Treating Aquaculture Wastewater
Analyzing aquaculture waste treatment methods and Increasing IMTA in the U.S.

Tag Words: Aquaculture waste, Fish farming, Wastewater pollution, Wastewater treatment

Authors: Qi Zhang, Sarah Traynor and Julie M. Fagan, Ph.D.

Summary: Aquaculture is an important tool to increase depleting fish stocks worldwide, but the accumulation of fish waste in water is a problem inherent in aquaculture. Physical, chemical and biological water treatment methods are all utilized in current industries, but biological treatments, especially those using secondary filtering organisms, are the most effective and sustainable. In Integrated Multi-Trophic Aquaculture, organisms consume the by-products of other organisms around them to create a balanced system that is environmentally responsible and less expensive than monoculturing. For our community service project we will write to the NJ DEP and ask for the creation of policy that will give monetary incentives to aquaculture farms that use mainly biological treatment methods over physical or chemical treatments.

Video Link: https://www.youtube.com/watch?v=Xb6zv_xyAGs&list=UUts4_1WyqXMmVDfu9ZffstA

Part I –Aquaculture and Wastewater Treatments Today

Introduction – Aquaculture’s Definition and Significance (ST)

Aquaculture, also known as fish farming, is the controlled breeding, rearing and harvesting of aquatic organisms such as fish, crustaceans, mollusks and aquatic plants in captivity. Finfish and shellfish are the most commonly grown organisms, though seaweed, microalgae, frogs, turtles, alligators and endangered species have also been cultivated (1).

Aquaculture, like agriculture, has become necessary to meet the food demands of a growing global population. It is not a recent development; however, the cultivation of marine organisms dates back to ancient times – records in Chinese manuscripts of the 5th century B.C. show evidence of fish farming, hieroglyphics indicate the Egyptians attempted aquaculture, and Roman records reveal that they cultivated oysters (2). The modern form of aquaculture began in the mid 1700s when a German farmer successfully gathered fish eggs, fertilized them and then raised the hatched fish (2). Since then, scientists have managed to successfully breed fish in large cage farms in saltwater. Aquaculture can now be seen all over the world, and production of fish by aquaculture has eclipsed the amount of harvested wild fish from commercial fishing. It currently provides about 60% of the fish products consumed by the global market (2). This is a dramatic increase from 1970, when less than 5% of fish products on the market originated from aquaculture (2).
Although aquaculture is extremely popular in China and around the globe, the United States only produces about $1 billion in revenue from cultured aquatic species (Figure 1). Eighty percent of the farmed species are freshwater organisms such as catfish and trout. Only 20% or $200 million in revenue stems from marine species such as salmon and shellfish (2). Two-thirds of that 20% of marine species are clams, oysters and mussels. In New Jersey, the amount of cultured shellfish greatly outweighs the amount of grown finfish. Combined, the United States’ freshwater and marine species culturing provides approximately 5% of the seafood consumed in the United States.

![Aquaculture Production Value (1984 - 2011)](image)

Figure 1: The U.S. produces a small portion of the world’s aquaculture. China produces the most and makes the most in revenue from aquaculture (6).

Perhaps unsurprisingly because of the aforementioned, the United States’ seafood consumption continues to outpace its production. The U.S. imports 84% of all its seafood, and about half of it is farmed. Of the imports, about 62% come from China (3). Because seafood imports outweigh exports by such a large amount, the United States had a seafood trade deficit of over $11 billion in 2011 (Figure 2). Importing is also a problem because the United States inspects just 2% of all imported seafood for residues of banned drugs (3).
Commercial fishing is already at (or even slightly over) its limit and therefore cannot be increased. To meet its projected seafood demand, the United States must either continue to export increasing amounts of seafood and “take what it can get” from foreign fish-farmed products or the United States can choose to increase the amount of its “home-grown” aquaculture.

**Aquaculture industry today and benefits (ST)**

Of the ten most consumed species of seafood in the United States, five are already cultured in high amounts. These include shrimp, salmon, catfish, tilapia and clams (2). Additionally, economists estimate that for every job directly created in aquaculture production, four more jobs are created in supporting industries such as processing and boat building.

