Asian Fisheries Science ***31S*** (2018): 182–193
©Asian Fisheries Society
ISSN 0116-6514
E-ISSN 2071-3720
https://doi.org/10.33997/j.afs.2018.31.S1.013

New Paradigm for Controlling EMS/APHNS in Intensive *P. vannamei* Boone 1931 Culture Ponds

DAVID KAWAHIGASHI*

5241 Keakealani St., Honolulu, HI 96821, USA

Abstract

Since 2014, a gradual paradigm shift has been taking place in Thailand, where the farmers have changed the dynamics of their ponds to maximize diversity to control *Vibrio* and prevent APHND/EMS outbreaks. The objective is a rather simple one… to keep the pond bottoms clean of sediments and sludge. To achieve this, farm modules can use a combination of recirculation and flow-through water exchange to maintain a low-risk, sustainable culture system. There are four major components that the “new” farm design incorporates into the strategy to maintain clean pond bottoms: reduction of grow-out pond size, increased reservoir to grow-out pond ratio, increased aeration/energy capacity, and construction of a "shrimp toilet" at the center of the pond. The most significant shift in strategy is the reservoir to grow-out ratio. Traditional farms that were once 20 % reservoirs and 80 % production were changed to 60 % reservoir and 40 % grow-out capacity. Transitioning a traditional farm into an intensive, controlled and sustainable “shrimp toilet” culture system may be the best solution to overcome APHND, Vibriosis and viral diseases.

Keywords: EMS, AHPND, disease control, intensive pond culture, *Penaeus vannamei*, shrimp toilets

Introduction

The Chinese word for "crisis" is “Wei-Chi”, translated as a combination of “danger” and “change”, and would be an accurate description of the state affairs of the global shrimp industry today. Although the cause of these fungal, bacterial or *Vibrio*-based outbreaks has been blamed on climate change (e.g. drought, typhoons, El Niño, earthquakes) and incrementing coastal pollution, the real cause remains a mystery.

*Corresponding author. E-mail address: dkawahigash@gmail.com

The spread and permanence of new pathogens, (early mortality syndrome (EMS), acute hepatopancreatic necrosis disease (APHND) and *Enterocytozoon hepatopenaei* (EHP) specifically) worldwide together with unpredictable climate conditions presents a new challenge to the global shrimp industry.In most shrimp-farming countries, it is becoming more evident and alarming that traditional shrimp farming may actually never recover, given the nature of these bacterial and fungal pathogens.

Bacteria are in constant competition for pond nutrients, favoring the dominance of specific strains over others. Under suboptimal pond conditions of low biodiversity, which are characteristic of most shrimp-pond environments, *Vibrio* bacteria can double every 10–20 minutes, which could change the dynamics of the pond environment quickly. Given the presence of the APHND plasmid, this rapid proliferation of potentially pathogenic *Vibrio* could elevate quorum sensing to toxin-producing levels. Or as some researchers have postulated, *Vibrio* proliferation can serve as a stimulus to trigger viral diseases such as white-spot syndrome virus (WSSV).

Because of the evolving and ubiquitous nature of the *Vibrio* + plasmid combination throughout Southeast Asia, shrimp farming countries such as the People's Republic of China, Viet Nam, Thailand and Malaysia have yet to recover fully from the EMS/ APHND epizootic. In addition, overall shrimp production from Indonesia and India also seems to have peaked out in 2015 and is on the decline in 2016. Table 1 shows the tendencies of the major shrimp-farming countries worldwide (according to the authors' own observations for 2016). The only exception is in Thailand, where a slight improvement of 10 to 20 % over 2015 is expected.

Table 1. Trends in shrimp production for major shrimp-producing countries.

