HATCHERY

Maturation

GLOBAL AQUACULTURE ALLIANCE

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Principles

A significant global trend in shrimp production is a shift from the use of wild spawners to domesticated, high-health, genetically improved stocks. This trend, while more prevalent in the Western Hemisphere, is becoming a driving force in the approaches to and management of maturation systems worldwide.

The use of wild broodstock is risky because they can be carriers of pathogens, and farmers who routinely use wild broodstock as spawners are unable to benefit from genetic improvement. As the economic benefits of biosecurity and genetic improvement become more compelling, it is likely the global shrimp-farming industry will invest in selective-breeding programs that rely on high-health or specific pathogen-free (SPF) stocks. This paradigm shift will require improved methods for captive reproduction that include innovative maturation technologies.

Survey

In the context of this survey, maturation was defined as the processes and techniques used to maintain and condition broodstock in order to stimulate gonadal development and spawning, and assess spawning performance.

Forty-eight respondents answered the maturation-related questions. Thirty-four of the respondents were from countries in the Western Hemisphere (West), and 14 were from the Eastern Hemisphere (East).

Once raised almost exclusively in the Western Hemisphere, L. vannamei *are increasingly cultured in the East. Note the attached spermatophore on this mature shrimp. Such open-thelycum species mate immediately before spawning.*

CULTURE SPECIES

There was a clear difference between the two hemispheres with regard to the dominant penaeid shrimp species cultured (Figure 1). About 95% of the Western respondents (representing Belize, Brazil, Colombia, Dominican Republic, Ecuador, Honduras, Mexico, Panama, United States, and Venezuela) said they raised Pacific white shrimp, *Litopenaeus vannamei*. In the East (India, Madagascar, Saudi Arabia, and Australia), 86% of the respondents grew black tiger prawns, *Penaeus monodon*.

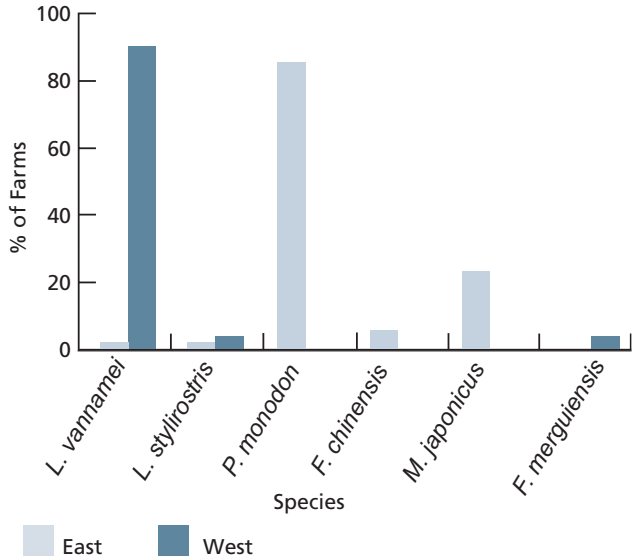


Figure 1. Species grown in the Eastern and Western Hemispheres.

Taiwan was the only Eastern country represented in the survey that cultured *L. vannamei*. However, since the survey was conducted in 2001, *L. vannamei* have been widely introduced in China, Thailand, Vietnam, and other shrimp-producing countries in the East.

Some respondents also grew other penaeid species, including *L. stylirostris* (three respondents), *Fenneropenaeus merguiensis* (three), *F. chinensis* (two), and *Marsupenaeus japonicus* (one respondent).

Black tiger shrimp, P. monodon, *are a closed-thelycum species in which mating occurs immediately after molting of the female. The spermatophore is inserted into the thelycum, where the sperm remain viable for days or weeks in advance of spawning.*

BROODSTOCK

The benefits of using domesticated broodstock were more recognized in the West than the East (Figure 2). The dominance of domesticated broodstock in the West, principally *L. vannamei*, developed over the past decade in response to disease management needs and the recognition of potential efficiencies from genetic improvement. The emergence of genetically improved, SPF stocks provided greater control over production, greater efficiency, and higher predictability of both stocking and harvest outcomes.

