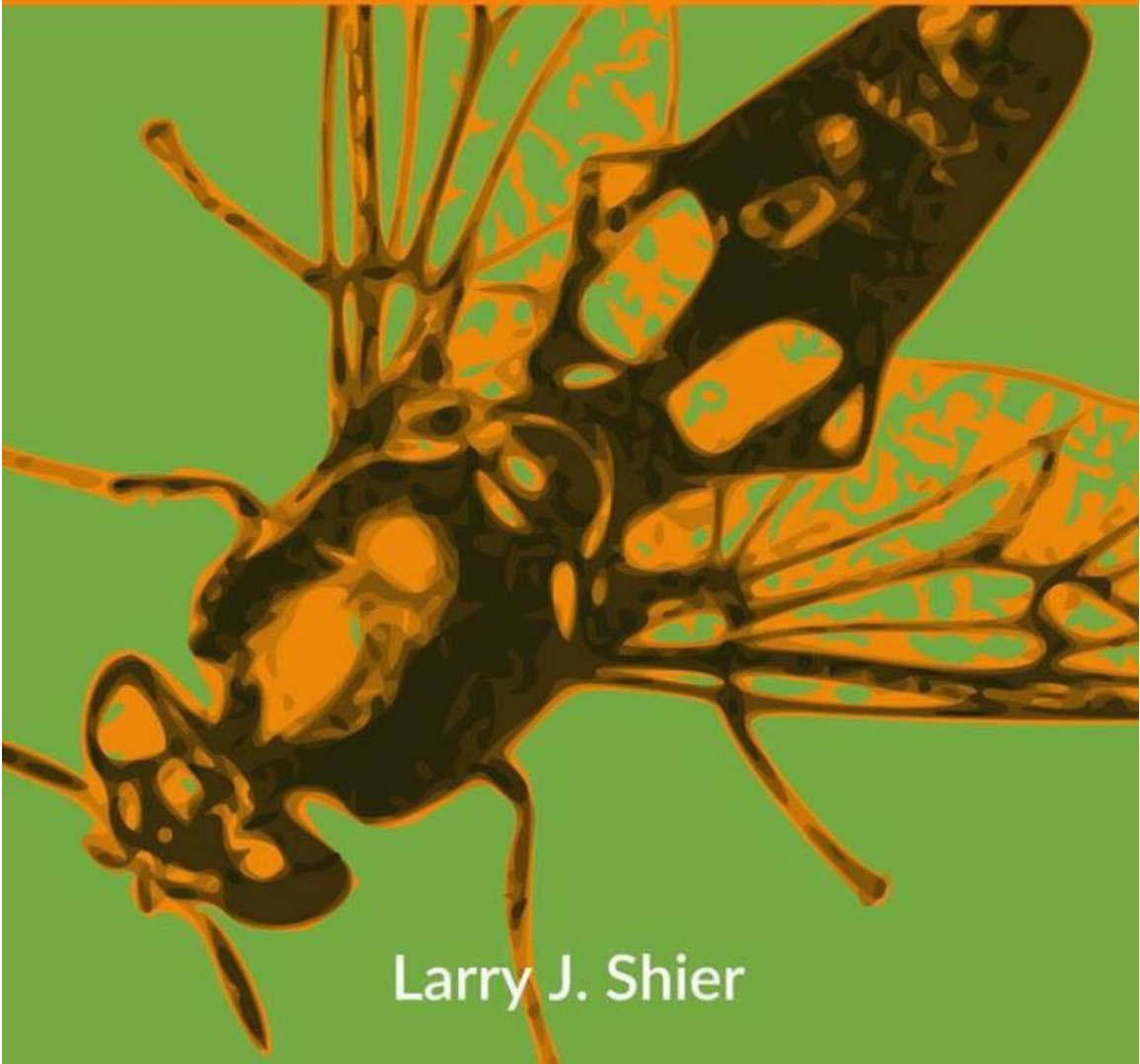


Black Soldier Fly

Eco-Technology For The Future



Larry J. Shier

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Introduction

Rarely do I get as excited about something as seemingly insignificant as an insect; but black Soldier Flies fascinate and excite me. Normally we think of maggots as disgusting, filthy and disease spreading. In reality maggots of many flies are a necessary part of nature's cleanup process. The potential of these tiny creatures to close waste loops and provide usable products from trash makes them an under exploited resource. Black soldier fly larvae (BSFL) in particular are an exceptional choice as an eco-technology to aid in cleaning up our environment, feed our livestock, process our sewage and even become a snack for humans. From the homeowner recycling kitchen waste to a large commercial operation; the larvae of black soldier flies are able to add value to our “garbage.” Whether the value is as simple as compost or as complex as biofuel, soldier flies are an environmentally friendly solution for several current dilemmas. Together we will look at the role BSFL could play in the future for waste management, remediation of polluted water and soil, food production for pets, livestock and even human consumption. Larvae may even serve as fuel for vehicles or home heating and may supply us cures for some disease in the future.



To their credit **The Bill and Melinda Gates foundation** has funded a lot of research into BSFL for third world sanitation, as a potential livestock feed and generally as an environmental asset. I would like to extend a thank you to the Gates family for making much of the research used in this book possible and for trying to make the entire world a better place.

Hermetia illucens (Linnaeus 1758)

is Latin for the insect commonly called the black Soldier fly. There are over 2700 species of soldier fly found worldwide but ***Hermetia illucens*** is the most studied. Like other insects they have 4 life stages:



egg, larva, pupae and adult. It is the larval stage of soldier flies we are interested in. The larvae have 5 stages of life called instars between including hatchling and pre-pupae. Black Soldier fly larva (BSFL) are voracious eaters of waste products, they are high in protein, high in fat, fast and easy to grow, self-cleaning and self-harvesting. Adult soldier flies have no mouth parts so they cannot bite nor do they regurgitate food or leave