Country	**Trending 2016**	**Target Market (majority)**	**Cause[1]**
Mexico	↓	Domestic	EMS, WSSV
Brazil	↓	Domestic	WSSV
P.R.China	↓	Domestic	EMS, EHP
Indonesia	↓	Export	EHP
India	↓	Export	EHP
Thailand	↑	Export	System & genetics
Viet Nam	↓	Export	EMS, EHP
Ecuador	↓	Export	*Vibrio* in hatcheries

[1]EMS = early mortality syndrome, WSSV = white-spot syndrome virus, EHP = *Enterocytozoon hepatopenaei.*

Management Strategy: Control *VIBRIO* => Control AHPND => Control WSSV

Over the past two to three years, a gradual paradigm shift has been taking place in Thailand, where the farmers have changed the dynamics of their ponds to maximize diversity to control *Vibrio* and prevent APHND/EMS outbreaks. The objective is a rather simple one… to keep the pond bottoms clean of sediments and sludge. Farm modules with layouts such as that shown in Fig. 1 can use a combination of recirculation and flow-through water exchange to maintain a low-risk, sustainable culture system.

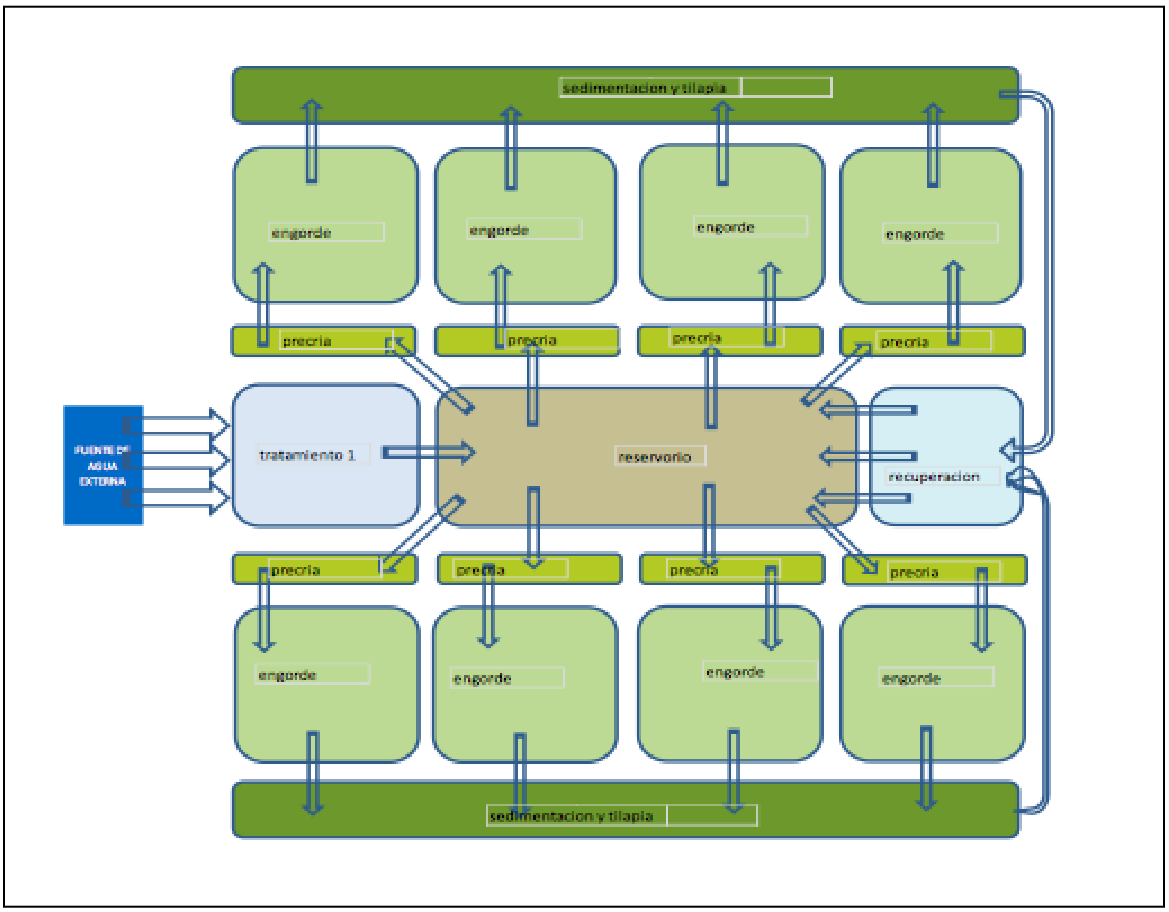

Fig. 1. Farm model for a low-risk, sustainable culture system.

