Training Manual

Effluent and Waste Management Course

A guide for the training of technicians responsible for overseeing the management of effluents and waste at 8 farms that form Belize's Shrimp Cluster, in preparation for ASC certification.

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Introduction

This manual is designed to serve as a guide for the delivery of the Effluent and Waste Management course developed to train personnel from 8 shrimp farm members of the Belize Shrimp Grower's association. The course is part of a training program developed by the Faculty of Science and Technology of the University of Belize, and is designed to improve human resource capacity at the farms as a means of improving farm sustainability and for better preparing farms for Aquaculture Stewardship Council (ASC) certification.

Purpose

The main purpose of this manual is to guide in-house training for staff of the eight shrimp farms stated below. The manual will serve as an easy reference for anyone to follow to orientated staff members of the farms.

Target Group

The target group for the training is the members of the Belize Shrimp Growers Association (BSGA). Eight (8) shrimp farms are participating in the Certification process and will be trained in accordance with this manual. These eight farm are; i. Aquamar, ii. Belize Aquaculture Limited, iii. Bel-Euro, iv. Cardelli, v. Paradise, vi.Royal Mayan, vii. Tropical Aquaculture Investment, and viii. TexMar.

Objectives

At the end of the course, farms will understand the nature and principal concepts of effective waste management by exploring:

1. An introduction to the identification of waste streams associated with shrimp farming,
    - Types and sources of solid and liquid waste
2. Legislated standards within the Environmental Protection (Effluent Limitations) Regulations, revised Edition 2003 and its 2009 amendments.
3. Compliance with Belize National Legislations:
    - Proper handling and disposal of solid waste (solid waste management)
    - Proper handling and disposal of liquid waste (liquid waste management)
    - Proper handling and disposal of animal bi-products
    - Proper handling and disposal of waste not directly related to production
4. Waste water sampling techniques (grab sample and preparation for analysis)
5. Familiarization and basic understanding of field equipment used to analyze waste water
6. The adverse impacts to the environment that is associated with improper handling and disposal of waste.

Duration of Training

The manual has been prepared for a 1-day theoretical and practical training session with each farm. Training sessions will commence at 8 a.m. and will conclude at 4 p.m. with one hour lunch break (12 p.m. -1 p.m.). Trainings will be held at each farm in an area that is well lighted and ventilated and has adequate space to hold the entire staff of the individual farm.

Evaluation

A two pronged approach to course evaluation will be conducted to ensure quality delivery of content that meets certification requirements. Trainee satisfaction will be measured using a questionnaire that will indicate participant's perception if they learned anything, relevance and application of the content, satisfactory on mode of delivery of course, effectiveness of particular strategies recommended, perception on adequacy of supporting information etc. This will allow for an assessment of effectiveness of the program design, participants perception of the program, successful instructional strategies used, caption of information by participants and means of identifying areas of improvement.

The second approach is through "achievement level of learning" which determines what participants learned in the program, the extent of learning, change in attitudes and identifies precisely what was learned versus not. To achieve this, pre and post tests will be carried out for both theoretical and practical components of the training.

Training Procedures

This training manual follows a logical sequence of sessions. Each session will build upon the previous one so that the participants can follow an organize sequence of thoughts. Most of the learning will be accomplished using a participatory approach (active discussions will be encouraged).

The following training methods will be utilized:

Theoretical Component:

i. Power-Point Presentations
ii. Open Discussion
iii. Group Discussions and presentations
iv. Videos

v. Handouts
vi. Question and Answer

Practical Component:

The ponds will not be available for practical field exercises because of current threat of diseases. In class practical exercises will be conducted.

i. Familiarization with field equipment (GPS, YSI (sonde), flow meter, digital camera, etc.)
ii. Waste water sampling methodology (grab sample procedures and storage)

Session Summaries:

Session Introduction: "Prelude to the training including purpose and objectives"

Training Sessions	Activities	Objectives	Durations (time)
Introduction Prelude to the training including purpose and objectives	- Introduction of Trainers and participants - Presentation of the purpose and objectives of the training - Expectations from participants	- To acquaint trainers and trainees - To establish the reason for being at the training - To create an atmosphere for learning	**8am-8:30am** 30 minutes

In order for any group meeting/training to be effective it is imperative that participants of the meeting/training are properly introduced and the purpose and objectives of the session is well understood. Also, order and organization is important so that coherent thoughts can be formed of the topic(s) being presented and discussed. The introduction component of the training will do just that; it will acquaint each participant with each other and also with trainers. Trainers will be able to present their qualifications in regards to being experts that are capable of delivering the material. Also, the time should be used to create an atmosphere that is conducive for learning and exchange of ideas. Individual expectations of the training will be presented and written down so that later an analysis can be done to determine if the group expectation was met.

Session I: "Identification of waste streams associated with shrimp production"

Training Sessions	Activities	Objectives	Durations (time)
Session I Identification of waste streams associated with shrimp production	- Pre-test - Overview of the farm: (Physical environmental within which is operates, layout out plan, production volumes, etc.) - Identify all waste streams (solid and liquid) - Classification of waste - Post-test	- To acquire working knowledge sources of solid and liquid waste - Understand the waste classification system in terms of organic, inorganic, animal bi-products, office waste, and others	**8:30am-9am** 30 minutes

This session will commence with a brief pre-test to ascertain the level of knowledge participants have in the subject matter. Similarly, at the end of the session a brief post-test will be given to assess if the objectives were met and information properly conveyed. The content below will be presented.

The production of shrimp is water intensive; therefore liquid waste, in the form of effluent is the main source of waste being generated (Boyd. et. al, 2007). Apart from effluent, sewage waste, run-off and other hazardous liquid waste are produced such as waste oil, acid from spent batteries, etc.

Waste stream can be defined at the aggregate flow of waste material from generation to treatment to final disposal. The identification of waste streams of each farm will vary a bit due to type of operation (intensive, semi-intensive, etc.), the design of the farm, volumes being produced, and the number of workers.

The three broad classification of waste at shrimp farms are solid, liquid and hazardous waste. The word "waste" within the Environmental Protection Act, 1992 means, "any matter prescribed to be waste, and any matter, whether liquid, solid, gaseous or radioactive, which is discharged, emitted, or deposited in the environment in such a volume, composition or manner as to cause an alteration of the environment."

i. Solid waste: refers to any non-soluble garbage, refuse, sludge, and other discarded materials including yard waste, domestic waste, etc.
ii. Liquid waste: any fluids such as wastewater, fats, oils or grease, used oil, and aqueous hazardous substances.