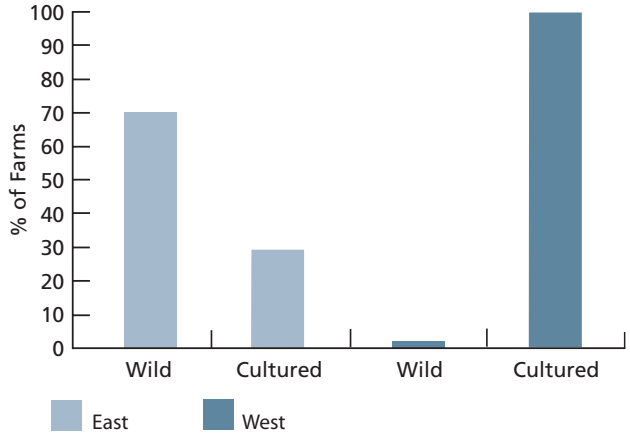
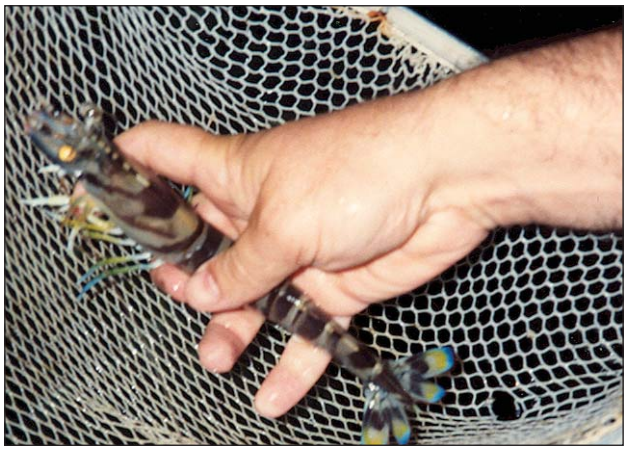


Figure 2. Sources of shrimp broodstock in East and West.

P. monodon raised in the East have been less amenable to domestication, hence the common use of wild broodstock in the region. A critical issue for the sustainability of *P. monodon* production there is the development of domesticated broodstock with reliable and predictable reproductive performance.

Several research efforts currently are directed toward this challenge, with some success seen on the research scale. There is a reasonable expectation that the development of domesticated lines on an industrial scale will take place in the next few years.

Domesticated *M. japonicus* and *F. merguiensis* stocks make up only 29% of the broodstock used in the East. There is an urgent need to develop genetic improvement programs and SPF stocks for all cultured penaeid shrimp species.



P. japonicus *is a closed-thelycum species.*

MATURATION FACILITIES

A significant trend in the survey was the increasing level of technology and industrialization of maturation facilities. Maturation facilities typically are in the second or third generation of development, resulting in highly specialized facilities capable of the consistent production and maturation of large numbers of broodstock. Strict environmental controls, rigorous biosecurity approaches, and automated monitoring systems are important features of several state-of-the-art facilities

Over 40% of the Eastern maturation facilities had between five and 20 maturation tanks, whereas facilities in the West tended to be larger. A significant number of facilities in the West had over 20 maturation tanks (Figure 3).

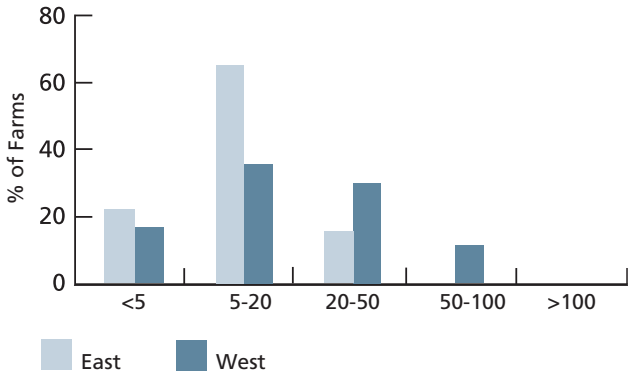


Figure 3. Numbers of maturation tanks used in maturation facilities.