However, this task is easier said than done, as the inputs that go into an intensive pond are very costly and are site dependent. Farms that have made the investment and renovation process have demonstrated that with good water quality and clean pond bottoms, very high harvest yields can be achieved. Albeit a very sizable investment, transitioning a traditional farm into a high-energy, high-exchange, and controlled culture system may be the best solution to overcome APHND, Vibrosis and viral diseases of shrimp. Table 2 summarizes the key differences between the traditional Thai shrimp ponds and the new pond design and inputs. The success of this new system is not due to any one or two criteria, but is due to a combination of many inputs.

Table 2. Key differences between traditional Thai shrimp ponds and the new pond design and inputs.

Pond Description	**Traditional**	**New**
Size (area)	1+ ha	1 000–4 000 m^2
Shape	Rectangular	Square
Depth	1.0–1.5 m	1.5–2.5 m
Bottom	Earthen	Lined (HDPE)[1]
Aeration	20–40 $hp.ha^{-1}$	55 to 75 $hp.ha^{-1}$
Discharge location	Side gate	Center drain
Water exchange	<50% over cycle	1 000%+ over cycle
Polyculture (reservoirs)	none	Tilapia
Feeding frequency	4–5 times, daytime	300+ times/12–24 hr
Feeding amount ($kg.m^{-2}crop^{-1}$)	1–2 $kg.m^{-2}$ (before EMS)	3–4 $kg.m^{-2}$

[1] HDPE = high-density polyethylene.

There are four major components that the "new" farm design incorporates into the strategy to maintain clean pond bottoms. These include:

- Reduction of grow-out pond size
- Increased reservoir to grow-out pond ratio
- Increased aeration/energy capacity
- Construction of a "shrimp toilet" at the center of the pond

The diagram given in Fig. 2 shows the difference in configuration of the ponds for a "traditional" farm design prior to APHNS/EMS and the "new" post-APHNS/EMS layout.

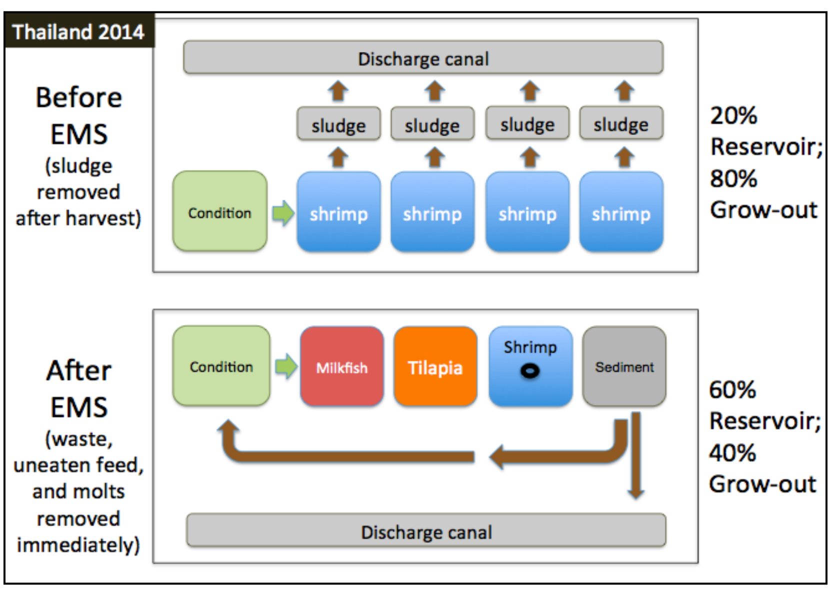

Fig. 2. Comparison of pond configuration between a "traditional" farm design prior to AHPNS/EMS and the new post-APHNS/EMS layout.