excrement behind. There is no stage in the life of *Hermetia illucens* where they are considered a pest or a vector for disease. Black soldier fly adults are not attracted to human homes so no incessant buzzing in your windows. The presence of *Hermetia illucens* is also known to deter the oviposition (egg laying) of disease spreading flies. *Hermetia illucens* is a fairly large fly that in some ways mimic wasps in their appearance. They're often found near livestock and manure sources, it's also common to find them and their larvae near compost piles or other places that organic waste accumulates and begins to rot. Beginning with the adult female soldier fly she will lay an average of 500 eggs above or adjacent to rotting organic material (compost/manure). In about 4-5 days tiny larvae hatch and drop or crawl into the waste to begin feasting. BSFL eat a lot of waste very quickly and convert much of it to biomass. In about 2 weeks in good conditions the tiny newborns will be mature larvae. BSFL have the ability to extend this time out to 6 months if conditions are harsh. In just 14 days they will grow from smaller than a grain of rice to a grub (proper term maggot) of about 5/8 inch (1.6cm) in length. These larvae are now about 40% proteins and 30% fat and high in calcium. Now they have taken on a much darker colour than the creamy white that they began their lives as. They begin seeking a way to leave the rotting waste and their own excrement that has been their home for their entire life thus far. On their way out they clean themselves and remove almost all traces of their former home. Man made BSFL bins often have a ramp installed to allow the mature larvae to climb out and into a waiting vessel. From this vessel they are harvested for their final usage. If the larvae get to the soil as in nature they burrow themselves under to pupate. Time in the pupae state is dependent on conditions. In spring and summer they can emerge as adults in approximately another 2 weeks. In fall they may

overwinter in this state. The adults live only 5-10 days seeking only to mate before succumbing to starvation and the cycle repeats.