Example of waste streams at these shrimp farms are:

i. Office waste: paper, plastics, e-waste, printer cartridges, discarded pens, lead pencils, batteries, etc.)
ii. Yard waste: grasses, tree limb, excavated material, construction materials, run-off, etc.
iii. Domestic waste: Grey water, black water, paper, plastics, metals, pharmaceutical waste, detergents and other chemicals, etc.
iv. Effluent: wastewater from ponds
v. Hazardous waste: waste oils, chemicals, lead acid batteries, used tires, etc.

Session II: "Compliance with ASC Shrimp Standards Version 1.0 March 2014 and Environmental Laws of Belize that are related to solid and liquid waste"

Training Sessions	Activities	Objectives	Durations (time)
Session II Compliance with ASC Shrimp Standards Version 1.0 March 2014 and Environmental Laws of Belize that are related to solid and liquid waste	- Pre-test - Review the Environmental Protection (Effluent Limitations) Regulations, 1995 and its amendments of 2009 - Review the Environmental Pollution Regulations of 1995 and its amendment in 2009 - Review of the Environmental Compliance Plan for the farm - Review of the Aquaculture Stewardship Council Shrimp Standard - Post-test	- To educate participant of the legal requirements of the environmental laws of Belize - Understand the legal definition of Effluent, environment, pollution, etc - To be able to understand what needs to be done or accomplish to be in compliance with the environmental laws of Belize - To acquaint participants with conditions of the Environmental Compliance Plan - To acquaint participants with ASC shrimp standards	**9am-9:45am** 45 minutes

This session will commence with a brief pre-test to ascertain the level of knowledge participants have in the subject matter. Similarly, at the end of the session a brief post-test will be given to assess if the objectives were met and information properly conveyed. The content below will be presented.

One of the main purposes of this exercise is to educate the staff of individual farms of the importance and requirement of ASC certification. Therefore the ASC Shrimp Standards version 1.0 of March 2014 will be presented and reviewed. The purpose of the standards is to provide a means to measurably improve environmental and social performance of shrimp aquaculture operations (Aquaculture Stewardship Council, 2014). For example the standard requires:

Principle 1: That shrimp producers comply with all applicable national and local laws and regulations

Principle 2: Those farms are located in environmentally suitable area while conserving biodiversity and important natural ecosystems

Criterion 2.1- That a biodiversity environmental impact assessment is conducted
Criterion 2.2- That protected areas and critical habitats are conserved
Criterion 2.3- Consideration is given to critical habitats and endangered species
Criterion 2.4- That ecological buffers, barriers and corridor are maintained
Criterion 2.5- The prevention of salinization of freshwater and soil resources

Session II will also look at the environmental laws of Belize that pertain to compliance and effluent discharge and other such pollutants.

Each shrimp farm is required by law (Environmental Protection Act, 1992 and its amendment of 2009) to receive environmental clearance before the project commences. The Department of the Environment grants clearance subjects to certain conditions that are contained in an Environmental Compliance Plan (ECP). The ECP is the main document that must be complied with apart from other sections of the environmental laws. The ECP guides the construction phase and operation phase of the farm and also calls for long term monitoring, especially of effluent.

The Effluent Limitations Regulations came into force in 1996, and were intended to control and monitor discharges of effluent into any inland waters or the marine environment of Belize. These Regulations prohibited the discharges of effluent from new and altered point sources. The Effluent Limitations Regulations established a licensing system for discharging effluents under specific conditions. The main objective of this licensing system was to have industries improve in their treatment of effluent before discharging into the environment. The Effluent Limitations Regulations also established the requirement for the treatment of effluent, as well as limitations or standards for physical and chemical parameters to be monitored for various industries.

In August 2009, the Effluent Limitations Regulations were amended to primarily include provisions for the treatment of domestic wastewater and the categorization of Class I and II Waters that differentiate waters with unique ecological characteristics that are sensitive to impacts of domestic wastewater. This amendment also made improvements for effluent standards for both industrial and domestic effluent.

The First Schedule of the 2009 Amended Regulation contains the following parameters and limits:

Shrimp Processing:	
Parameters	**Standards**
BOD	30 mg/L
TSS	30 mg/L
Temp	35^{o} C
pH	6-9 units
NO_3	10.0mg/L
PO_4	1.0 mg/L
SO_4	200 mg/L
COD	200 mg/L

Session III "Proper Solid Waste Management in the Shrimp Industry"

Training Sessions	Activities	Objectives	Durations (time)
Session III Proper Solid Waste Management in the Shrimp Industry	- Pre-test - Development of a solid waste management plan of the farm (Group Activity) - Identification of ways to reduce solid waste generation - 3 R's (reduce, reuse and recycle) - Solid waste treatment options - Post-test	- Develop and appreciation for solid waste management - To develop a preliminary solid waste management plan - To understand techniques for reducing solid waste generation	**10am-10-30am** 30minutes

This session will commence with a brief pre-test to ascertain the level of knowledge participants have in the subject matter. Similarly, at the end of the session a brief post-test will be given to assess if the objectives were met and information properly conveyed. The content below will be presented.

Proper management of waste in shrimp farming is critical for the overall sustainability of the industry. Farms must store and handle fertilizers, liming material, feed, fuels, lubricants, scrap metals/plastic, feeds and agrochemicals at the ponds. Administrative offices store papers, cartridges, plastics, cans, containers, etc… In addition to these, field operations demand use of heavy equipment that requires regular maintenance that must be done safely and in an environmentally responsible manner. The appearance of shrimp farms therefore projects how well organized and responsible they are in the eyes of visitors.

Farms must have procedures for regular and sanitary collection and disposal of all their waste. Containers for collecting garbage and other farm waste should be located in strategic locations throughout the facilities. Garbage separation must be practiced at farm cafeterias as organic waste need to be separated from recyclable waste material. These containers must be emptied on a regular basis while ensuring that they never overflow, becoming an eye soar or even create other nuisances. Preferably, these wastes should be properly disposed of in landfills, but in the absence of one, at approved dumpsite sites identified by the Solid Waste Management Authority (SWMA). If these are not viable options, the DoE and SWMA must be consulted to obtain recommendations on acceptable methods which might include burning, burying or a combination of both.