Grow-Out Pond Dimension, Reservoir Capacity, Aeration and Shrimp Toilet

There is a direct efficiency correlation between the pond size, area and depth of the "shrimp toilet"; energy/water movement and water flow volumes to remove the accumulated solids from the pond effectively.

Pond Dimension

The dimension of the lined grow-out pond must be as close to square (or round) as possible. Reducing pond size from an average of 0.8 ha (8 000 m^2) down to 0.2 to 0.3 ha improves oxygenation and more importantly, water movement efficiency to push settled organic matter towards the center of the pond. To compensate for the reduced surface area, water column depths of up to 3 m are developed to increase stocking densities to 300–500 animals.m^{-2}. In addition to reducing pond size, investment in upgrading the power grid and capacity was possibly the highest renovation expense in transforming a traditional farm to an intensive farm. Figure 3 shows a photograph of a post-APHNS/EMS shrimp pond in Thailand.

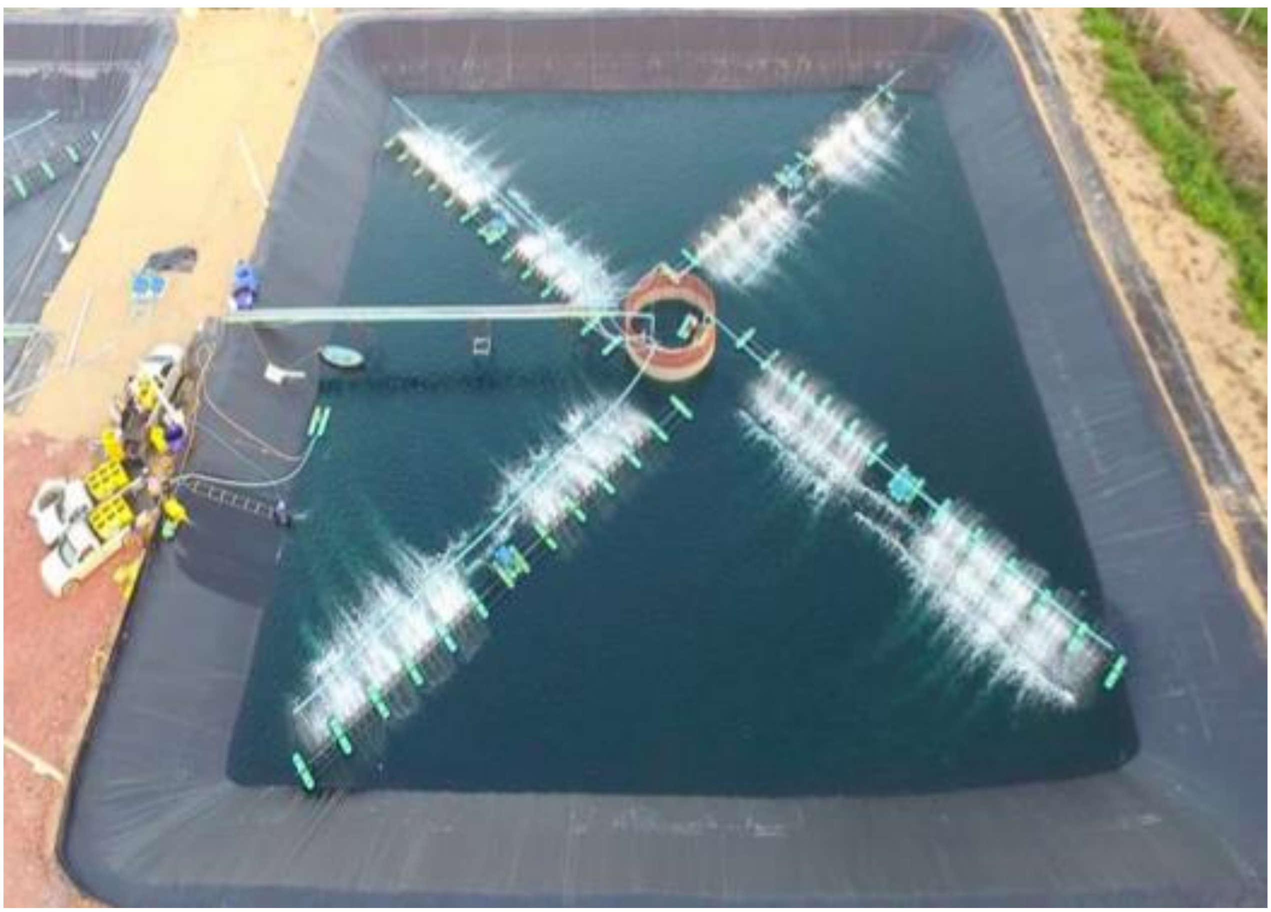

Fig. 3. Photograph of a 50 x 50 x 2.5 m deep post-AHPNS/EMS shrimp pond in Thailand.

Reservoir Capacity

The most significant shift in strategy is the reservoir to grow-out ratio. Traditional farms that were once 20 % reservoirs and 80 % production were changed to 60 % reservoirs and 40 % grow-out capacity. Psychologically, this change alone was probably the most difficult for the farmers to accept, given that less area would be dedicated to shrimp production. However, the loss in overall production from fewer production ponds has been more than compensated by higher and more reliable yields. Reservoir capacity is largely dependent on the availability of good quality water for the “new” farm. Coastal beachfront farm locations with unlimited ocean or well-point water could pump prefiltered water directly into the grow-out ponds, such as along the central coast of Viet Nam. However, farms located in estuaries where several farms share the same water source often sacrifice production ponds to become sedimentation and water storage ponds.

Daily water exchange during the course of the grow-out cycle begins at 2–5 % over the first two months and increases to up to 10–15 % over the last month of grow out. Total water exchange for a given pond could amount to over 1 000 % exchanged over the entire grow-out cycle. This water budget is 5 to 10 times higher than water exchange rates in traditional semi-biofloc ponds. Figure 4 illustrates a flow-through or recirculating aquaculture system (RAS) for enhanced biosecurity and water storage.