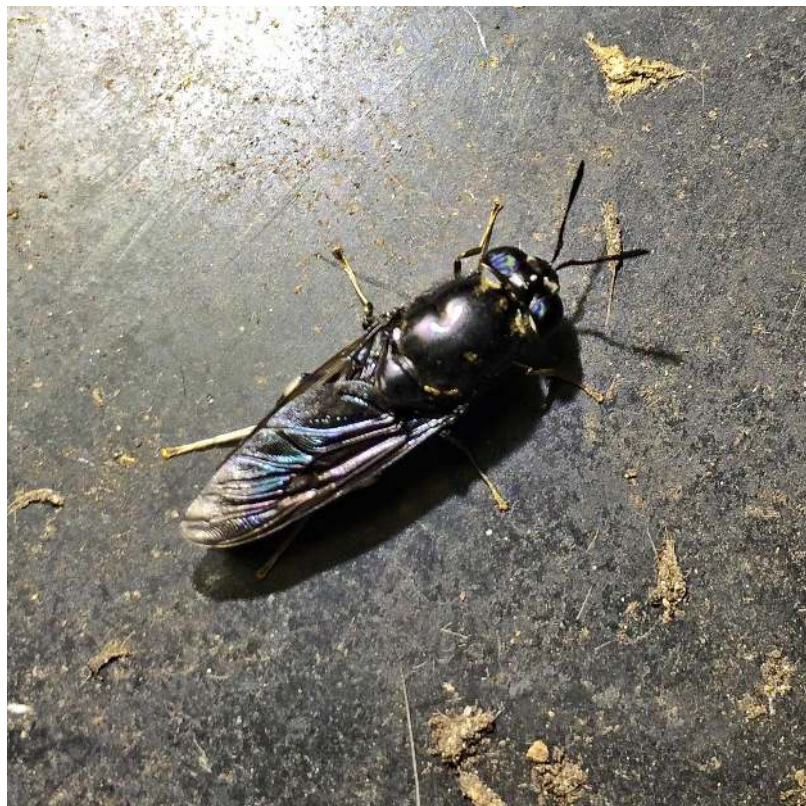
Eggs of Black Soldier Fly

BSFL in Waste Management

Roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes — gets lost or wasted, according to a Food and Agriculture Organization study commissioned in 2011

With an ever growing world population the amount of waste is likely to increase at a similar rate.

Black soldier flies can compost waste in a manner similar to earthworms by eating and excreting. BSFL however can convert this food much faster but leave behind less



compost (frass/dung) as more is converted to biomass than with earthworms. In some cases mass of the waste is reduced by over 60% making them ideal for large waste streams. Some current and potential waste streams that BSFL would work well for are:

- Spent grains from brewing

- Grape waste from winemaking
- Fish offal from processing plants
- Non edible waste from meat processing (except bone)
- Spent grains or olives from cooking oil extraction.
- Pulp from commercial juicing
- Aging produce from retail grocery stores
- Manures from livestock production
- Municipal sewage

On a smaller scale household food and garden waste can be composted and kept from landfill.

Many of these waste by-products are currently burned or buried in landfills contributing to environmental pollution; or the best case scenario, composted traditionally.

Benefits of using BSFL to compost these wastes include:

- Producing high protein animal feed from larvae
- Greatly reducing bulk and mass of the waste by-products.
- Potentially feeding people (except from animal origin waste. Manure/meat etc.)
- Pet food supplements
- Fish meal replacement in aquaculture and aquaponics.
- Production of oils suitable for conversion to high quality biodiesel.

- Minimizing environmental impact by converting otherwise waste product into rich fertilizer.
- Keeping waste from landfill
- Possibly saving transportation costs and fossil fuel usage of moving waste by reducing mass and bulk
- Turning costly disposal costs into an income stream.

There is a great opportunity in this sector for someone (or numerous people) with an entrepreneurial spirit to capitalize on useful products from a free waste stream.

On the farm, manures from livestock, waste material from cash crops and other waste can be processed quickly on site. The resulting compost can be returned to the fields directly or further processed by worms to produce valuable worm castings. The larvae can be sold as reptile or fish food. A small biodiesel plant could be built to supplement fuel for farm machinery (See chapter 4) from the larvae.

BSFL in Remediation of Pollution

Many of our freshwater sources are becoming polluted, this we know.

Leaching from chemical fertilizers and manures from farms can create large algae blooms in surface water. These algae can compete for oxygen with fish and other aquatic fauna and leave lakes, ponds, wetlands, creeks and streams dying. Compost differs from fertilizers and raw manures in that nutrients are released more slowly as the crops require them. If we can use BSFL to begin composting much of the manure and using compost to replace fertilizer we can reduce or nearly eliminate this leaching. Furthermore the algae could be harvested and fed to BSFL to return plant nutrients to the soil for another cycle.