Sanitary facilities for proper human waste disposal must be constructed and be within acceptable design as authorized by the relevant regulatory agencies. Septic tanks or other effective waste treatment system should be installed using Central Building Authority's standards and must consider soil type in an effort to prevent underground contamination. At no point should human waste be allowed to contaminate ponds or bordering ecosystems.

Waste Minimisation

Waste minimisation has clear environmental benefits. Companies that are careful with the resources will contribute towards sustainable development. By exerting greater control over their operations, they will also reduce their risk of breaching environmental regulations.

Waste minimisation also offers potential cost savings for companies that can reduce energy careful with the resources they use will have less impact on the environment consumption and waste generation. As energy and waste disposal costs continue to rise, companies need to become more efficient in order to absorb these costs. Disposing of waste to landfill is becoming a very expensive option and the aquaculture industry is seeking alternatives to this unsustainable activity. This guide will help your company achieve these potential cost savings and gain a competitive advantage.

Reduce, reuse and recycle – Bags, Office Papers, Packaging Material, Oils, Scrap metals, batteries, chemical containers etc….

Reduce

- Change to bulk delivery from containers - this would lower the waste disposal costs, reduce the volume of bags being used and feed packaging and staff handling time. However, bulk feed delivery would require new or modified infrastructure throughout the supply chain and on the farms. This would require significant investment in many cases and may not be practical at all locations
- Reduce office paper waste by implementing a formal policy to duplex all draft reports and by making training manuals and personnel information available electronically.
- Work with customers to design and implement a packaging return program.
- Switch to reusable transport containers.
- Purchase products locally to reduce transport cost for recycling.

Reuse

- Ideally, bags should be taken back for reused for the same purpose e.g feed, fertilizer, chemical etc.

- Reuse office furniture and supplies, such as interoffice envelopes, file folders, and paper.
- Use durable towels, tablecloths, napkins, dishes, cups, and glasses.
- Use incoming packaging materials for outgoing shipments.
- Encourage employees to reuse office materials rather than purchase new ones.

Recycle

- Club together with others in the area to share loads of used feed bags to make it more economical to recycle (Belize Recyclables Company Ltd).

Pond Sludge Waste

Waste products are being produced continuously during shrimp culture in a mixture of gases, liquids, semi-solid and solid forms. When the concentration of wastes builds up to undesirable levels in pond water some is discharged and ponds are topped up with better quality water to maintain water quality. Some of these waste materials are removed in the discharge; however, some settles out on the pond bottom and becomes semisolid and solid waste.

Shrimp pond waste affects greatly to growth and survival of shrimp and water quality of the pond. Too frequent removal of SPW deposited in the pond bottom, significantly reduces the organic nutrient concentration in water and can result in low levels of phytoplankton and low pond productivity. Accumulation of SPW may lead not only to increases in sediment oxygen demand but also to anaerobic conditions resulting in production of undesirable gasses such as hydrogen sulphide.

The environmental impact of SPW can be divided into three parts: (1) impact on coastal water quality and hydrology, (2) impact on aquatic organisms, and (3) impact on mangrove and terrestrial vegetation.

- **Impact on Coastal Water Quality and Hydrology -** Since SPW contains high level of nutrients, it will cause eutrophication to nearby aquatic environment if discharged without any treatment.
- **Effect on Aquatic Organisms –** High turbidity reduces light penetration into water, which is limiting factor for photosynthesis and may lead to lower dissolved oxygen value in receiving waters, which may stress to aquatic organisms. Long-term exposure to high suspended sediment levels can have an adverse effect on bottom-dwelling organisms as it settles

- **Effect on Mangrove and Terrestrial Vegetation -** Some studies show that SPW has positive impacts on the growth of some species of mangroves, for example a mixture of soil and SPW (up to 75%SPW and 25% soil) increases the growth of *Rhizophora mucronata*, *R.apiculata* and *Bruguiera cylindrica*.

Guidelines for Shrimp Pond Waste Management during culture operation

The following should be observed as a general guideline for SPW management. Although these are mainly for the farm operators and owners to follow it still needs assistance of related government agencies.

- All production farms (regardless of size or production capacity) should have area for disposing waste before planning any production activities.
- Waste disposal area should be adjusted after every crop in line with waste production level, local environmental conditions and government requirements.
- Farms that use 'remain' management approaches should have additional management systems to lower SPW volume and improve quality of SPW while in operation.
- Farms that use 'remove' management approaches should have a proper waste management system before disposing out of farm environment.
- Use of chemicals and drugs to manage SPW should be avoided where possible.

Guidelines for Post-culture SPW management

- Shrimp Pond Waste should not be discharged to outside environment.
- There should be proper and sufficient disposal area for Shrimp pond waste on farm.
- Primary treatment such as sedimentation and sun drying should be performed before the waste is disposed off.
- A certain degree of treatment should be applied to SPW before the disposal based on SPW condition:

  Quality, volume and especially if the pond had received some probiotic and antibiotic treatment or if the pond had disease problems

Session IV "Proper Liquid Waste Management in the Shrimp Industry"

Training Sessions	Activities	Objectives	Durations (time)
Session IV Proper Liquid Waste Management in the Shrimp Industry	- Pre-test - Develop a water quality monitoring programme - Understand the difference between effluent, run-off, class I and Class II waters, etc. - Liquid waste treatment options	- Develop an appreciation for liquid waste management - To develop and preliminary liquid waste management plan - To understand liquid waste treatment options	**10:30am-11:30am** 30 minutes

This session will commence with a brief pre-test to ascertain the level of knowledge participants have in the subject matters in Session IV, V, and VI, since these Session are sequential and related. Similarly, at the end of the Session VI a brief post-test will be given to assess if the objectives were met and information properly conveyed. The content below will be presented.

Shrimp aquaculture practices can produce substantial quantities of nutrient-rich effluent that is highly polluting if released untreated into surface water bodies (Szuster, 2003). Waste produced by shrimp farms include solid matter (primarily eroded pond soils), organics (uneaten shrimp feed, feces, shrimp mortalities, dead plankton) and dissolved metabolites such as ammonia, urea and carbon dioxide. Effluent production and water exchange are modest during the first 60 days of the grow-out cycle because the juvenile shrimp are small and require little supplemental feeding (Szuster, 2003). During the latter half of the culture cycle, however, the adult shrimp require increasingly large feed inputs and daily water exchanges are needed to maintain a suitable growing environment (Szuster, 2003). Uneaten food pellets, feces, and eroded pond soil tend to accumulate at the center of the pond enclosure due to the action of mechanical aerators. This "sludge" is enriched in nitrogen, phosphorus and carbon relative to surrounding sediments and its accumulation is associated with anaerobic decomposition and the release of ammonia, organic sulphur and hydrogen sulfide.