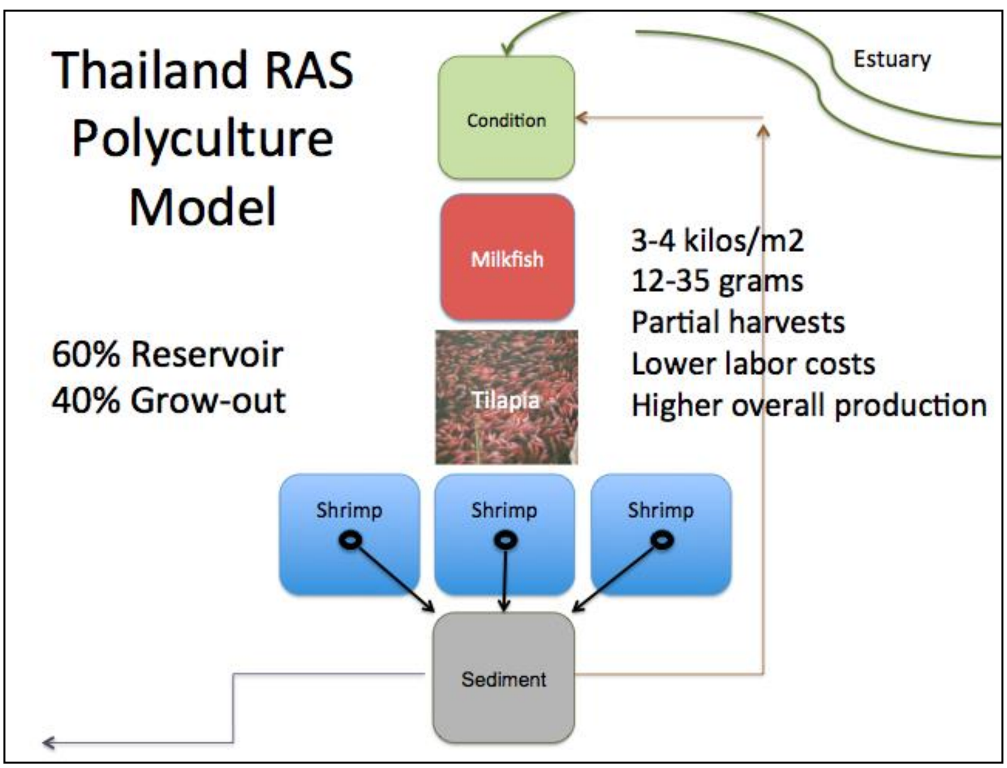

Fig. 4. Diagram illustrating a flow-through or recirculating aquaculture system (RAS) for enhanced biosecurity and water storage.

Farm modules such as in the layout shown in Fig. 1 can use a combination of recirculation and flow-through water exchange to maintain a low-risk, sustainable culture system.

Shrimp Toilet

Inclusion of the “shrimp toilet” has vastly improved the efficiency of concentrating and removing all sediments (faeces, uneaten feed, moults, algae and biofloc) from the pond bottom. Because the bottom of the cone or “shrimp toilet” is up to two meters below the bottom of the pond and discharge canal, submersible or floating pumps (2 