Industrial leaching of heavy metals and toxins is another crisis facing our water supply. One solution may be present in a most unlikely source; an invasive species called water hyacinth. Water hyacinth grows very quickly and creates a mat of plants that can make passage through water impossible and greatly lower the dissolved oxygen of water. However, water hyacinth is also known to accumulate heavy metals and many toxins in its tissues leaving water much cleaner and purer than before its growth. Water hyacinth is also readily eaten by soldier fly larvae. At least in areas where this plant has already invaded the possibility exists to remove toxins and heavy metals from a water source with the plants. This process of using plants to clean water or soils is well known and is called phytoremediation. Studies show BSFL is capable of eating this plant, even when tainted with pollutants without a significant effect on its life cycle. A proposal of this science could

be to harvest the weed from swamps and ponds where it may cause environmental harm and feed it in a closed system of BSFL. Potentially could be dried and stored while research continued. The toxins would at least be greatly lowered from our water and the health of such water improved with regular and frequent harvesting of the plants. Wetlands are nature's water filters, constructing man-made wetlands and using water plants like rushes, bamboos, duckweed and others is a viable method of removing nutrients and toxins from polluted waters diverted through them or as a water treatment option for sewage from flush toilets.



Water Hyacinth Flower

Many cities in industrialized nations have streets lined with abandoned factories and industries of the past that weren't aware of the impact of improper dumping. Eventually these buildings will need rehabilitation or to be torn down. The toxic nature of these soils leaves this land with little value. Many methods of remediation become costly; offsetting any increase in value. Using deep rooted plants with large root systems (specifically chosen or genetically modified for ability to absorb toxins) toxic soils can be

remediated more cost effectively. These plants need to be harvested and moved to a different location or stored to complete the remediation process. Composting this material using BSFL onsite could greatly reduce transportation costs. Perhaps we can begin remediating the land surrounding abandoned factories and perhaps even return it to where it could grow at least a portion of food for the poor of our cities safely. The property values of these sites would be greatly increased after remediation and could bring new business into run down areas of our cities.

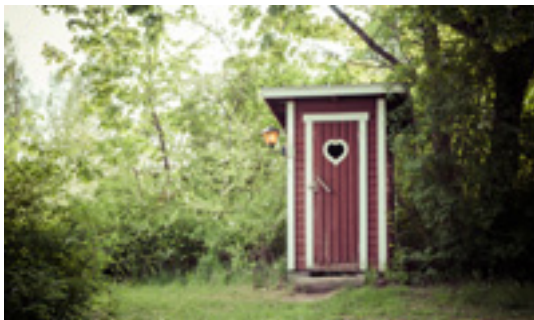


Water Hyacinth can make waterways impassable to boat traffic

BSFL in Sewage Treatment



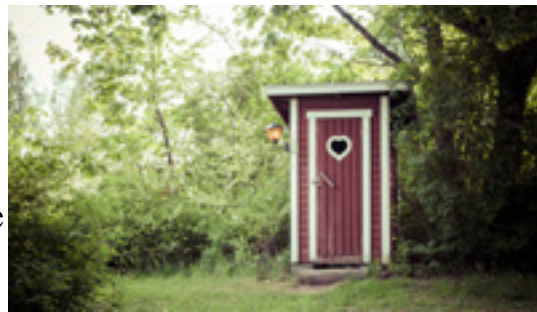
According to The World Health Organization 68% of the world's population now have sanitary methods to treat their faeces. This is a great improvement



from 1990 when it was 54%. This is still almost one in three people worldwide left exposed to disease and unsanitary facilities. Treatment of human sewage can be divided into two main categories; on site processing and offsite processing. Western industrialized cities primarily use off site processing. Off-site sewage processing requires a level of infrastructure to pipe, pump or otherwise deliver waste to the processing site. Piping and pumping require large amounts of water to thin the faecal sludge sufficiently. Some tropical and subtropical areas of the world are experiencing huge population growth. In some places there is a lacking infrastructure to deal with the sewage waste of the growing population. In other regions of the world a scarcity of water makes setting up off-site

sewage processing plants impossible. In many developing nations the use of pit latrines is common. There are numerous variables that determine the effectiveness of pit latrines. In some cases people can't afford emptying services or there isn't a way to get equipment to the latrine to empty them. Often the pits are emptied manually; exposing the people emptying them to potential health hazards. In other cases people resort to open defecation once the pits are full.