Currently, the regulatory agency allows for liquid waste to be discharged into settlement ponds, a portion is to be recycled and a portion of the settled/treated effluent can be released for bio-filtration through the mangrove wetland (buffer). The settlement pond should have at a minimum, a surface area equivalent to 5% of production ponds (ration of 1:25).

Also, the settlement ponds should be constructed as a series of contiguous canals to facilitate discharge nitrogen uptake and recycling of production ponds. Under strict supervision some treated/settled effluent can be allowed to discharge in the intake canal where it is pumped back in the circulation system.

The preference however is that farms be designed and operated in a close-loop fashion where most of its liquid waste is re-circulated back into the ponds and thus reducing, significantly, the volumes of liquid waste discharged in the mangrove wetland.

An important misconception in water pollution is the fact that many confuse effluent waters from run-off and Class 1 and 2 waters. Effluent is referred to the waste water generated directly from the ponds while run-offs includes not only the waters that travel over the land surface and through channels to reach a stream but also interflow, the water that infiltrates the soil surface and travels by means of gravity toward a stream channel and eventually empties into the channel. Class 1 water is classified as waters that can be used for public drinking while Class 2 are waters used for propagation of fish and wildlife.

The ammonia/nitrate/nitrite and phosphate levels in effluent are of major concerns due to their ability to seriously impact the receiving environment (Boyd, et. al, 2007). These two elements are limiting factors for both aquatic and terrestrial plant and therefore if they are added into an ecosystem in large amount can lead to algal bloom (eutrophication) and later oxygen depletion. Oxygen depletion in a water-body causes mortality of aquatic organism and disruption of the balance of the ecosystem.

In an open water type ecosystem algal bloom can be devastating to the ecosystem but in a shrimp farm the amount of nitrates and phosphates can be controlled to increase or decrease algal growth (shrimp food). The main source of nitrogenous waste in effluent is from feed and fertilizers (Boyd, et. al, 2007). Feeding regime and seeding ponds with fertilizers if controlled correctly can reduce environmental impacts and reduce the overall cost of operation (saving money). Therefore, each farm should scientifically determine the optimum levels of these elements for each pond. This will ensure that the ponds are concentrated with the right amount of these nutrients and that excess is not going into the nearby environment during discharges.

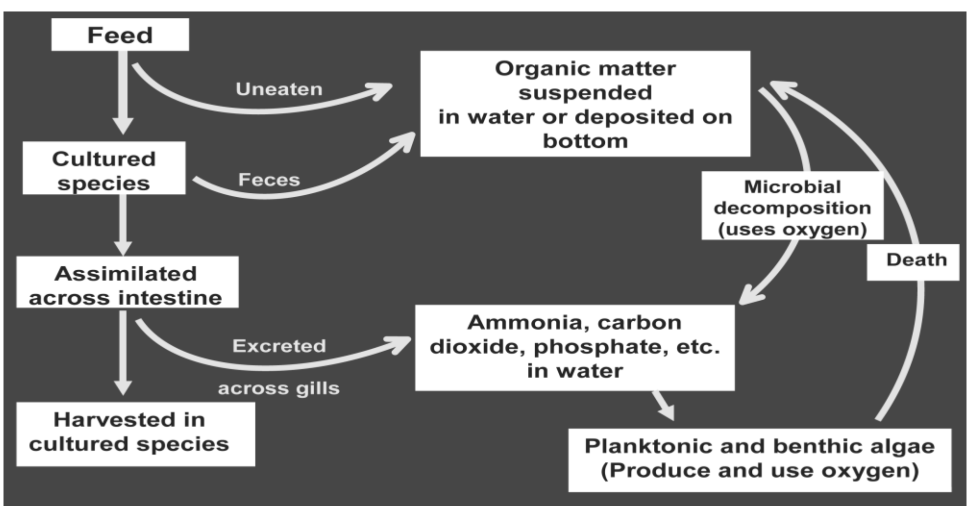

Figure 1: Fate of feed applied to an aquaculture pond

Recommendations for lowering nitrogen and phosphorus levels in effluent

1. Develop a good larval inventory programme
2. Incorporate the use of nursery systems in farms
3. Conduct water and soil samples to determine nutrient content and requirement
4. Develop a plan for gradual compliance of ASC requirement in specified time-frame
5. Experiment with lower protein content as a strategy to reduce nitrogenous waste
6. Assess current feeding program to determine areas that can improve feed efficiency

Session V: "Water Quality Monitoring Parameters"

Training Sessions	Activities	Objectives	Durations (time)
Session V Water Quality Monitoring Parameters	- Present the parameters that are the be monitored according to law - Present the limits of each parameter according the law - Understand the importance of monitoring and analyzing each parameter	- Understand water quality and why certain parameters are monitored and tested - Acquaint participants with the permissible levels of each parameter according to law	**11:30am-12:00pm** 30 minutes

<u>Temperature</u>

Water temperature is important because it may indicate thermal pollution and it influences most physical, chemical, and biological processes. Gas-diffusion rates, chemical-reaction rates, and the settling velocity of particles are just a few of the many processes related to water temperature. In addition, temperature differences between water sources and seasonal variations of temperature make temperature useful in hydrologic investigations (Stednick & Gilbert, 1995).

<u>pH</u>

pH is the negative logarithm of the hydrogen ion (H+) activity in the water. Values may range from pH 1 to pH 14, with pH 7 neutral, less than 7 acidic and greater than 7 basic. Each pH unit represents a tenfold change in H+ activity. pH is important in the toxicity and solubility of many constituents.

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewater, effluents, and polluted waters.

A measured sample of wastewater is placed in one of the bottles on the Hach BOD apparatus. The bottle is connected to a closed end mercury manometer. In the airspace above the wastewater sample is a quantity of air which contains 21% oxygen (atmospheric). Over a period of time, bacteria in the wastewater utilize oxygen to oxidize organic matter present in the sample, consuming dissolved oxygen from the sample. The air in the closed sample bottle replenishes the utilized oxygen resulting in a decrease in pressure in the airspace in the sample bottle. This pressure decrease is measured on the mercury manometer and is measured directly as mg/L BOD. During the test period (typically 5 days), the sample is continuously agitated by a magnetic stirring bar driven by the magnetic platform of the BOD apparatus. Carbon dioxide is produced by the oxidation of organic matter and must be removed from the system so that the pressure difference observed is proportional to the amount of oxygen consumed. This is accomplished by the addition of potassium hydroxide solution to each sample bottle. (Stednick & Gilbert, 1995).

Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a water sample that is susceptible to oxidation by a strong chemical oxidant. COD can be related empirically to BOD, organic carbon or organic matter.

Nitrogen, ammonia dissolved

Dissolved ammonia is the reduced form of nitrogen in solution. Ammonia is a highly soluble, colorless, gaseous compound and can exist as NH_3 or NH_4+ (ammonium ion) depending on solution temperature and pH. Ammonia and related oxidized nitrogen compounds are a major limiting nutrient in most aquatic systems an increase of which may result in eutrophication. Typically indicative of agricultural pollution or anaerobic degradation of nitrogen containing compounds.

Session VI: “Water Sampling Procedures and Techniques (take sample and preparation for analysis)”

Training Sessions	Activities	Objectives	Durations (time)
Session VI Water Sampling Procedures and Techniques (take sample and preparation for analysis)	- Present on the effluent sampling techniques (insitu and laboratory testing) - Present on the sample preparation requirement and packaging procedures - List of Laboratories in Belize that does waste water analysis - Post-test	- Participants will acquire a working knowledge of sampling techniques including in situ and grab samples - Participant will understand how the water quality data can assist the farm and is submitted to the government department so as to be in compliance - Participants will know where to take samples	**1:00pm-1:30pm** 30 minutes

It is imperative that water quality sampling techniques are done according to already established techniques and procedures. The results can be influenced by negligent collection techniques and procedures and mislead decision makers. Water quality data when analyzed into information, can greatly assist farm both from an environmental and financial standpoint.

It is recommended that water quality monitoring program be developed and implemented. This program will include at minimum 5 sampling points:

1. Control point (water intake from sea)

2. Intake to the ponds
3. Entrance of settlement pond
4. Settlement pond discharge point
5. Within the mangrove area

The following are some parameters and how they are sampled and tested. These sampling procedures and techniques are taken from the Environmental Water Quality Monitoring Program written by Stednick, D, J. 1995.

Temperature

Container:	In-situ determination
Volume Required:	Not applicable
Preservation:	Not applicable
Holding Time:	Not applicable

Field Procedure:

Water temperature is important because it may indicate thermal pollution and it influences most physical, chemical, and biological processes. Gas-diffusion rates, chemical-reaction rates, and the settling velocity of particles are just a few of the many processes related to water temperature. In addition, temperature differences between water sources and seasonal variations of temperature make temperature useful in hydrologic investigations, particularly those that involve the mixing of groundwater and surface water.

For economy and ease of use, the liquid-in-glass thermometer is recommended for field use. A pocket-sized thermometer protected by a plastic or metal case is recommended. Mercury filled thermometers should be avoided since breakage may occur in the stream and the spilled mercury may be toxic. To eliminate the problem of column separation, it is best to use a thermometer with gas-filled capillary.

Most thermometers shipped from the manufacturer are not highly accurate. Before each new thermometer is issued for field use, it should be checked for accuracy. This is done by comparing the field thermometer to a precise instrument such as an ASTM calibration thermometer at three points. The comparison is usually made in a water bath to eliminate erratic readings. Any thermometer found to be off by more than 0.5^{o}C should be rejected.

Temperature measurements should be made directly in the stream if possible. The following steps should be taken when making temperature measurements:

1. Check thermometer for liquid-column separation
2. Immerse bulb into source.
3. Allow the reading to stabilize.
4. Read temperature with bulb immersed (removing the bulb from water can result in an erroneous temperature reading due to rapid thermometer response to changing conditions).
5. If temperature cannot be measured in the source, collect (at a minimum) an 8-ounce (500 mL) bottle or beaker of water and measure the temperature immediately. Shield the sample from the sun and wind while measuring.
6. Return thermometer to protective case

Note: Temperature of the sample is required for accurate calibration of the instrumentation for dissolved oxygen, pH and conductivity. Temperatures should be recorded with results of these analyses. Air temperatures can be collected on-site, and provide useful information for site characterization as well. (Stednick & Gilbert, 1995).

Analytical Method: ASTM E1-58: Standard Specifications for ASTM Thermometers
APHA 2550: Temperature
STORET No: 00010
EPA Method: not available

pH

Container: Field determination (Polyethylene or teflon beaker)

Preservation: Refrigeration to 4oC

Holding Time: 6 hours

Field Procedure:

Because the pH of some samples can change in a short time, it should be measured in the field with a reliable instrument or field test kit. Two different methods may be used to determine the pH of water.

Colorimetric Measurement: A wide variety of chemical reagents that display color changes over broad or narrow ranges of pH changes are used as indicators to show the approximate pH of the solution. Litmus type papers can be used to screen waters that may be extremely acidic or basic. Field kits can be used to estimate the pH of colorless, nonturbid, well-buffered water solutions, provided the reagents are fresh. Field data obtained with colorimetric kits can be used to screen waters and select appropriate buffers. Colorimetric measurements should be supported with a reliable pH meter or verified by laboratory analysis.

Electrometric: The pH meter used in conjunction with a glass electrode and reference electrode (or a combination glass plus reference electrode) develops a voltage potential in response to the hydrogen-ion activity without interference from most other ions. This method of measurement has become the standard for accurately determining pH in the field and laboratory.

It is important that maintenance and calibration be provided for all pH meters. If the pH meter is properly maintained and calibrated, field values may be more valid than lab values due to changes in pH with time and temperature fluctuation.

Calibration:

Calibrate meter and electrode according to manufacturer's instructions using two buffer solutions (for example 4 and 7, or 7 and 10). Use last the buffer having a pH nearest that anticipated for the sample. To avoid contamination of buffers, calibration and meter checks should be conducted in buffer solution in separate containers, such as small disposable paper cups. Buffer solutions should be discarded after use.

