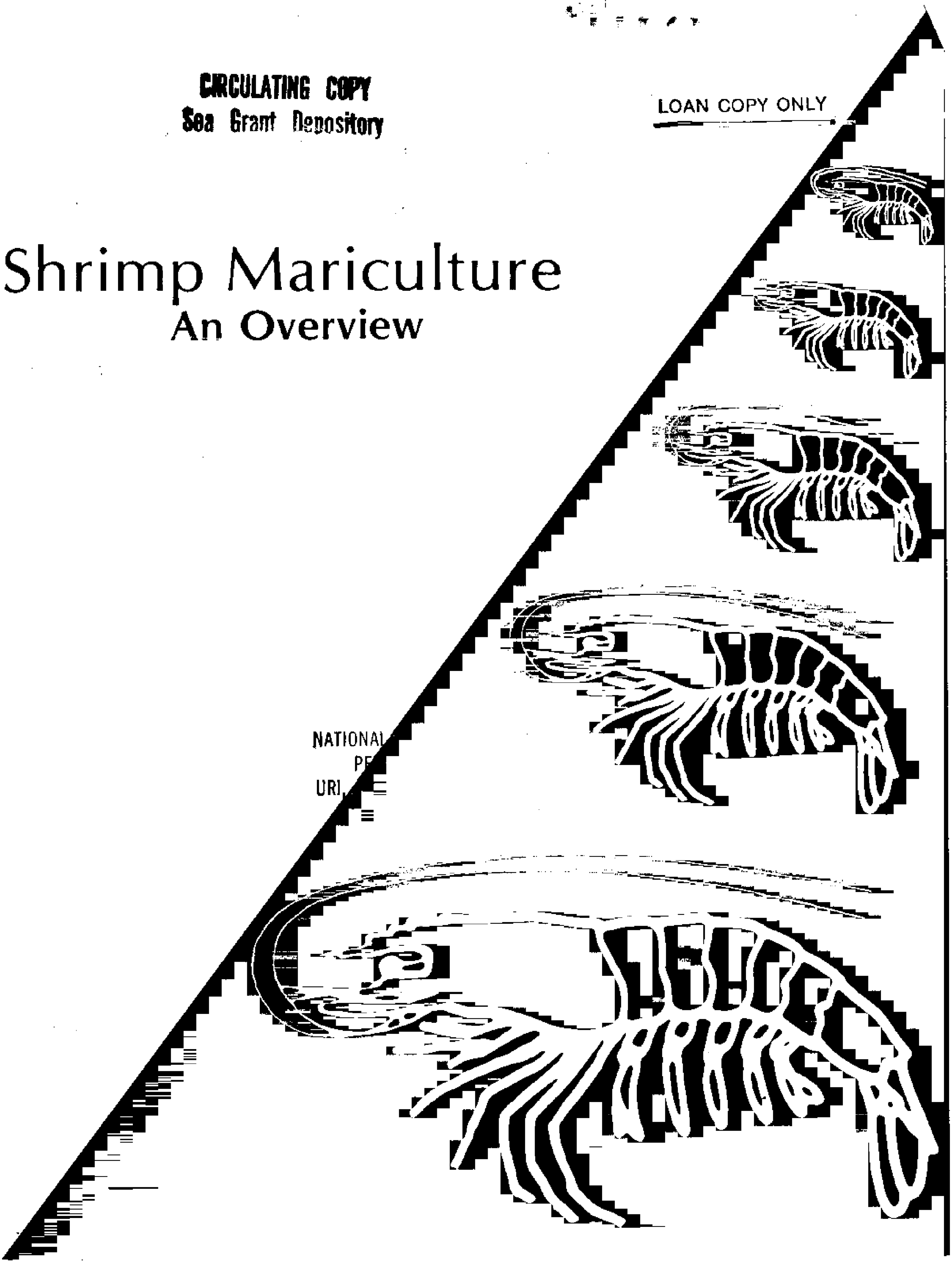
Shrimp Mariculture
An Overview



Texas A&M University Sea Grant College Program

This is the first in a series of information sheets on shrimp mariculture and its potential in Texas. The material that follows is basically an overview of what shrimp mariculture involves and its status both worldwide and in Texas. This overview will be followed by six additional information sheets on permitting, maturation/reproduction, hatchery, pond grow-out, diseases and the economics of shrimp mariculture.

Upon completion, these information sheets will be compiled and published under one cover.