Though private sector aquaculture aims to sell its products for a profit, many public sector-funded aquaculture farms exist to restore and replenish depleted fishery stocks or wild stocks of endangered species. This aquaculture is usually done by non-profit organizations or by the state or federal government (2).

The health benefits of eating seafood are scientifically supported and numerous. Rich in omega-3 fatty acids, seafood’s long-established health benefits greatly outweigh its downsides (4). Benefits include increasing cognitive function, improving cardiac health and decreasing the risk of stroke. Newer research indicates that omega-3 fatty acids have some ability to protect against dementia, and possibly fight diabetes, menopause, depression and obesity (2). Nutritionists are encouraging Americans to double their consumption of seafood to two seafood meals per week.
An industry not to be ignored (ST)

There are many reasons to produce more seafood through domestic aquaculture. It supplies a source of healthy and local seafood. Eating locally in general means lower transportation costs, fewer carbon dioxide emissions and less time from ocean to plate. Aquaculture can support domestic jobs if the amount of exporting were to decrease. Other “upstream” and “downstream” industries that supply aquaculture could produce jobs as well. Agriculture, hatcheries, feed manufacturers, equipment manufactures and veterinary services, processors, wholesalers, retailers, transportation and food services are all jobs that could be affected by an upsurge in “home-grown” aquaculture (2).

Clearly seafood production is an important economic and health factor to the United States. Aquaculture seems the best route to increasing fish products in the U.S. that are grown in the U.S. It begs the question, why is aquaculture not more abundant in the United States?

Problems in Aquaculture (ST)

Aquaculture has many inherent problems, despite its benefits. Unlike land cultivation, the world’s oceans, lakes, rivers and streams are usually deemed public resources and management is problematic when ownership is vague (2). Aquaculture that uses cage systems tends to have little space for the fish to swim around (high density) (3). Non-native fish escaping and becoming invasive species is also a problem. Fish are fed hormones and antibiotics to help them grow, which leads to waste in the surrounding water. Polluted water is a serious issue, but one that has been addressed. The following sections detail the problems associated with aquaculture waste and how those have been addressed so far.

Negative Environmental Impacts from Fish Waste (QZ)

No matter what kind of aquaculture system, there are wastes produced by fish. The aquaculture wastes include solid wastes, chemicals, released bacteria, pathogens and farmed species escapees. Solid wastes are organic matters like feces and uneaten food that could accumulate in the bottom of the recirculation system, and suspended in the thoroughly water column and dissolved in the water body. The finest dissolved solids are a main concern and should be avoided because they can cause gill irritation and other health problems that would directly reduce the amount of fish production. In addition, the solid waste accumulation is extremely harmful because it leads to dissolved oxygen depletion and ammonia concentration build-up in a short period of time. Generally speaking, the ammonia from organic matter degradation is not toxic to humans if in a low concentration in the aquaculture system, but it turns toxic when the concentration is above a certain threshold (7).

Compared to the solid waste, toxic chemicals are also a major environmental problem caused by the aquaculture systems. In the daily life of fish, they discharge urine and feces that would lead to high ammonia and nitrogen contents and an increase in biochemical oxygen demand (BOD).
Ammonia, a main source of nitrate ions, is produced by fish metabolism and is excreted across their gills to their living environment (7). The high level of nitrate concentration associated with other essential nutrients causes eutrophication and toxic algae blooms on the surface of the water. It is an unhealthy environmental condition that kills fish and other aerobic species in water (8). The eutrophication conditions reduce water clarity, deplete dissolved oxygen, create a hypoxia environment called a “dead” zone and also block the sunlight from going through the surface water. All these are serious environmental issues that affect both aquaculture organisms and human life. In a study of coastal Florida, “Extensive sectors of coral reef die from increased loading of near-shore waters by elevated nitrogen (N) and phosphorus (P) nutrient levels delivered to the coast by submarine groundwater discharge (SGD)”(9). It is clear that the high concentration of nutrients were leached from the agriculture area near the coast into the submarine groundwater. Then the contaminated submarine groundwater discharge killed the coral reef in ocean. Also, aquaculture waste with a high concentration of N/P that could flow around and cause problems in both local and downstream areas. The water pollution changes the environmental dramatically, and the environment degradation may last for decades. These make the water pollution issues more complex.

