim ~~30~~29, wherein the optical sensor is positioned adjacent the first pupae outlet or the second pupae outlet, and wherein determining the number of pupae comprises receiving data from ~~an~~ the optical sensor ~~positioned adjacent the first pupae outlet or the second pupae outlet~~.

~~32~~31. The method of claim ~~29~~28, wherein adjusting the first flow of liquid comprises introducing ~~a third~~the second flow of ~~fluid~~ liquid in a second direction opposite the first direction.

~~33~~32. The method of claim ~~29~~28, wherein providing the second flow of ~~fluid~~ liquid comprises opening the first pupae outlet or the second pupae outlet based on the pupa type.

~~34. The method of claim 29, wherein the pupa type is at least one of:~~

~~a male pupa;~~

~~a female pupa;~~

~~a larvae; or~~

~~debris.~~

~~35. The method of claim 29, further comprising determining a characteristic of the individual pupa based at least in part on the image, and wherein the pupa type is determined based on the characteristic of the individual pupa.~~

33. The insect pupae sorting system of claim 1, wherein substantially all of the first flow of liquid, the second flow of liquid, and the third flow of liquid that enters the primary channel exits the primary channel at the outlet.

34. The insect pupae sorting system of claim 1, wherein the inlet of the primary channel is the only inlet of the primary channel and the outlet of the primary channel is the only outlet of the primary channel.

35. The insect pupae sorting system of claim 1, wherein the outlet is selectively operable between an open position and a closed position such that, when the outlet is in the closed position, a first insect pupae of the adjacent insect pupae is separated from other insect pupae of the adjacent insect pupae by remaining stagnant in the third flow of liquid while the other insect pupae are carried by the third flow towards the inlet of the primary channel.