Concrete maturation tanks were most common in the East (64% of respondents), followed by fiberglass (30%), and plastic-lined tanks (7%). In contrast, 66% of Western respondents used plastic-lined tanks, followed by fiberglass (15%), and concrete (15%) tanks.

The configuration of maturation tanks varied substantially between the East and West (Figure 4). Round tanks were most common in the West (81% of respondents), whereas 62% of the Eastern respondents used round tanks along with square and rectangular tanks. Maturation tank volume typically was 5 to 20 cubic meters (72% in the East, 78% in the West).

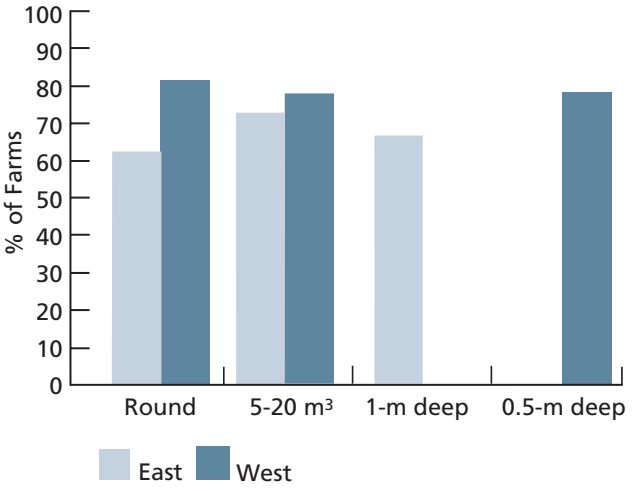
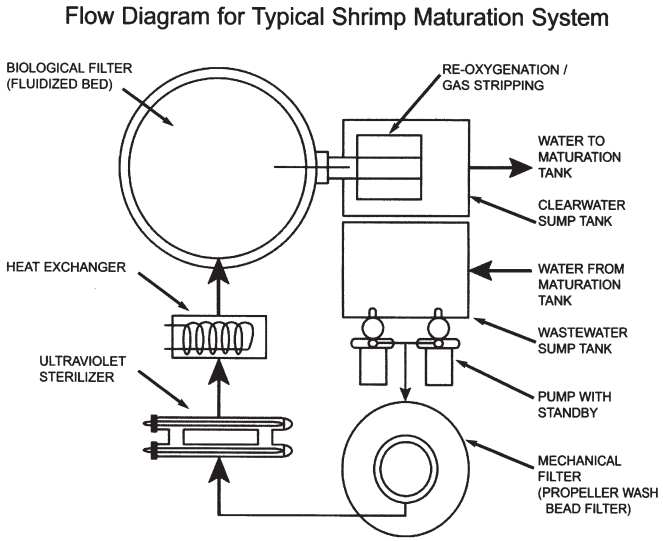


Figure 4. Common configurations of maturation tanks in the Eastern and Western Hemispheres.

A major contrast between hemispheres was tank depth, where 67% of Eastern respondents used tanks about 1 meter deep, and 78% of Western respondents used tanks of 0.5 meter depth or less. This was likely a consequence of the different shrimp species cultured.



Schematic diagram of a recirculating system for maturation. Diagram courtesy of Aquaneering.

Maturation tanks are typically round in shape and black in color.

TANK MANAGEMENT

As management practices of maturation facilities evolve, the strategy of flow-through water exchange is progressively giving way to recirculating or partially recirculating systems, particularly in the West. Recirculating systems provide advantages for biosecurity, water quality control, and potential savings in heating and pumping costs.