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Shrimp Mariculture

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Fisheries...it's a big business in the United States. The dockside value of all fisheries is consistently more than two billion dollars a year (for 1980 it was $2,237,202,000). Yet in 1980 the United States imported $3,648,082,000 worth, or 62 percent, of the fishery products consumed here. Importation of fishery products accounted for 10 percent of the national trade deficit in 1979.

The shrimp fishery is the most valuable of the U.S. fisheries, with most shrimp being caught in the Gulf of Mexico. Still, the dockside values of shrimp imported for U.S. consumption were $713,238,000 in 1979 and $719,263,000 in 1980. The value of the U.S. shrimp catch, in contrast, was $471,573,000 and $402,697,000, respectively.

The imbalance is increasing. The demand for shrimp is predicted to increase 26 percent worldwide and 33 percent in the United States from 1975 to 1985. This increased demand comes at a time when harvests are at, or near, maximum sustainable yields. Between 1977 and 1980, for example, the amount of shrimp caught by American fishermen decreased from 476,654,000 pounds to 339,707,000 pounds.

One alternative which could help augment the shrimp supply as well as reduce the trade deficit and create a new industry is shrimp mariculture.

Shrimp mariculture occasionally is referred to as shrimp farming, and, like the land-based agricultural process, it involves three phases: seeding, growing and harvesting. The difference is in terminology; in mariculture, these procedures are called maturation/reproduction and hatchery, grow-out and harvesting.

Shrimp farming duplicates in captivity what occurs in nature. In nature, the marine shrimp spawn and develop through the larval stages into postlarvae (a miniature shrimp) in the Gulf of Mexico. This is equivalent to what occurs during the maturation/reproduction and hatchery phases in captivity. The postlarvae then migrate from the Gulf of Mexico into the adjacent bays and estuaries. Following growth into juvenile shrimp, they migrate back into the Gulf of Mexico to become adults. This is equivalent to the grow-out phase in farming.

The maturation/reproduction phase produces seedstock, or shrimp larvae, to supply the hatchery phase which, in turn, produces 6- to 10-day-old postlarvae. These postlarvae are used in the grow-out phase to produce marketable-size eating shrimp or smaller shrimp for use as bait or to augment natural populations by stocking bays.

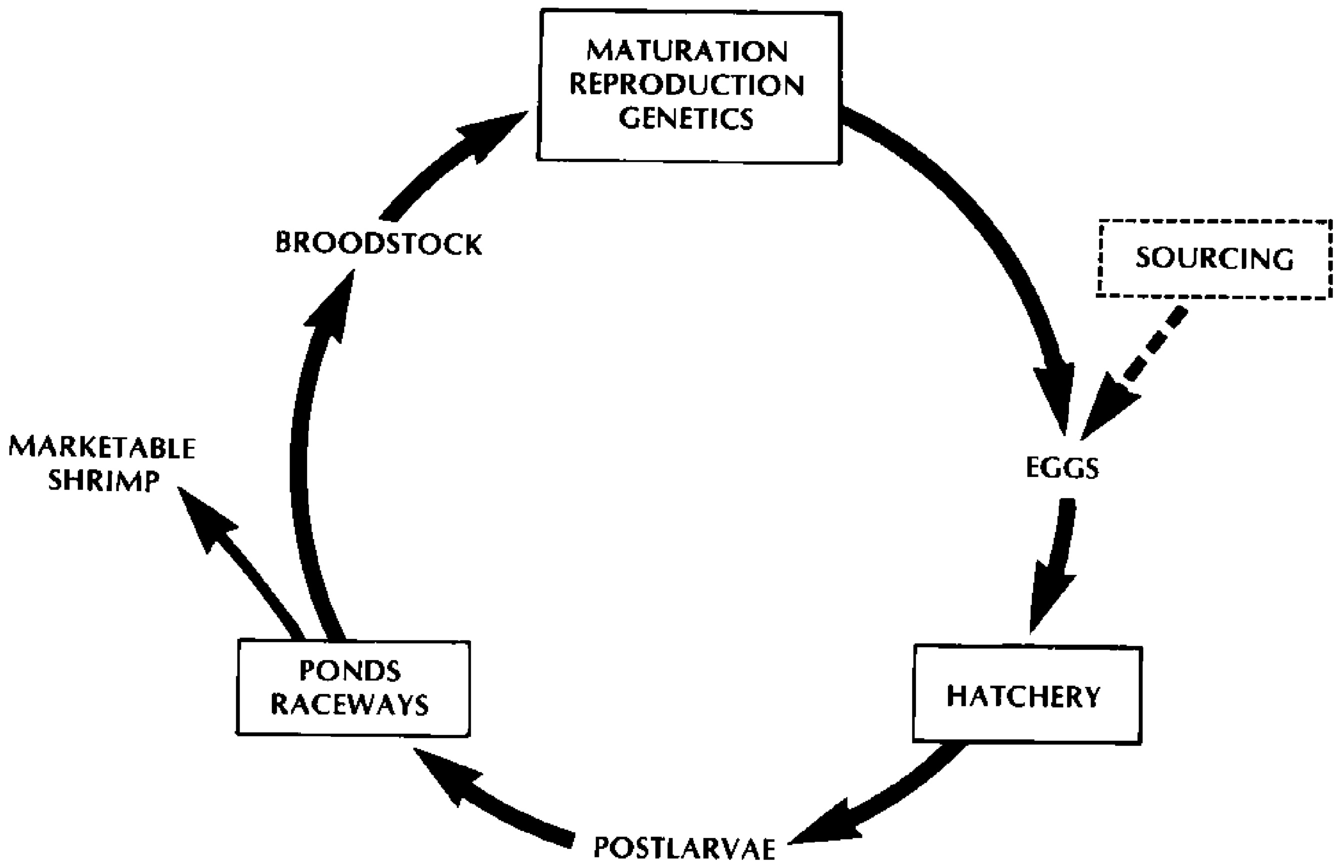
Commercial grow-out production of shrimp requires an abundant and reliable stock of postlarvae or juveniles. Some Central and South American shrimp culture farms which have low production requirements capture these animals directly from wild populations. Intensive pond production, however, requires a more manageable stocking system where predators, competitors, densities and stocking dates are controlled. A hatchery phase is necessary to insure that there is a predictable postlarvae supply of the same species and of an equivalent age.