hp) are used to pump out the sediments continuously. This relatively inexpensive excavation includes a center pit and a smooth lined cover using plastic sheets or HDPE. A photograph of a shrimp toilet is given in Fig. 5.

Fig. 5. Photograph of a "shrimp toilet".

The surface area of the “shrimp toilet” should be 5–7 % of the total area of the pond. Thus, a 4 000 m^2 pond would require a shrimp toilet measuring 16 m in diameter. The slope within the center depression should be 25–30 degrees to facilitate the solids to fall into the center pit. The “shrimp toilet” should be lined to create a smooth surface (Fig. 6).

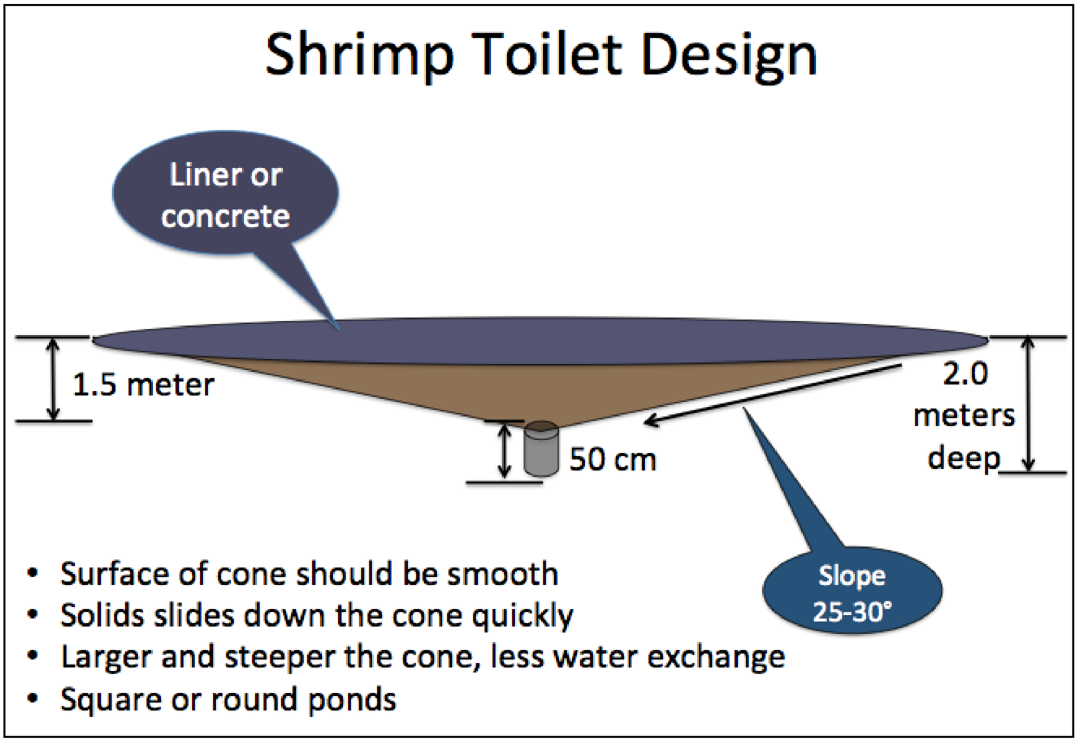

Fig. 6. Design of a "shrimp toilet".