At the time of this survey, only 18% of the Eastern respondents used recirculating systems, in contrast to 54% of the Western respondents. For respondents who recirculated water, the most common types of biofilters were fluidized-bed filters (33%) and pressurized-sand filters (33%). Filtration of incoming water was common in both the East and West, with pressurized-sand filters (22%) and cartridge filters (19%) the most common filter types.

Fluidized-bed biofilter installed in a shrimp maturation system. Photo courtesy of Aquaneering.

Daily water exchange rates were lower in the West, possibly due to the more frequent use of recirculating systems. Water exchange rates typically ranged from 50 to 150% per day (52% of respondents), although 20% used higher exchanges of 150 to 200% per day.

The use of substrates in maturation tanks is a relatively recent innovation applied principally in the East, where *P. monodon* is the dominant species. The benefits of substrates are more aligned with the natural behavior of the species than with *L. vannamei*.

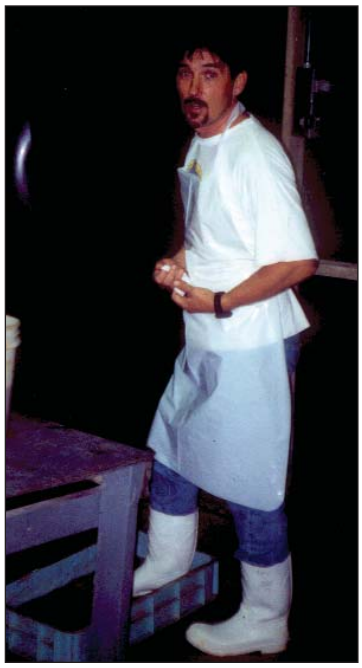
The potential benefits of sand or gravel substrates in maturation tanks include stress reduction by providing shelter and allowing natural burying behavior, improved water quality, and improved reproductive performance of broodstock. However, only 17% of the Eastern respondents claimed to use substrates. Only 3% of Western respondents used them.

Sand substrates are not required for the captive maturation of L. vannamei.

BIOSECURITY

Over the past decade, attention to biosecurity issues in maturation facilities has become critical to the successful management and performance of stocks. In response to outbreaks of virulent shrimp pathogens throughout the major shrimp-farming regions of the world, the industry developed SPF stocks.

The concomitant need to monitor and preserve SPF status in broodstock facilities is the first step for disease management in the overall production environment. Viral-screening protocols, quarantine protocols, disinfection of incoming water, feed irradiation, worker sanitation protocols, and the use of saline groundwater are additional components in the improvement of biosecurity in maturation facilities.



Sanitation procedures like apron use and foot baths are important for health management in maturation facilities. Photo courtesy of Harlingen Shrimp Farms.

Viral screening of stocks for White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), and Yellow Head Virus is prevalent in the West, whereas WSSV, TSV, IHHNV, Monodon Baculovirus, and Gill-Associated Virus are commonly checked in the East (Figure 5). Only 7% of Western respondents and 11% of Eastern respondents did not screen broodstock and/or larvae for viruses.

It is common for maturation facilities and hatcheries to have on-site polymerase chain reaction laboratories for viral screening. Continued attention to biosecurity issues will likely remain critical for the successful operation of maturation facilities.