1. Check battery
2. Expose electrode solution to atmosphere by uncovering filling port during measurements
3. Place function switch on "standby" or "ready"
4. Measure temperature of buffers
5. Set temperature compensator to temperature of buffers
6. Rinse electrode with deionized or distilled water thoroughly before placing it in a different buffer or into the sample
7. If the approximate pH of sample is known (based on field- kit or multi-range pH paper results), place electrode in a buffer solution having pH near that anticipated for the sample. Turn function switch to "measure." Adjust meter to read pH of buffer by turning "standardize" knob
8. Repeat this procedure using another buffer to closely "bracket" the anticipated pH of the sample, this time adjusting the meter reading with the "slope" knob (or equivalent) until the meter reads the pH of this second buffer
9. If the pH range of the sample is not known, place electrode in pH 7 buffer. Turn function switch to “measure." Adjust meter to read pH 7 by turning "standardize" knob. Then, place electrode in the sample to determine an "anticipated" or "approximate" pH value for that sample
10. Complete calibration by “bracketing” the approximate pH value of the sample
11. When only occasional pH measurements are made, calibrate the instrument before each measurement. When frequent measurements are made, the meter calibration should be checked at least twice a day. If the meter is drifting appreciably it will need to be recalibrated more frequently - or it may need new electrodes. In all cases where readings indicate a violation, it is advisable to calibrate the instrument and double-check readings.

If in-situ measurement is not possible, a water sample should be collected and analyzed immediately for pH. This sample is then discarded.

12. Measurement of Sample pH
13. Place electrode into sample
14. Measure temperature
15. Set temperature compensator to temperature of sample
16. Turn function switch to "measure" or equivalent
17. Allow meter readout to stabilize (this may take several minutes if the solution is poorly buffered)
18. Record pH to nearest 0.1 pH unit
19. Rinse electrode with deionized water
20. Cover electrode with protective cap of deionized water or pH 7 buffer
21. If the pH reading does not stabilize, record reading after 2 minutes.

Precautions

1. Never remove electrode from buffer or sample unless meter is in "standby" or "off" position. To do so may polarize the electrodes, permanently damaging them and resulting in unstable meter readings
2. Dirty connectors on pH electrodes may result in erroneous readings; do not handle the plug; if it is dirty, clean it with ethanol or isopropyl alcohol
3. Static electricity on meter face may be reduced by an antistatic cloth such as those used on phonograph records. If problem continues, check for broken or loose cable- shield wire
4. Keep electrode filled with the recommended solution to within 1/2 inch of filling opening. Do not substitute a filling solution of different chemical composition made for another electrode. Keep the fill hole closed when the electrode is not in use to prevent evaporation of the filling solution
5. Keep electrode tip moist by filling the provided rubber cap with either pH 7 buffer solution or deionized water. If the tip dries out, soak it in pH 7 buffer solution for 24 hours
6. Never immerse the electrode to such a depth that the surface of the filling solution is below that of the test solution
7. The temperature compensator on most meters must be set for the temperature of the sample that is being measured; however, on several brands of inexpensive meters the "temperature" compensation knob is also used as a "slope" knob to calibrate the meter to the second buffer. When these meters are used the buffers must be at the same temperature as the water being sampled. This can be accomplished by immersing the container of buffer in the stream being sampled until the temperatures are similar
8. Do not let the electrodes freeze
9. Avoid contamination of buffer. Use a separate container (cup) and discard it after use

10. Broken or scratched electrodes can give erroneous readings
11. Do not leave meter exposed to extreme weather conditions.

Note: Change in temperature will affect the ionic equilibrium of the solution resulting in an alteration of the pH measurement. Effort should be made to calibrate the instrument using buffer solutions within 5o C of the sample. The pH meter should include temperature compensation mechanism to minimize temperature effects on the electrode. Calibrate instrument at a maximum every 3 hours of use. (Stednick & Gilbert, 1995).

Analytical Method: ASTM D1293-84: Standard Test Methods for pH of Water
APHA 4500-H+: pH Value
STORET No: 00400
EPA Method: 150.1

Electrometric - glass electrode in combination with reference potential (typical: saturated calomel) electrode. pH measurement of waters of low conductivities: ASTM D5128-90.

Biochemical Oxygen Demand (BOD)

Container: Amber glass

Volume Required: 50 mL (or more depending on BOD)

Preservation: Refrigerate to 4oC or colder

Holding Time: No more than 6 hours preferred, not to exceed 24 hours

Lab Procedure: Manometric (from Hach, 1993)

A measured sample of wastewater is placed in one of the bottles on the Hach BOD apparatus. The bottle is connected to a closed end mercury manometer. In the airspace above the wastewater sample is a quantity of air which contains 21% oxygen (atmospheric). Over a period of time, bacteria in the wastewater utilize oxygen to oxidize organic matter present in the sample, consuming dissolved oxygen from the sample. The air in the closed sample bottle replenishes the utilized oxygen resulting in a decrease in pressure in the airspace in the sample bottle. This pressure decrease is measured on the mercury manometer and is measured directly as mg/L BOD. During the test period (typically 5 days), the sample is continuously agitated by a magnetic stirring bar driven by the magnetic platform of the BOD apparatus. Carbon dioxide is produced by the oxidation of organic matter and must be removed from the system so that the pressure difference observed is proportional to the amount of oxygen consumed. This is accomplished by the addition of potassium hydroxide solution to each sample bottle.

Initial Setup:

Installing Seal Cups

1. Remove the sample bottle caps and insert a seal cup in the neck of each of the bottles
2. Filling Manometers with Mercury

Caution: Mercury is poisonous and should be handled with extreme care. If spilled, clean and dispose of waste according to MSDS instructions.

3. Remove the screw cap from each manometer body and carefully pour the contents of one mercury bottle furnished with the BOD apparatus. After all 5 manometers contain mercury; add 10 to 20 drops of water to each. This ensures adequate water vapor pressure in the space above the mercury during a test run. Before manometer caps are replaced, lightly grease each manometer O-ring with lubri-seal grease (or equivalent). Check the water level above the mercury in the reservoir and add as necessary.