Mated females captured in the wild or those matured in captivity can supply the eggs for the hatchery phase. Catching mated females in the wild is not recommended in the United States, however. The supply is unpredictable, non-indigenous species are unavailable, collection is restricted to the local spawning season, and genetic manipulation and selective breeding are impossible. The preferred alternative is to mature, breed and spawn the females in captivity under controlled conditions. This produces a low-cost, predictable supply of shrimp seedstock (larvae). For example, a 6,000-square foot metal frame maturation/reproduction facility which costs approximately $400,000 could produce about 1.5 million shrimp larvae per day at a cost of 30 to 50 cents per thousand.

Seedstock are transferred to a hatchery when they change (metamorphose) into postlarvae, usually after 10 to 12 days. The postlarvae are maintained in the hatchery for an additional 6 to 10 days to increase their chances of pond survival. A 7,000-square foot metal frame hatchery facility costing about $700,000 could produce about three-quarters of a million 6- to 10-day-old postlarvae per day from the seedstock at a cost of about $4 per thousand. In comparison, shrimp postlarvae produced by this method presently are selling for $5 to $12 per thousand in Central and South America.

Postlarvae are transferred to 5- to 20-acre grow-out ponds where they can be raised to 25 to 45 count heads-on shrimp in three to four months. For each crop, 700 to 2,000 pounds of shrimp valued at between $1,500 and $4,000 can be produced per acre at an operating cost of approximately $1,200 to $2,800 per acre of water. The operating cost will vary with the size of the ponds, total number of acres of water and the number of pounds of shrimp produced per acre. To complete the cycle, some of the shrimp can be maintained in the ponds for another two months for use as broodstock in the maturation/reproduction phase.

MAJOR ASPECTS OF SHRIMP MARICULTURE



Shrimp mariculture in other countries

Most shrimp mariculture activity involves the use of penaeids, such as **Penaeus japonicus**, native to the northwestern Pacific; **Metapenaeus ensis, Penaeus monodon, P. indicus, P. semisulcatus** and **P. merguiensis**, native to the western central and southern Pacific; **Penaeus stylirostris, P. vannamei, P. californiensis** and **P. occidentalis**, native to the eastern Pacific; and **Penaeus setiferus, P. brasiliensis, P. duorarum, P. aztecus** and **P. schmitti**, native to the western Atlantic.

There are viable commercial shrimp mariculture operations in Central and South America, Southeast Asia, Taiwan and Japan. These rely primarily on animals from natural populations, with a very small percentage coming from seedstock produced in captivity. Experimental production of seedstock in captivity is being accomplished in Australia, Japan, Brazil, Costa Rica, Ecuador, Honduras, Mexico, Taiwan, the Philippines, England, Indonesia, the People's Republic of China, Panama, Tahiti and France. In general, the inability to adequately mature, breed and spawn shrimp in captivity is the most limiting aspect of shrimp mariculture.