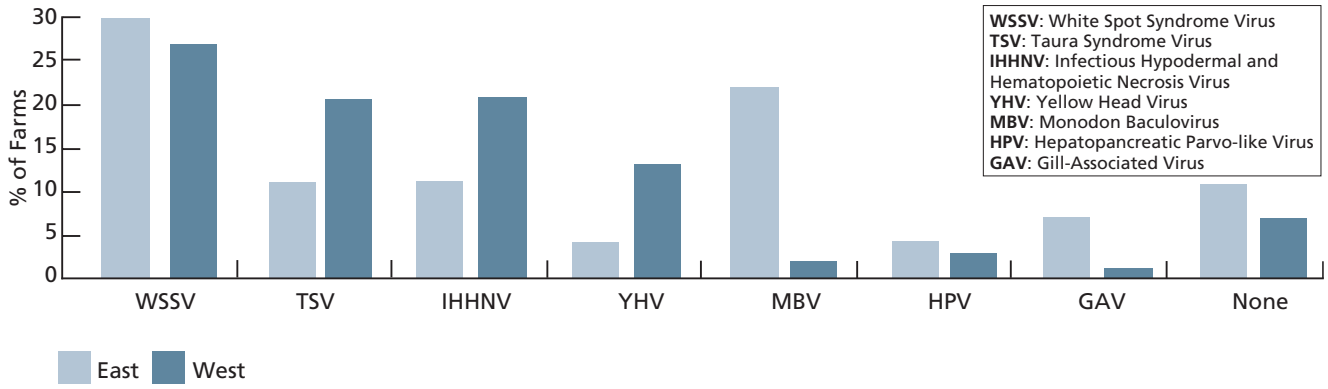


Figure 5. Viruses screened by East and West respondents.

MATURATION

Stocking densities in maturation tanks were lower in the East, possibly as a consequence of the shrimp species cultured. Most (62%) Eastern respondents stocked two to five broodstock per cubic meter of water, predominantly using *P. monodon*. In the West, most (87%) respondents stocked six or more *L. vannamei* broodstock per cubic meter. In the East, the most common female: male ratios were 1:1.5 (25%) and 1.5:2 (25%). In the West, the most common (59%) strategy was to stock equal numbers of females and males.

Typical natural food supplements offered to maturing shrimp include squid (left) and polychaete worms. Worm photo courtesy of Seabait, Ltd.

Proper feeds and feed management are essential to maintain healthy broodstock and stimulate gonadal development. The most common (86%) item used in maturation diets was squid (Figure 6). Polychaetes (66%), adult *Artemia* (57%), and dry feeds (49%) also were important dietary components. Bivalves such as mussels (29%), clams (20%), and oysters (17%) were used less frequently.

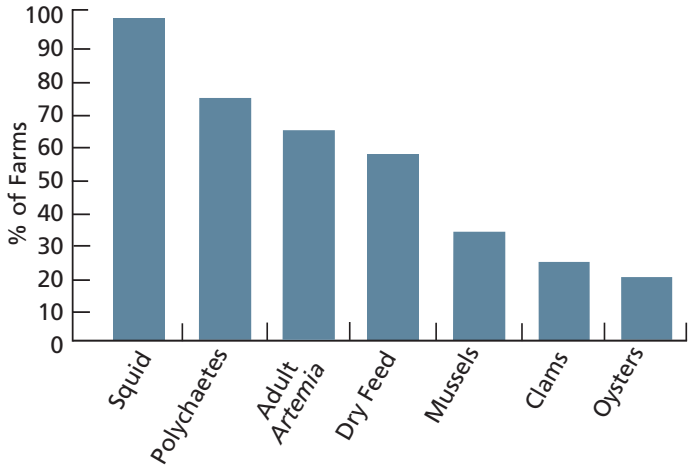


Figure 6. Common ingredients used in maturation diets for commercially important penaeid shrimp.

Maturation diets containing ingredients of marine animal origin must be used with caution because these items can serve as vectors for disease. Interestingly, only 5% of respondents in the West irradiated their feeds, whereas none of the respondents in the East reported this.

Most (67%) respondents from the East fed broodstock to satiation, whereas 64% of the Western respondents determined feeding rates based on shrimp body weight. About half the respondents in the East and West fed broodstock four times per day, although a significant percentage (38%) of Western respondents reported feeding broodstock five or more times daily.

To ensure adequate gonadal development, Eastern respondents reported that broodstock typically were held two to five days in maturation tanks prior to the induction of spawning. In contrast, Western respondents indicated broodstock were typically held six to 20 days – a difference that likely reflected the varied requirements of *P. monodon* and *L. vannamei*.

After an initial preconditioning period, ovarian development was assessed visually, although the most common method to accomplish the assessment differed between hemispheres. Most (76%) respondents in the East reported visual inspection of female broodstock using an underwater light to candle the ovary. In contrast, 88% of the Western respondents reported they visually inspected female broodstock above the water using a flashlight.