General Procedure:

1. Accurately measure the desired sample volume (typically 157 mL for direct scale reading) into the amber glass liter bottle. The sample should be temperature adjusted to within 2-3oC of the incubation temperature before measuring (typically 20oC);
2. place a 4 cm (1.5 inch) magnetic stirring bar in each bottle;
3. Remove the sample bottle caps and place 2 drops of 45% potassium hydroxide solution into each of the seal cups. Do not allow any of the solution to leak into the sample. If leakage of potassium hydroxide to the sample occurs, discard sample, clean the contaminated glassware and prepare a fresh sample;
4. Place the bottles on the BOD apparatus base and start the stirring bar by connecting the electrical plug. Check to ensure that all stir bars are functioning. Check bottles and pulley if stirrer bars are not functioning. With the manometer caps open, screw the sample bottle caps loosely in place (do not tighten). After approximately 30 minutes (approximate thermal equilibrium), tighten both sample bottle and manometer caps. If the sample is not at thermal equilibrium, an extremely rapid initial negative reading will result. This indicates that the sample is too cold and is releasing oxygen. If this occurs, loosen both the sample bottle and the manometer cap briefly and reclose. Proceed to step 5 immediately;
5. Loosen the set screws on the manometer scale and set the zero mark adjacent to the top of the mercury column. If the scale cannot be zeroed, loosen the bottle cap and manometer cap briefly, then tighten and reset the scale. Record the time and composition of each sample bottle. Manometer readings can be periodically recorded and plotted (mg/L BOD vs. time). An approximation of final BOD can be determined from this plot.

Cleaning the apparatus:

Cleaning the apparatus after each operation is essential for accurate BOD determination. The following procedure is recommended:

Sample Bottles

After each test, rinse the sample bottles with hot water. Clean thoroughly with a laboratory detergent and triple rinse with deionized water (Note: detergents can produce a BOD, thorough rinse is necessary). Air dry. Cap if stored.

Stirring magnets

Clean using same procedure as sample bottles.

Seal Cups

Clean thoroughly with a laboratory detergent and triple rinse with deionized water. Air dry.

Results:

A 5-day, 20^{o}C BOD test, if carried out as described above, should provide the following information:

1. The daily BOD reading should be higher for each successive day of the test;
2. The difference in readings between each successive day's readings should be decreasing, at least for the first 5 days.

Standard Samples:

Although the Hach BOD apparatus has been shown to produce results equivalent to the dilution method, the occasional analysis of a standard BOD sample will provide quality assurance in both apparatus operation and procedure. A procedure for the standard BOD sample follows:

1. Prepare a solution of deionized water containing the nutrient solution indicated on pg 489-490 Standard Methods for the Examination of Water and Wastewater.
2. Using the solution prepared in step 1, prepare a solution containing 150 mg/L glucose and 159 mg/L glutamic acid. This solution must be freshly prepared as it will deteriorate upon standing.
3. Seed a selected volume of solution from step 2 with 10% by volume of the seed (e.g. 180 mL plus 20 mL of seed), Mix thoroughly.
4. Use 157 mL of the seeded standard for the test run following the general procedure for the BOD test.
5. Perform a BOD test on the seed (full strength) used at the same time as the sample.
6. Correct the BOD result obtained
7. the corrected BOD of the standard solution should be 220±11 mg/L

Analytical Method: ASTM: not available
APHA: 5210B Biochemical Oxygen Demand
STORET No.: not available
EPA Method: not available

Chemical Oxygen Demand (COD)

Container: Amber glass

Volume Required: sufficient volume

Preservation: Acidify to pH<2 with H_2SO_4

Holding Time: 24 hours

Lab Procedure: Open reflux or closed reflux method - Refer to Standard Methods for the Examination of Water and Wastewater.

Analytical Method: ASTM: not available
APHA: 5220B, 5220C Chemical Oxygen Demand
STORET No.: not available
EPA Method: not available

Nitrogen, ammonia dissolved

Container: HDPE

Volume Required: 400 mL

Preservation: pH<2 with H2SO4, Refrigerate to 4oC

Holding Time: 28 days

Lab Procedure:

Concentration of ammonia in water is typically determined using either the phenate method for low ammonia concentrations (0.1 - 0.5 mg/L NH_4 - N) or the Nessler Method for higher ammonia concentrations (0.2 - 5.0 mg/L NH_4 - N). The phenate method involves the catalyzed reduction of hypochlorite and phenol and comparison of the color to a standard curve. The Nessler Method also involves colorimetric analysis but consists of simple addition of "Nessler's reagent" to the sample.

Phenate Method:

1. Set spectrophotometer to 630 nm;
2. Pour 20 mL of sample into a 100 mL beaker, place on magnetic stirrer and initiate stirring;
3. Add 1 mL (approximately 2 drops) of MnSO4 solution (dissolve 50 mg $MnSO_4$ in 100 mL analytical grade water);
4. Add 1 mL hypochlorous acid solution (see Standard Methods for solution preparation);
5. Add 1.2 mL phenate reagent immediately, drop by drop;
6. Wait 10 - 15 minutes for color change. Interference from alkalinity, acidity, color and turbidity may result in erroneous spectrophotometer determination. If necessary, the sample can be distilled prior to analysis to minimize interference;
7. Place sample in spectrophotometer and record transmittance and compare to deionized water;
8. Compare with standard curve to determine mg/L ammonia.

Nessler Method:

1. Set spectrophotometer to 425 nm;
2. Pour 25 mL sample into a 50 mL Erlenmeyer flask;
3. Pour 25 mL analytical grade water into a separate 50 mL Erlenmeyer flask for use in spectrophotometer calibration;
4. Add 1 mL Nessler's reagent (see Standard Methods for preparation procedure) to flasks, stopper and mix thoroughly by inverting the flasks several times. If water is of high hardness, interference may result in erroneous measurements. If necessary, add approximately 1 mL (one drop) of Rochelles salt reagent to both flasks prior to addition of Nessler's reagent to minimize interference;
5. Let sample stand for a minimum of 10 minutes for color change to occur (the sample should not be allowed to stand for greater than 25 minutes prior to reading);
6. Calibrate the spectrophotometer using the blank prepared as indicated above;
7. Place an aliquot of the sample into the spectrophotometer and record the result;
8. Compare percent transmittance to the standard curve and record mg/L ammonia nitrogen.

Analytical Method: ASTM: D 1426-89 Standard Test Methods for Ammonia Nitrogen in Water

APHA: 4500 NH3 C. Nessler
STORET No.: 00610
EPA Method: 350

Session VII: "Negative environmental impacts associated with improper waste management at shrimp farms."

Training Sessions	Activities	Objectives	Durations (time)
Session VII Negative environmental impacts associated with improper waste management at shrimp farms.	- Pre-test - The adverse environmental impacts of improperly management shrimp farm will be presented - Post-test	- Participants will understand why it is important the take waste management seriously - They will understand the negative impacts of shrimp farming	**1:30pm-2:00pm** 30 minutes

This session will commence with a brief pre-test to ascertain the level of knowledge participants have in the subject matter. Similarly, at the end of the session a brief post-test will be given to assess if the objectives were met and information properly conveyed. The content below will be presented.

