New Mexico Aquaculture

Circular 543

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Cooperative Extension Service • College of Agricultural, Consumer and Environmental Sciences

INTRODUCTION

Aquaculture is a broad term that refers to the breeding, rearing, and harvesting of fish, shellfish, and plants in all types of aquatic environments, including tanks, ponds, rivers, lakes, and the ocean. Aquaculture is used to produce seafood for human consumption, to enhance wild fish and plant stocks for harvest, to help restore threatened or endangered aquatic species, and to culture fish for aquariums. Among these, seafood production is of greatest importance for a number of reasons. First, commercial fishing is rapidly depleting wild stocks in the oceans. Capture fisheries are fully exploited and cannot satisfy the increased consumer demand. As such, future increases in seafood production are forecast to come from aquaculture. Second, edible fish and seafood per capita consumption in the U.S. has risen from 12.8 lb in 1980 to 15.8 lb in 2009 (the last year for which data are available). The U.S. is the third largest consumer of fish and shellfish behind China and Japan. Over 91% of the seafood consumed in the U.S. is imported. Because of this, the U.S. has a seafood trade deficit of over $11.2 billion annually (NOAA Fisheries, n.d.), making seafood second only to oil as the largest natural resource contributor to the U.S. national trade deficit. Aquaculture has helped improve food security in many parts of the world. In fact, more than 70% of the seafood imported into the United States is produced by aquaculture. It is one of the most resource-efficient ways to produce protein because fish convert more of the food they eat into body mass compared to land animals. Furthermore, sustainable aquaculture provides safe, sustainable food and creates jobs and business opportunities, which significantly contribute to rural inland and coastal local economies. Aquaculture production is expected to grow worldwide to about 172,000,000 metric tons by 2021, an increase of 15% over 2009 levels.

New Mexico has unique environmental and biological resources that could be used to develop a viable aquaculture industry in the state. Approximately 15 billion acre-feet of saline water (2 ppt and greater salinity) are available for use in New Mexico. Saline water resources cannot be used for traditional agriculture or for drinking water, but could be used for aquaculture. Furthermore, interest in less water-demanding forms of aquaculture, such as indoor recirculating aquaculture systems (also known as zero-exchange), aerobic systems used in shrimp production, and aquaponics—systems that grow both aquatic animals and plants in a recirculating system—has increased greatly in New Mexico. The wide array of climatic conditions found throughout the state can support a diversified and strong aquaculture industry.

Illustration of rainbow trout provided by Joe Tomelleri (www.americanfishes.com).

This publication is designed to assist individuals seeking to learn more about aquaculture and its potential in New Mexico. The first section asks you to answer some simple questions to determine if aquaculture is right for you. The next section discusses the basic design and biological criteria that must be considered when selecting a site for an aquaculture enterprise. Next is a review of the aquaculture status of various species found in New Mexico and the culture techniques that can be used to rear these species. Then the aquaculture potential of several non-native, non-indigenous species in New Mexico is discussed. The next section divides New Mexico into regions based on estimated aquaculture growing season. Also in this section is a list of species with potential for farming in each region. The next section gives potential yields for several species of fish and crustacea at different levels of management intensity. The publication concludes with a discussion of the aquaculture successes in surrounding states and lists the addresses of several state

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and federal culture facilities that can be visited. A list of aquaculture-related trade and scientific publications is also given; the list includes subscription addresses and phone numbers.

IS AQUACULTURE RIGHT FOR ME?

Aquaculture is a relatively new industry in the U.S. Many people in the industry have been successful while a greater number have failed. A common theme unites most failed aquaculture enterprises: failure of the investors and managers to honestly assess the viability of their enterprise before beginning their operation.

Many investors are duped by unrealistic promises of success and the belief that the developer of the plan is knowledgeable. Developers often inflate the potential of the operation in order to attract investors and begin their farming operation. Reading unbiased published reports and asking people in the industry who are knowledgeable about the viability of the proposal are good starting points for avoiding common pitfalls. Before beginning an investigation, however, there are some simple questions you should ask yourself to determine if aquaculture is appropriate for you.

Questions To Ask Yourself

Am I a risk seeker or am I risk averse?
Aquaculture, like most farming enterprises, is highly risky. Many variables must be controlled over a long period to produce a marketable crop. If control is not maintained, a crop can be lost, resulting in substantial financial losses. Aquaculture market prices vary. This variation means the risk of possible financial loss is higher in aquaculture than in some other ventures.