Respondents induced spawning a number of ways, including eyestalk ablation; manipulation of temperature, photoperiod, and salinity; and the use of dietary additives (Figure 7). Eyestalk ablation, the preferred method in both hemispheres, typically was accomplished on all females, irrespective of whether they had ripe ovaries or were in post-molt.

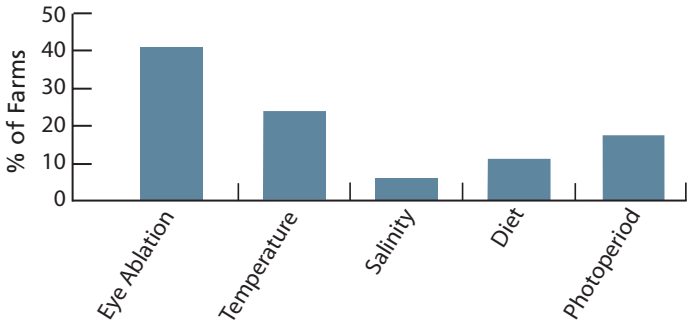


Figure 7. Methods used to induce spawning of shrimp.

The most common ablation techniques differed between hemispheres. Cauterization with a hot iron dominated (57%) in the East, and cutting with a blade dominated (53%) in the West.

Eyestalk-ablated female with numbered band attached to intact eyestalk to monitor reproductive performance.

Irrespective of hemisphere, natural mating in the maturation tanks was the most common mating system used. Over 90% of the respondents indicated they used natural mating, while about 9% used artificial insemination. Artificial insemination was typically performed when it was important to identify parents, such as in a selective-breeding program. Once females were inseminated, they typically were removed from the maturation tanks.

In the East, 60% of the respondents stocked one female in a single spawning tank, whereas in the West, 69% o fthe respondents stocked multiple females in a single spawning tank. Only 4% of the respondents indicated that bulk spawning occurred in the maturation tanks.

PERFORMANCE

The differences in spawning performance between hemispheres likely reflected the physiological and/or behavioral differences between *P. monodon* and *L. vannamei*, as well as differences in our understanding of the reproductive biology and captive rearing of these two species.

For example, Eastern respondents reported variable nightly spawning ranging from 5% to greater than 12%. In contrast, 42% of the Western respondents reported 7 to 8% of females spawning. In addition, there were differences in the number of spawns achieved by each female.

In the East, 75% of respondents reported that each female spawned two to five times. In the West, 45% of respondents reported that each female spawned six to 10 times, and 31% of respondents reported that each female spawned more than 10 times.

Significant differences in shrimp performance between hemispheres and species were reflected in the number of eggs produced per female (Figure 8). In the West, 90% of females produced less than 200,000 eggs per spawn – typical for *L. vannamei*. In contrast, in the East, 75% of the females produced more than 200,000 eggs per spawn, which was typical for *P. monodon*. Hatching rates also varied. In the East, 40% of respondents reported hatching rates of 50 to 60%, whereas in the West, 50% of respondents reported hatching rates of 71 to 80%.

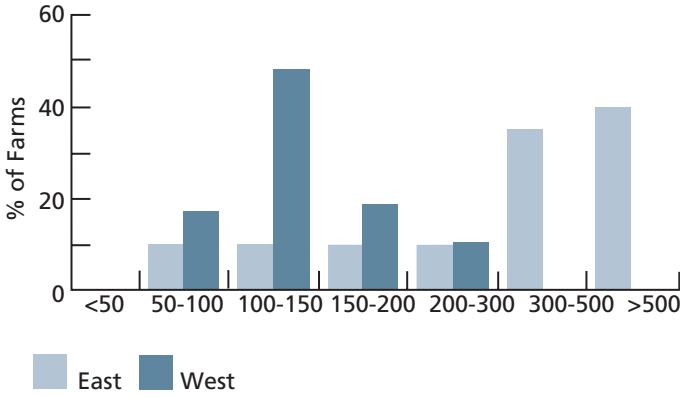


Figure 8. Reported number of eggs per spawn (x 1,000) for shrimp broodstock in the East and West.