Several companies are innovating sanitary toilet systems for developing nations. Some collect the excreta and use thermophilic compost methods to



produce fertilizer by using additives like sawdust. Others are using anaerobic digestion on collected excrement to produce methane (CH_4) to be used as cooking or heating fuel. Research into using detritivores to process human excrement in these situations is ongoing. Bear Valley Ventures is a company that has run numerous successful field trials on their Tiger Toilets. The Tiger Toilet uses tiger worms (*Eisenia fetida*) to process human bio-solids into vermicompost to be used as fertilizer to enrich agricultural soils. Human faeces can be processed by BSFL either on site or off site and provide at least some reduction in human pathogens. It seems very likely large scale public restrooms could be built around using BSFL to process large amounts of excrement very quickly. Alternatively excrement could be collected and processed in a central facility. A further step in processing (pasteurization and/or vermicomposting) the BSFL frass would be recommended before using it directly in agriculture as a further precaution against spreading

disease. BSFL can process faeces without the need for using water in a flush toilet. This makes the technology of using soldier fly larvae potentially ideal for inhabited desert regions. The presence of black soldier flies has been shown to greatly eliminate oviposition (egg laying) and appearance of common house flies which can spread human pathogens.



Pupal stage of soldier flies, pictured with a composting worm

BSFL as Biofuel

Being 30% fat pre-pupae BSFL can be pressed to make oils that are very well suited to the production of biodiesel. Studies suggest that they could also make the cost of creating this fuel less cost prohibitive and nearly double the quantity attained from a plant. As an example we can press any number of seeds to produce oils for cooking, wood finishing products or for fuel. Currently the remaining solids from this process are burned or hauled away (using fuel) and buried (environmental danger). If the waste from the pressing of these seeds were fed to black soldier fly larvae (especially on site) the amount of fats and oils in the larvae can be almost equal to that in the seeds pre-pressing; essentially doubling the output of oils from a single crop. While the mass and volume of the waste is reduced 50-80% and can be further processed for organic fertilizer or at least with fewer trips with trucks, saving on disposal costs. This could also be accomplished at a food processing factory and the resulting biofuel used to power a fleet of trucks for product delivery. A March 17 2009 story in Business Wire spotlighted a New York company called EcoSystem. This company had, at the time filed to trademark the name Magfuel for the oils and fuels they sought to create from soldier fly larvae. They claimed that using food scrap waste the potential production of non-food oils from BSFL was 19000 US (719228 liters) gallons annually per acre (0.4 hectare). A search of the trademark application in 2016 seems to show the trademark application for Magfuel was abandoned. At this time I'm unsure of the status of the EcoSystem biofuel program. If worldwide we were to compost even half of the 1.3

billion tonnes of food waste that FAO study suggests exist; we could greatly reduce our dependency on fossil fuels. Returning the compost to our agricultural land could help to sequester carbon into our soils and reduce greenhouse gas emissions. One common process for creating biodiesel separates glycerine as a by-product. (<http://biofuel.org.uk/how-to-make-biofuels.html>) Glycerine is a common food additive and is used extensively in the beauty product industry for soaps and makeup. There is no waste from this process but there are several potential streams of income.

BSFL for Pet, Livestock or Human Consumption

The high protein and lipid content of BSFL is comparable to that of fish. BSFL are high in dietary calcium and contain several trace minerals. Live, fresh or dried this makes them an ideal feed supplement for the diets of reptiles, amphibians, fish, birds and mammals alike. Reptiles, amphibians, fish and birds will eat BSFL as is with no processing whatsoever. For livestock consumption it's most likely drying and mixing them with food as a powder or would make them more appealing. A great deal of land is used to grow food for livestock. Using some of that land to create compost, fuel and livestock feed seems a more efficient usage of land resources. Using blood meal and other meat products as a protein supplement in bovine diets (making cows into cannibals) led to mad cow disease. There may be a case to be made for BSFL as an alternative from a food safety perspective. For a food supply the use of "clean waste" (i.e. spent brewing grains or pressings from the juice industry) would be a prudent precaution against foodborne illnesses. Laboratory testing for pathogens and hygienic practices in processing each batch for consumption should be considered mandatory practice.