Most of shrimp production is carried out in ponds. The most common shrimp aquaculture systems use inland ponds that are near or on the coast. Water is discharged from these shrimp ponds to coastal ecosystem as part of the water exchange when ponds are drained. The main components in the shrimp farm effluents are organic matter mainly in particulate form from different sources, as well as nitrogen and phosphorus in both organic and inorganic forms, and suspended solids.

Production systems in the culture of marine shrimp, semi-intensive or intensive, lead to significant increases in the levels of nutrients, phytoplankton biomass, organic matter, and suspended solids in the environment receiving the farm's effluents. Some reports indicate that water quality shows short term increases in parameters of water bodies receiving shrimp discharge waters, but other studies otherwise. The impact of pond effluents on adjacent ecosystems is variable and depends on various factors, including the magnitude of the discharge, the chemical composition of the pond effluents, and the specific characteristics of the environment that receives the discharge, such as circulation and dilution rates.

The characterization of the shrimp farm's effluents in terms of water quality is very important to gauge the environmental health of an ecosystem in order to achieve a better regulation of the industry. Further, the continuous monitoring of the physical, chemical, and biological parameters of pond, effluent, and inlet waters helps not only to predict and control negative conditions for shrimp farming but also avoids environmental damages and collapse of the production process.

Effluent and waste management is therefore critical if we are to minimize the impacts on farms adjacent ecosystems. Three major resources that are impacted poor waste management include water, forest and fishery resources.

a. **Impact on water resource**

The load of effluent exiting from the shrimp farms normally exceeds the carrying capacity of the receiving water bodies. Nutrients in effluent promote the eutrophication to produce plankton in adjacent estuary or near-shore ecosystems along with sedimentation. However, nutrients from the effluent and plankton serve as the potential food source for many species of coastal fish and invertebrates.

b. **Impact on forest resource**

Indiscriminate and extensive clearance of mangrove forest may cause significant environmental, economic and social impacts. Naturally, mangroves and mud play an important role in regulation of the nutrient balance in the coastal environment. Mangrove absorbs excess nutrients and other pollutants from entering in to the seawater while facilitating the export of the large amounts of organic matter in the form of detritus by tidal current to support the productivity of the adjacent coastal ecosystem. Thus, if there are any remaining mangroves in the vicinity of the shrimp farm, it will act as a “natural sewage treatment plant” by absorbing excess nutrients originating from effluent. Destruction of mangrove forest impedes the natural process of nutrient supply, carbon fixation and oxygen release. Through the process of decomposition of its bio-mass, mangrove forest improves the soil quality by supplying adequate soil organic matter, nutrients and aeration.

Carbon fixation is a process that transforms the low-energy carbon dioxide in to high-energy compounds. Mangrove forest also releases oxygen in the process of carbon fixation. The ratio of oxygen and carbon fixation release is reported to be 1:1.3.

Mangroves also play an important role in protection of coastlines from storms and tides. Destruction of mangroves may cause coastal erosion, changing the patterns of sedimentation and shoreline configuration. As a part of natural resources, mangrove also provides livelihood of coastal communities with fishery products, timber, fuel and thatching material.

c. **Impact on fishery resource**

Destruction of mangrove forest due to shrimp farming causes adverse impact in fishery production. Mangrove forest provides a habitat for breeding and nursing of some marine fishes, oysters and crabs which eventually gives the livelihood for fisherman. The detritus in these mangrove forest areas also supplies valuable organic nutrients to the waters, which serve as a rich food source for many coastal and offshore species. However, mangrove ecosystem varies from submerged inter-tidal zone to semi- terresrial wetland with considerable variations in salinity, tidal regime, and subsurface conditions and water quality. Thus, the role of mangrove forest in fishery production is limited to sub-tidal and inter-tidal zones where good quality water and abundant food staff exists.

Summary of Potential Impact of Shrimp Pond Effluent to water resources:

- Eutrophication (nutrient enrichment) causing algal blooms
- Increase of organic matter loading resulting in greater oxygen demand
- More sedimentation
- Toxicity following discharge of hypolimnetic waters
- Contamination with pathogenic bacteria
- Ultimate effect will result in an overall degradation of the ecosystem and loss of biodiversity

Extent of impact depends on following factors:

- Type of water exchange and frequency
- Intensity of culture system (density & feeding)
- Characteristics of water bodies that will receive effluents
  - Water circulation (closed or open system)
  - Existing water quality

Use Good Management Practices (GMPs)

- Limits on stocking and feeding rates
- Reduction of N and P in feeds without impairing feed quality
- Use conservative feeding practices to reduce wasted feed
- Minimize water exchange
- Reuse water
- Restrict use of certain chemicals in ponds
- Minimize erosion through good pond construction and aerator placement
- Discharge effluents through sedimentation basins (25%)
- Treat pond bottoms
- Prohibit discharge of brackish water into fresh water bodies

Session VIII: “Practical Session”

Training Sessions	Activities	Objectives	Durations (time)
Session VIII Practical Session	- Practical exercise will be conducted such as YSI and flow meter use, sampling and packaging procedures , etc	- Familiarization with field equipments (GPS, YSI (sonde), flow meter, digital camera, etc) - Waste water sampling methodology (grab sample procedures and storage)	2:00pm-4:00pm 2 hours

Due to concerns of disease currently within the industry, practical sessions will be conducted in the pond area. Instead the practical session will be conducted in the same room where the training is done.

This session will be conducted to acquaint participants with equipments that are used for water quality analysis (YSI, GPS, Sample bottles). Also, a simple demonstration of grab sample will be done by each participant to familiarize them with the procedures and techniques that they have learnt.

Conclusion

The shrimp industry in Belize has grown considerable from its humble beginnings in the early 1980’s. Because the aquaculture industry could seriously impact the environment if it is not operated in an environmentally sound manner, it is important that all players in the industry are knowledgeable of potential adverse impacts and of ways to reduce such impacts.

It is envisioned that this manual will greatly assist the farms in terms of increase in-house capacity to handle and manage waste in a more environmentally sound way. The main purpose of this manual is to guide in-house training for staff of the eight shrimp farms stated below. Also, it should improve the position of each farm and bring them closer to ASC Certification. By following the national and ASC standards, each farm will be in compliance and therefore maintain its certification status. This will greatly increase the global competitiveness of the industry as a whole.

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