With regard to survival of shrimp from nauplii to 15-day postlarvae, 60% of the respondents in the East reported survivals ranging from less than 30% to 50%. In contrast, 67% of respondents in the West reported survivals ranging from 51% to greater than 70%. Again, these collective differences likely were the result of inherent biological differences between the two dominant species in the East and West.

For those respondents who used both wild and domesticated broodstock, the majority indicated that domesticated shrimp were easier to handle and/or showed less fright response than wild shrimp, irrespective of hemisphere. However, 73% of the respondents from the East claimed that wild shrimp had better survival in maturation tanks, higher spawning rates, and more spawns per female. About 89% said the wild animals provided more eggs per spawn, while 54% said they exhibited a higher hatching rate than domesticated shrimp.

In contrast, all respondents from the West claimed that domesticated shrimp had better survival in maturation tanks, 79% claimed higher spawning rates, 57% reported more eggs per spawn, 92% indicated more spawns per female, and 79% claimed a higher hatching rate than wild shrimp.

Eastern respondents reported that wild shrimp delivered better reproductive performance than captive animals, while Western respondents reported the reverse.

As mentioned previously, despite the perception in the East that wild shrimp perform better than domesticated shrimp, there are compelling biosecurity, environmental, and economic reasons to domesticate all commercially important penaeid shrimp species with the ultimate goal of producing SPF, genetically improved stocks for the industry.

FUTURE RESEARCH

Although tremendous advances have occurred over the past decade with regard to maturation technology, a number of areas require further research. In identifying the top research priority areas for improvements in maturation performance, respondents in the East keyed on broodstock growout and preconditioning (54%), hormonal manipulation (23%), diet (15%), and spawning systems (8%). Western respondents indicated diet (45%), broodstock growout and preconditioning (34%), spawning systems (10%), and other areas (10%) as areas for improvement.

In light of disease problems within the global shrimp-farming industry, there have been fundamental changes in the way broodstock managers operate their maturation facilities. The use of domesticated stocks from SPF sources has increased, and biosecure protocols are now common.

In a maturation survey conducted by David Kawahigashi in 1992, 80% of the broodstock used by shrimp farmers in the West were from the wild. In contrast, GAA's survey indicated that about 97% of respondents from the West used broodstock from captive populations, and there appears to be an increasing trend in the East to use captive stocks.

In a 1998 survey, Kawahigashi reported that only four of 34 respondents used water recirculation technology at their facilities. Several years later, this survey reported that 56% of the respondents depended on partial or complete water recirculation. It appears that technologies to enhance biosecurity will continue to be adopted by broodstock managers with the expectation that they will increase production and profitability.

Pond-reared P. monodon *broodstock.*

Recommendations

In order to ensure a predictable supply of high-quality postlarvae to the growing shrimp-farming industry, hatchery managers must adopt rigorous biosecurity protocols that include the use of SPF shrimp, adequate water filtration processes, and proper disinfection protocols. In addition, the use of domesticated stocks must become a routine practice.

Domesticated stocks can be protected from pathogens more easily than wild stocks and used in genetic improvement programs to enhance commercially important traits such as growth and disease resistance. By adopting rigorous biosecurity protocols and taking advantage of genetic selection, the global shrimp-farming industry will be in a better position to supply high-quality products to the growing market.

For Additional Information

Bray, W. A., Jr., and A. L. Lawrence 1991. Reproduction of *Penaeus* species in captivity. P. 93-170 in A. Fast and L. J. Lester (Editors), Culture of Marine Shrimp: Principles and Practices. Elsevier Scientific Publications Co., Amsterdam, the Netherlands.