In conclusion, the contaminate-water discharge, without proper treatments, is very harmful and should be avoided. The negative impacts includes oxygen deficiency, eutrophication, water deterioration, diseases spread-wide and so on. How do these problems occur? First, the decomposition and degradation of organic substances leads to oxygen deficiency and kills organisms within the system. As mentioned before, the accumulation of organic substances increases concentrations of nitrogen and phosphorus, which causes eutrophication and an exponential growth of biomass in the surface aquifer. Also, water deterioration causes low productivity and human diseases may break out without control because it is easy to pollute people’s drinking water supply when there is flooding (7). Therefore, polluted water discharge without treatments causes serious consequences like drinking water supply contamination, food chain break down, and improper environment and economic development. It definitely increases the potential risk of infection, deteriorating groundwater and other local ecosystems.

Aquaculture FAILS to clean up its waste (QZ)

Pond effluent is produced during the harvest time and exchange water period that for clear water quality maintains of pond. The effluent is mainly composed of particulates, organic substance, nitrogen and phosphorous compounds (10). The discharge comes from various sources of the aquaculture system with diluted pollutants in it. In studies of many fish farms operating in West Virginia, farmers don’t treat their aquaculture waste by any means before discharging the water (11). That is to say, the regulation of the aquaculture farms is not as effective as people expected because most of the aquaculture farms are small, and individuals who operate the aquaculture system do not have enough technical knowledge of the system principal. They are also short of monetary support, so there is a high demand for a more efficient and technical method with low costs for water clean-up. In addition, government subsidies, technical improvement and increased farmer’s education level are all good ways to help people meet the effluent standards.

General waste treatment methods (Physical/Chemical/ Biological) (QZ)
The general aquaculture waste treatments include physical, chemical and biological methods. Physical methods are widely applied all over the world because they are very useful in removing suspended small particles, and reducing BOD and COD in the water. It is also a low cost, simple and low-tech method that is easy to use on aquaculture farms. The method is mainly about sediment filtration. However, this method can only count as a pretreatment process to reduce the organic matter in water like nitrogen and phosphorus (7).

Compared to physical methods, chemical methods are a better way to kill pathogens in a short time period. Chemical methods are mainly composed of neutralization, coagulation, sterilization and oxidation. These are more expensive than physical methods and can cause secondary pollution in the discharged water if designed improperly. For example, a high concentration of chlorine, included to kill pathogens, could have a toxic effect on humans. The organic chlorine will pollute the already treated water again and cause serious health threats (7).

Finally, biological methods include aerobic treatment, anaerobic treatment and aquatic life-form treatment. All these rely on microorganism degradation to convert organic substances into harmless carbonates and nitrates that are in inorganic form. Both the low investment and less secondary pollution make the biological method the most promising treatment technology (7). In order to reuse water and make the system sustainable, biological treatments are obviously the most economical approach for the aquaculture waste treatment.

**Case study: An Aquaculture System and Constructed Wetland (QZ)**

A constructed wetland (CW) is an efficient and cost-effective eco-technology for water pollution control. The artificial wetland was created as a restored habitat to act as a bio-filter to remove pollutants and undesired chemicals like nitrogen from the water body (7). Plant and media material selection are key criteria for efficient water treatments. In the Northeastern U.S. some of the common plants used in constructed wetlands are cattails, bulrushes, rushes, and sedges (11). The media size, uniformity, porosity, hydraulic conductivity and phosphorus binding capacity will also have a big affection on the efficiency of wastewater treatment (11). Based on the data from EPA, more than 95% of the total suspended solids and 80% - 90% of the nitrogen and phosphorus were removed (12). Therefore, using constructed wetlands not only avoids environmental pollution, but it also makes it possible to take advantage of the nutrients being discharged in waste. These kinds of sustainable aquaculture systems are highly demanded in order to keep the pollution within environmental capacity.