Though the hatchery technology is far from optimum, it is adequate to support commercial shrimp mariculture operations for abvout 10 different species of marine shrimp in many countries. Several commercial farms currently rely primarily on hatchery production of 6- to 10-day-old postlarvae rather than on capturing postlarvae or juveniles from the wild. Postlarvae raised either from mature mated females from nature or from cultured populations also have been used to augment natural shrimp populations in the Inland Sea in Japan and in the Gulf of Arabia.

The technology required for the pond grow-out phase presently is being used for commercial operations in many countries, although, again, it is far from optimum. Commercial shrimp farms have obtained 200 to 500 pounds of 10 to 30 count shrimp per crop in about six months in unmanaged ponds and 600 to 1,500 pounds of 20 to 40 count shrimp in about four months in managed ponds. An average of 2.25 crops per year (four months per crop) is possible in countries where shrimp can be farmed continuously rather than seasonally. Most shrimp, such as **P. vannamei, P. stylirostris** and **P. setiferus**, require a minimum water temperature of about 23°C (73°F) for 8 to 12 hours a day for commercial growth rates.

The technology required for the grow-out phase using intensive culture methods involving raceways or tanks is not sufficiently developed for a commercial operation. Although several companies are investigating the feasibility of intensive shrimp mariculture, none is known to be making a profit. Through increased technology and domestication of shrimp, however, it is probable that shrimp ultimately will be raised in raceways or tanks. A production level of 50,000 to 100,000 pounds of 30 count heads-on shrimp per year per acre of water is being predicted for intensive culture.

Status in Texas

The Texas A&M University System has the largest shrimp mariculture research program in the United States, amounting to about 30 to 40 percent of the total effort. This research program concentrates primarily on five species. These are **Penaeus setiferus**, the native Gulf coast white shrimp, **P. aztecus**, the native Gulf coast brown shrimp, **P. monodon**, a brown shrimp from the indo-western Pacific, and **P. stylirostris** and **P. vannamei**, white shrimp from the eastern Pacific.

Although shrimp mariculture in Texas is relatively young in comparison to that in other countries, the technology used is approaching worldwide state of the art. Three shrimp species have been matured, mated, spawned and reared in captivity in Texas, **P. setiferus**, **P. stylirostris** and **P. vannamei**. The technology level for the maturation/reproduction phase, however, is very near but not yet adequate for commercial production. The hatchery and grow-out technology is adequate, although not optimum, for shrimp mariculture in Texas.

Shrimp mariculture has reached a commercial level in Central and South America and Southeast Asia, but not in the United States, for the following reasons:

1. A longer growing season (in most cases it is year round);
2. the availability of mature and mated female shrimp in nature;
3. the availability of postlarvae or juvenile shrimp in the wild.

The exception to this is Japan, where the price per pound for shrimp is two to three times what it is in the United States. The higher sales price per pound allows shrimp mariculture to be profitable with a lower level of technology. For example, at these much higher selling prices, shrimp farming can be profitable without shrimp seedstock being produced in captivity. A shrimp mariculture company in the United States, in contrast, must have seedstock produced in captivity to be economically successful. One to three years will be required before the maturation/reproduction technology is sufficient to support a commercial shrimp mariculture company in this country.

Shrimp mariculture for bait production has much potential because of the greater price per pound (for live bait) and smaller operating cost as compared to production of shrimp for food. Bait shrimp mariculture would be restricted to native species, however, and would require larger numbers of seedstock. Because of this, commercial bait-shrimp culture may not develop as quickly as food shrimp culture. The higher selling price per pound ($4 per pound of 30-count live shrimp) compared with the same sized food shrimp may partially compensate for this.

Of all the states, Texas probably has the greatest potential for mariculture. Its long coast line, coastal topography, the composition of the soil and the ideal climate are all conducive to a successful program. Additionally, there are millions of acres of land in West Texas that could be used for mariculture since there is seawater 10 to 25 feet underground in the region. Mariculture development in West Texas also would provide the added benefit of a needed new industry.

The shrimp fishery already is a major industry in Texas. The expertise and facilities required for processing, packaging, storing, transporting and marketing already are available. Of all the marine animals, shrimp has the greatest mariculture potential because of the existing value and market in this country and elsewhere.

Other considerations

Aside from technology requirements, shrimp mariculture has distinct requirements in terms of site selection, personnel, legal constraints and permitting.