Browdy, C. L., 1992. A review of the reproductive biology of *Penaeus* species: perspectives on controlled shrimp maturation systems for high-quality nauplii production. P. 22-51 in J. Wyban (Editor), 1992 Proceedings of the Special Session on Shrimp Farming. World Aquaculture Society, Baton Rouge, Louisiana, USA.

Browdy, C. L.; K. McGovern-Hopkins; A. D. Stokes; J. S. Hopkins; and P. A. Sandifer 1996. Factors affecting the reproductive performance of the Atlantic white shrimp, *Penaeus setiferus*, in conventional and unisex tank systems. Applied Aquaculture, 6(1): 11-25.

Clark, W. H., Jr., and F. J. Griffin 1993. Acquisition and manipulation of penaeoidean gametes. P. 133-171 in J. P. McVey (Editor), CRC Handbook of Mariculture, 2nd edition. Volume 1, Crustacean Aquaculture. CRC Press, Boca Raton, Florida, USA, 526 p.

Courtland, S., 2000. Fluidized bed biofiltration technology for oligotrophic water quality. Global Aquaculture Advocate, 3(3): 18-19.

Harrison, K. E., 1990. The role of nutrition in maturation, reproduction, and embryonic development of decapod crustaceans: a review. J. Shellfish, 9(1): 1-28.

Harrison, K. E., 1997. Broodstock nutrition and maturation diets. P. 390-408 in L. R. D'Abramo, D. E. Conklin, and D. M. Akiyama (Editors), Crustacean Nutrition. Advances in World Aquaculture, Volume 6. World Aquaculture Society, Baton Rouge, Louisiana, USA.

Jory, D. E., 1996. Penaeid shrimp hatcheries, part II. Broodstock maturation. Aquaculture Magazine, 22(6): 77-86.

Kawahigashi, D., 1992. A survey of commercial maturation technology in the Western Hemisphere. P. 52-54 in J. Wyban (Editor), 1992 Proceedings of the Special Session on Shrimp Farming. World Aquaculture Society, Baton Rouge, Louisiana, USA.

Robertson, L.; W. A. Bray; T. Samocha; and A. Lawrence 1993. Reproduction of penaeid shrimp: an operations guide. P. 107-132 in J. P. McVey (Editor), CRC Handbook of Mariculture, 2nd edition. Volume 1, Crustacean Aquaculture. CRC Press, Boca Raton, Florida, USA, 526 p.

Treece, G. D., and J. M. Fox 1993. Design, Operation and Training Manual for an Intensive Culture Shrimp Hatchery (with emphasis on *Penaeus monodon* and *P. vannamei*). Texas A & M University Sea Grant College Program. Publication TAMU-SG-93-505, 187 p.

Treece, G. D., and M. E. Yates 1993. Laboratory Manual for the Culture of Penaeid Shrimp Larvae. Texas A & M University Sea Grant College Program, 95 p.

Wilkenfeld, J. S., 1992. Commercial hatchery status report: an industry panel viewpoint. P. 71-83 in J. Wyban (Editor), 1992 Proceedings of the Special Session on Shrimp Farming. World Aquaculture Society, Baton Rouge, Louisiana, USA.

Wyban, J., 1996. Sustainable development and commercial potential of SPF *Penaeus monodon*. P. 446-447 in R. L. Creswell (Editor), Book of Abstracts. 1996 Annual Meeting, World Aquaculture Society, Bangkok, Thailand, 498 p.

Yano, I., 1993. Ultraintensive culture and maturation in captivity of penaeid shrimp. P. 289-313 in J. P. McVey (Editor), CRC Handbook of Mariculture, 2nd edition. Volume 1, Crustacean Aquaculture. CRC Press, Boca Raton, Florida, USA, 526 pp.

Yashiro, R., 1996. Effects of 17-d hydroxyprogesterone and thoracic ganglion on ovarian maturation of *Penaeus monodon*. P. 452 in R. L. Creswell (Editor), Book of Abstracts. 1996 Annual Meeting, World Aquaculture Society, Bangkok, Thailand, 498 p.