**Biological Treatment methods that also Recycle Waste (ST)**

As mentioned above, biological aquatic life-form treatment methods are the most environmentally-friendly and economically sustainable. One example of such biological treatment practices is Integrated Multi-Trophic Aquaculture (IMTA). In IMTA, the wastes or by-products from one species are recycled to become inputs like fertilizers or food for another species. Finfish aquaculture is combined with shellfish and seaweed aquaculture to create balanced systems that are more environmentally sustainable.
Ideally, the biological processes in an IMTA system should balance, leaving little to no waste left in the water. IMTA’s greatest benefit comes from its mutual benefits of the species involved – one species benefits from the first species’ presence in direct and indirect ways. Once the cost of new management equipment for the second species has been paid off, IMTA systems are severely more profitable than monoculturing systems, which are always reliant on chemical inputs for cleaning.

**Part II – Aquaculture and Wastewater Treatments Today (ST)**

Despite the benefits listed above, IMTA is not as prevalent and one would think. The NJ DEP reported in their Assessment 309 2011-2015 that of the licensed aquatic farms in New Jersey, 116 are shellfish farms, 12 are finfish farms, 1 is an aquatic plants farm and only 1 facility combines aquatic plants and shellfish (5). If only 1 out of 130 licensed aquaculture farms utilizes biological treatment methods like IMTA, New Jersey’s shore waters can expect to see the environmental costs of chemical treatments used in monoculturing.

To take action to solve this issue, we chose to write to the NJ DEP, because they train law enforcement patrols that look at shellfish in polluted waters. Our plan is to use our research and findings on biological treatment methods to make a case for why aquaculturists that use primarily biological treatment methods, as opposed to physical or chemical methods, should be monetarily rewarded by the NJ DEP. This will act as an incentive for aquaculture farms that do not utilize biological treatment methods or IMTA (the majority of aquaculturists, according to Assessment 309) to switch to more sustainable and environmentally responsible methods. Our inquiry to the NJDEP stresses that farmers would benefit economically from a switch to IMTA methods, and the barrier to them switching now, we believe is partly in the cost of new equipment. Change never comes easily for those who are comfortable with their current practices, but in the interest of maintaining waters clean of pollutants while still increasing aquaculture production in the United States, methods like Integrated Multi-Trophic Aquaculture will have to be utilized on a large scale.

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Community Action: Letter to NJ DEP

Email to: bmwm@dep.state.nj.us

NJ Department of Environmental Protection
Bureau of Marine Water Monitoring
PO Box 405, Stoney Hill Road
Leeds Point, NJ 08220

To Whom It May Concern:
Our names are Qi Zhang and Sarah Traynor and we are students at Rutgers University in New Brunswick, NJ taking the class “Ethics in Science and Society”. Prior to taking the class we both had interests in water quality and aquaculture so our professor, Dr. Julie Fagan, suggested that we conduct a research project on aquaculture pollution and wastewater treatment methods.

The results of our research were surprising, and we wanted to inquire to the NJ DEP about prospects for future aquaculture waste treatment procedures.

We found that biological treatment methods that use aquatic life forms as natural filters are the most effective in eliminating waste. In Integrated Multi-Trophic Aquaculture (IMTA), seaweed and shellfish filter out fish by-products in the surrounding water and consume those products as food. IMTA creates balanced systems for environmental remediation and is much more sustainable than monoculture growing methods, which must use large amounts of chemical filters to clean the water to the same degree.

What we were surprised to find was in your Assessment 309 (2011-2015). The NJ DEP stated that of the licensed aquatic farms in New Jersey, 116 are shellfish farms, 12 are finfish farms, 1 is an aquatic plants farm and only 1 facility combines aquatic plants and shellfish. Only 1 facility out of 130 uses a form of IMTA, while the others rely on monoculturing wastewater treatment methods.

We would like to see incentives for aquaculturists, especially those who farm finfish, to switch from monoculturing to combined culturing methods like IMTA. Such switches would save fish farmers money in the long-run, as IMTA allows fish farmers to harvest products from at least two different organisms (finfish and shellfish) while simultaneously not spending money on chemical treatment inputs required when managing monoculture fish farms. Not to mention, biological treatment methods like IMTA do not leave secondary pollutants in the treated wastewater, like chemical treatment methods do.