Water Movement and Aeration

Creating a current strong enough to push settled organic matter to the "shrimp toilet" requires an energy budget of 70 to 100 hp of energy per ha, depending on the surface area and depth of the pond. Contrary to popular belief, the aerators or paddlewheels need to be operating day and night, regardless of dissolved oxygen levels. Continuous water exchange to remove accumulated sediments is a 24/7 operation. To ensure water quality, water going into the grow-out pond first goes through a series of sedimentation ponds, fish reservoirs, conditioning reservoirs and finally, a 200 µm filter (Fig. 7). This multistep water treatment process continues to evolve as some farms seed their conditioning reservoirs with macro-algae to further strip excess nutrients from the incoming water.

Fig. 7. Photograph of a shrimp pond in Thailand showing pond water exiting the "shrimp toilet" and incoming water passing through a 200 μm filter before returning to the same pond.

Polyculture

In areas of medium to low-salinity estuaries, many farmers stock their reservoir ponds with tilapia (*Oreochromis* sp.) and sometimes, milkfish *Chanos chanos* (Forsskål 1775), if available. The anti*Vibrio* "treatment" from the mucus membrane of the tilapia has been documented to lower the risk of a disease outbreak. A standing fish biomass density of around 1–2 kg.m^{-2} of tilapia in the reservoir is recommended. The tilapia or milkfish are mostly underfed, as the fish graze on the excess biofloc and organic matter. Figure 8 shows the role of tilapia as a biomanipulator in shrimp ponds, while Table 3 presents the criteria for fish biomass in a water-conditioning reservoir.

Table 3. Criteria for fish biomass in a water-conditioning reservoir.

Criteria	**Reservoir**
Stocking size	50–70 g
Stocking density	10 fish.m^{-2}
Stocking biomass	500 g.m^{-2}
Harvest size	400–500 g per fish
Harvest biomass	5 kg.m^{-2}
Aeration	Yes; 2–3 per reservoir
Feeding	Yes

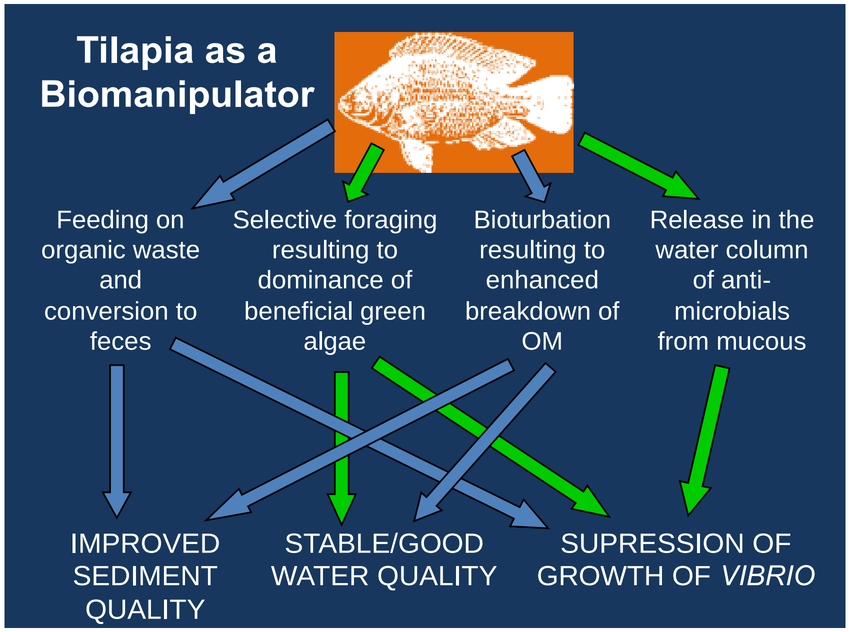

Fig. 8. The role of tilapia as a biomanipulator in shrimp ponds.