Several permits are required for a shrimp mariculture company to operate. In Texas, these include state and federal permits or licenses from the following agencies: Texas Department of Health, Texas School Land Board, Department of Water Resources, General Land Office, Texas Antiquities Committee, Texas Parks and Wildlife Department, U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. The National Marine Fisheries Service and U.S. Fish and Wildlife Service serve in an advisory capacity to the Corps of Engineers. A separate publication in this series will deal with legal constraints and permits.

The site selected and the personnel hired in a commercial mariculture venture will be primary factors in determining success or failure. The criteria for site selection will vary with the objectives of the commercial endeavor (seedstock, bait, shrimp for human consumption or combinations of these), size (acres of water), the nature of the physical facility (intensive versus extensive culture) and the location. The following is a checklist of items which should be considered for a commercial shrimp mariculture venture. This list also indicates the complexity of choosing a proper site, especially when one realizes that many of the biological and physical factors interact.

Biological Factors
- Shrimp species tolerances
- Shrimp species availability
- Primary productivity
- Secondary productivity
- Eutrophication and microorganisms

Physical Factors
- Hydrological
  - Items for which mean, maximum and minimum values should be known for daily and monthly variations.
    - Temperature
    - Salinity
    - Dissolved inorganic compounds (calcium, nitrate, nitrite, phosphate, magnesium, iron, etc.)
    - Dissolved organic compounds (amino acids and sugars)
    - Toxic compounds (chlorinated and petroleum-derived hydrocarbons and heavy metals)
    - Turbidity
    - pH (acidity and alkalinity
    - Tides
    - Water currents
    - Wave action
    - Silt burden
  - Watershed characteristics
    - Topography
    - Cover
  - Ground water (salt and fresh)
  - Evaporation rates
- Soils
  - Acidity and potential acidity
  - Alkalinity and potential alkalinity
  - Topsoil and subsoil characteristics
    - Depth
    - Permeability (percolation rate)
    - Composition (clay, sand, etc.)
    - Organic content
    - Inorganic content
    - Leachable toxins
  - Topography
  - Load-bearing capacity
- Meteorological (daily and seasonal mean, maximum and minimum values)
  - Wind
    - Velocity
    - Direction
  - Rainfall (means are less important than seasonal trends, e.g., floods)
  - Air temperature

Economic Factors
- Raw materials and maintenance
  - Prepared feed
  - Fresh marine invertebrates
  - Electricity
  - Fuel
  - Equipment
  - Repair parts
  - Service maintenance
  - Import duties
  - Packaging materials availability
- Land
  - Cost
  - Restrictions on ownership
  - Zoning regulations
  - Potential developments or encroachments
- Labor
  - Wages
    - Minimum
    - Severence pay
    - Fringe benefits
  - Availability
  - Qualifications (biological, engineering)
  - Unions
  - Government regulations
  - Liability laws
- Transportation
  - Accessibility of facilities
  - Trucking service
  - Railroad service
  - Shipping ports
  - Airport service
- Construction costs
  - Draining requirements
  - Land clearing
  - Earth moving
  - Piping/pumps
  - Wells
  - Buildings
- Communications
  - Mail
  - Telephone
  - Telex
  - Cable
- Financial
  - Commercial banks
  - Development banks
  - Government assistance
  - Financial controls
  - Constraints on movement of capital
  - Currency stability
- Markets
  - Proximity to domestic and foreign
  - Trade practices/restrictions

Legal Factors

- Stability of Government
- Natural resources policies (permitting restrictions)
- Tax laws
  - Incentives to private investment
    - Tax abatement
    - Duty free import
- Fishing limitations
- Water rights and use
- Waste water permits
- Culture permits
- Import-export
- Environmental protection
- Laws on foreign personnel
- Food and drug regulations
- Labor laws
- Land-use laws
- Ownership
  - Land
  - Facilities

Social Factors

- Community services
  - Schools
  - Medical care
  - Housing
  - Protection
  - Cultural resources

Further Reading

An increasing number of magazines and books are being published concerning fresh-water aquaculture and mariculture. The following is a list of magazines, journals, books and reviews for those who want additional information.

Books and Articles

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Iverson, E.S. 1968. **Farming the edge of the sea.** Fishing News Books, Ltd., Surrey, England. 301 pp.

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Fish Boat. P.O. Box 2400. Covington, Louisiana. H.L. Peace Publications.

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Gulf Coast Fisherman. P.O. Box 397. Port O'Connor, Texas.

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Proceedings of the World Mariculture Society. Contact Dr. Dan Walsh, Division of Continuing Education, 177 Pleasant Hall, Louisiana State University, Baton Rouge, Louisiana 70803.

The Progressive Fish Culturist. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

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