BSFL may soon be feeding our food

Enterra Food Corp. in Langley B.C. Canada is leading the way in North America as a company moving towards using the renewable and sustainable protein supplement as a replacement in livestock feed for soy meal and fish meal. In a July 2016 press release on Enterra's website they announced getting regulatory approval to use BSFL protein in commercial chicken feed in Canada. The year previous regulators of animal feed and the FDA in the United States approved Enterra's BSFL as an ingredient in food for farmed salmon. Using fish meal to feed livestock could lead to overfishing and depleting our oceans. Using soy meal takes many acres of land that could be used for producing food for humans. By 2050 FAO (Food and Agriculture Organization) estimates the global demand for food will increase 70% over 2015 levels. Meeting this demand will require using much of the land currently used to grow corn and soybean for animal feed to be used in human food production. Taking a long term look at food security, the use of insects as a food supplement in animal feed makes good sense.

EnviroFlight is a company near Dayton Ohio that is also growing BSFL as a fish food supplement. EnviroFlight's owner and CEO Glen Courtright, in an interview with inc.com claims to be able to produce the protein equivalence of a fattened pig every 10 days in only 7 square feet. Mr. Courtright hopes to continue getting approvals for BSFL as livestock feed and perhaps eventually as an ingredient in food for humans. He would eventually like to setup a business model similar to franchising; where someone can purchase their breeding and growing system and set it up near a large waste source anywhere in the world. In return they would receive a percentage of profits.

BSFL can be used in aquaculture or aquaponics to feed fish. With aquaponics fish are grown in tanks. The excrement laden water is used then to nourish plants and the water is recycled back to the fish. It's a fairly closed system of food production. With the addition of BSFL to consume fish leftovers and plant waste and the BSFL fed back to fish; this becomes a very waste free and sustainable method of food production.

BSFL are sold in the USA under a few names as food for pet reptiles. Phoenix Worms® and Repti-Worms® and dried BSFL from EnviroFlight mentioned above are packaged and sold under the name Tasty Grubs. An informal study of bearded dragon hatchlings indicated a growth and molting rate over 30% faster with BSFL than with feeding cockroaches. Some breeders of bearded dragons claim their dragons can survive solely on BSFL as a complete diet; with no further supplementation required.

BSFL in Medicine

Maggots have been used for centuries for cleaning serious wounds and preventing infections (debridement therapy). While the larvae of black soldier flies aren't commonly used in these therapies they have shown similar anti-microbial and anti-pathogenic properties. Laboratory studies have extracted and tested compounds from soldier fly maggots in prevention of infection with seeming success. Indications are that there may be a potential to fight methicillin resistant *Staphylococcus aureus* (MRSA) infections that have plagued the recovery of patients in hospitals for a number of years. Studies are ongoing into potential new antibiotics and antifungal medications derived from soldier fly larvae.

Omega 3 fatty acids are recommended in the prevention of heart disease and for overall good health. Oils from soldier fly larvae can contain significant amounts of Omega 3's and could potentially be used as a dietary supplement for this purpose.

BSFL in Forensics

Many readers will have watched the original TV crime series CSI and remember the character Gil Grisham. In the show he was a forensic entomologist, he studied insects for the purpose of solving crimes. Black soldier flies are one insect that can be used to determine an approximate time of death. The life cycle of soldier flies is well studied and the stage of development of larvae found on a body compared to recent weather conditions can narrow time of death down to a window of around 24 hours. Comparing the time frame to missing person reports can eliminate some persons from being included in attempted identifications. A time frame may also help to eliminate suspects in the case of suspected foul play or homicide. In cases of abduction it can also determine if or how long the abducted person was kept alive prior to being killed.

Information on Raising Soldier Flies

I won't be going into great detail on raising soldier flies in regards to enclosures, bins or systems. Each setup can vary somewhat based on variables in your own needs, goals and climate. Here we will provide some guidelines only as to temperatures, relative humidity, lighting and conditions. These should only be considered as starting points in your own experiments to maximize production for your goals.

Temperature

Humidity

Lighting

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