Shading the Pond

A technique that was made popular in Brazil and now adopted in other countries is to shade the nursery, grow-out ponds and reservoirs with black or green netting to reduce phytoplankton blooms and maintain slightly lower water temperatures. As high water temperature and blue-green (Cyanophytes) algal blooms have been associated with APHND, partial or complete blocking of direct sunlight helps to stabilize culture conditions, enabling beneficial bacteria to dominate the pond. A viable option to covering the ponds with shade cloth or orchid net is to apply commercial pond dye to darken and shade the pond water directly (see Fig. 9).

Fig. 9. Blue-green algal bloom, Shading ponds in Vietnam and Philippines, use of pond dyes to shade pond water.

Cost of Production

Table 4 shows the cost to produce one kg of 17–33 g shrimp in Thailand using the new "shrimp toilet" intensive culture method. Although the cost to produce 3–4 $kg.m^{-2}$ of large shrimp may be high, as long as a profit margin of at least 30 % can be realized, the farmer will continue to farm. The most important benefit of this new "shrimp toilet" technique is that shrimp yields per crop are much more predictable and the risk of crop loss is much lower.

Table 4. Cost to produce one kilogram of 17–33 g shrimp in Thailand using the new "shrimp toilet" intensive culture method.

Cost Breakdown	Thai Baht (THB)	USD
Feed	65	$1.86
Electricity	40	$1.14
Probiotics, treatments	20	$0.57
Seedstock (juveniles)	15	$0.43
Misc.	5	$0.14
Total	145	$4.14

Harvest Size	Weight (g)	% of Harvest	THB	USD
60 kg^{-1}	17	25%	150	$4.29
40 kg^{-1}	25	25%	180	$5.14
30 kg^{-1}	33	50%	220	6.29
Average			192.5	$5.50

Production Cost per Kilogram	Farm Gate Value	Net Profit	% Profit
$4.14	$5.50	$1.36	33%

Production numbers using specific pathogen free (SPF) "fast-growing" stocks in Asia range between 3 and 8 $kg.m^{-2}$. Target production for a typical "shrimp toilet" farm is 3–4 $kg.m^{-2}$ per crop, times three crops per year, or close to 100 tons per year.

Importance of the Best Genetics for the Culture System

Having the most ideal culture system that can effectively control pathogenic *Vibrio* and other diseases is only half the battle. The other 50 % is having the right genetics to optimize the culture system (or the culture system to optimize the genetics). Given that a tolerant but slow-growing specific pathogen resistant (SPR) strain of *Penaeus vannamei* Boone 1931 is no longer an essential requirement to produce shrimp successfully in an intensive "shrimp toilet" farm, it makes sense to stock fast-growing, SPF origin shrimp to maximize output. Table 5 ranks four different sources of breeding stocks according to four different performance traits at stocking densities above 100 animals per m^2. In the new "shrimp toilet" grow-out model, stocks of *P. vannamei* with the fastest growth rates would be the origin of choice.

Table 5. Ranking for four different sources of broodstock according to four different performance trials at stocking density above 100 animals.m^{-2}. Scores are 1, 2 or 3 stars, with 3 being the highest.

Trait	Ecuador (SPR)	Mexico (SPR)	Brazil (SPF)	Hawaii (SPF)
Survival	***	*	*	*
Growth/week	1.0 g	1.0 g	1.0	2.0 g
High density	*	*	*	***
Uniformity	*	*	*	***

Conclusion

As new shrimp diseases continue to spread to other shrimp-farming countries worldwide, farmers who adopt new technologies will thrive in these challenging times. Transitioning a traditional farm into an intensive, controlled, and sustainable “shrimp toilet” culture system may be the best solution to overcome APHND, Vibrosis and viral diseases.