We believe that one barrier to change is the initial cost of new equipment for growing the secondary organisms. As policy makers, you, the NJ DEP, can take the first step to overcoming this barrier by creating monetary incentives for aquaculture farms to make the switch to IMTA and similar biological treatment methods today. Our cleaner oceans and the fish farmers’ wallets will both thank you.

Please feel free to contact us with further information/inquiries. We thank you for your time and hope to hear back from you soon.

Sincerely,

Qi Zhang and Sarah Traynor, with Dr. Julie Fagan Ph. D.
References


Letter to the Editor: by Qi Zhang

Dear Marielle Sumergido:

Please consider my post below for publication in your online newsletter. If you have any questions or would like to contact me, please email me. Also, if you do publish it, please send me your reference so I can look it up! Thank You, Qi Zhang.

It is noticeable that the water supply contamination affect from aquaculture are increasingly recognized, though they are point sources that just a small proportion to land-based pollutants. The nutrient-rich waste may cause eutrophication that is the condition with a high concentration of N or P in the waterway and causes an excessive growth of algae. The toxic algae blooms would reduce the water clarity and deplete dissolved oxygen, which called the hypoxia environment or the “dead” zone. This environmental condition kills fish and other aerobic species in water. The wastewater discharged with a high concentration of N/P could flow around and cause problems both in local and downstream. The aquaculture waste changes the environmental dramatically and the environment degradation last for a long time period that make the pollution issue more complex.

The continuously wastewater discharge without treatments could lead to remarkable elevation of the total organic matter contents and cause considerable economic lost. The factors affect the quality and quantity of aquaculture waste includes culture system characteristics, the choice of species, the feed quality management and also the waste treatment strategies. Rutgers University professor Dr. Julie Fagan and student researchers, me included, are conducting a research study in the aquaculture waste and water pollution. We plan to arrange an online seminar system, which utilize the crowd wisdom of general public, to educate the large industrial polluters how to feed fish and manage wastewater properly. Also, we will collect consequences of polluted aquifer system as case studies to encourage the industrial polluters to run their business properly and be friendly to the environment.

Qi Zhang

Rutgers University student majoring in Environmental Science
Letter to the Editor: by Sarah Traynor

TO: The Cape May County Herald newspaper
Letters to the Editor can be submitted online
Approximately 600 words allowed

Title: FISH FARMING NEEDS MODERNIZING TO BE SUSTAINABLE

Dear Editor,

In a beach vacation community such as Cape May, the availability of reasonably-priced fish courses in restaurants is a big draw for tourists. Worldwide overfishing has lead to an ever-decreasing stock of fish to be caught, and alternative ways to raise fish for consumption have become necessary. Underwater ocean fish farming, or mariculture, might seem like a sustainable alternative to commercial fishing, but there are problems inherent in mariculture that need to be addressed. Mariculture usually consists of raising fish in an area of the ocean contained by a large, underwater net. Wastes from the high concentration of fish in one area accumulate on the ocean bottom, which harms bottom-dwelling organisms that are vital to the ecosystem. This waste accumulation is not too high a liability to address; there are affordable options that can be put in practice to make mariculture more environmentally-friendly.

Integrated Multi-Trophic Aquaculture, or IMTA, is a practice in which the waste from the farmed fish becomes fertilizer and food for another species, often shellfish. The beauty of this technique is the secondary species can then also be sold to negate the cost of their inclusion in the mariculture system, and the system becomes restorative rather than harmful. Mariculturists who have not adopted IMTA practices state that the current methods that focus only on raising one species (called monoculturing) yield more product (fish) than IMTA methods.

Mariculturists don’t want to pay the cost of polluting the local ocean ecosystem via high densities of fish waste, but IMTA practices could negate the extra cost all together. Changing from old to new methods may be daunting, especially in rising industry such as aquaculture, yet in the near future clean fish farming will become a necessity. If not, the very ocean acting as a “nest” for mariculture will become unusable.

Sarah Traynor
Rutgers University student majoring in Biological Sciences