Do I like farming and business?
An aquaculturist is a farmer and a business person. Farmers must be willing to work long hours in all kinds of weather, and must be dedicated to the crop and its successful production. A business person must be aware of where, when, and how to market the product to obtain the best price. If investors or bankers are funding the enterprise, the manager must account for every dollar spent and be able to justify the expenditure.

How large an operation do I want and how am I going to achieve that goal?
Every good business develops a business plan to answer this question. If you are an investor, ask to see the business plan and analyze it closely to determine its accuracy and the enterprise's viability. A safe operation starts small and builds on its successes. An enterprise that seeks to start full-scale with little or no preliminary testing will have a difficult start and may not succeed. It is also important to adjust the plan as the operation proceeds.

How easily do I adapt to new technologies and a changing industry?
Aquaculture is a young industry that is still in the process of developing techniques and production methods. A good manager is able to keep abreast of new technologies and to apply what others have learned. Because industry prices are constantly in a state of flux, a manager must be able to adjust the marketing plan to achieve the highest value for the farm's product(s).

Do I or the manager have the technical expertise to select a site that meets the biological criteria of the proposed species, as well as the engineering criteria needed to construct the required facility?
Aquaculture site selection is one of the most important aspects of planning an enterprise. A site must have acceptable water temperature, growing season, and water quality and quantity for the proposed species. If the facility is an outdoor, pond-type aquaculture operation, the site also must have the appropriate slope, soil type, and related engineering criteria to meet facility design requirements.

Do I or the manager have the knowledge and skill to run the enterprise?
Raising fish is not simply a matter of filling a hole with water and throwing in some fish. Managers must know fish production techniques, water quality, fish disease, fish nutrition, business management, and marketing. Managers must not only be able to produce a high-quality, reliable product but must also be able to market that product for a profit. A manager's qualifications can be determined by talking to references and people in the field who are familiar with the manager's reputation and abilities. Talk to the manager to determine how much he/she knows about the industry as a whole. A good manager will be able to discuss successes and failures of related operations, markets, and potential competitors.

There also are preliminary financial questions that must be asked and answered: How much money do I have to invest? How long can I wait for an acceptable return? How do I define an acceptable return?
Aquaculture is a capital-intensive enterprise that requires a large initial investment. Returns to an investment will not occur for several years due to the time required for the production of a marketable crop. Aquaculture, like many areas of farming, often provides investment returns in terms of the satisfaction of producing a crop rather than in financial terms.

SITE SELECTION FOR AQUACULTURE IN NEW MEXICO

The site selected for an aquaculture enterprise will have a significant impact on the success of the operation.

Table 1. Water Quality Components	
Chemical Component	**Acceptable Range**
Total alkalinity (as $CaCO_3$)	10–400 ppm[a]
Total hardness (as $CaCO_3$)	>20 ppm
pH	6.5–8.5
Ammonia	<0.03 ppm
Nitrite	<0.1–0.2[b] ppm
Carbon dioxide	0–10 ppm
Chlorine	<0.03 ppm
Temperature	Species specific
Dissolved oxygen	5.0 ppm to saturation
[a] Parts per million [b] Depends on water hardness	

A site must meet the biological criteria for the species proposed, as well as the design criteria for the facilities required. Even the most skilled aquaculturist and business person can fail if the site selected does not meet these criteria.

Biological And Design Criteria

Water Quality

The list of water quality components given in Table 1 is not complete. However, testing for these factors with a portable water quality test kit will give an initial indication of the quality of the water for rearing fish. A complete analysis should be conducted to determine trace metal concentrations and other potential toxicants. A full test can be obtained from a commercial testing laboratory. Contact the laboratory before sampling to ensure that proper collection and shipping procedures are followed.

Water Quantity

A water budget must be created to determine the amount of water necessary for the proposed production system. Water budgets include the amount of water needed to fill the culture units: ponds, raceways, or tanks. Culture units will often be filled and drained several times during a growing season, and each filling and draining must be included in the water budget. Budgets must also include water needed to compensate for poor water quality, water used to replace evaporative loss (a particular problem in New Mexico), and water used in incubating eggs and rearing fry (see **Glossary**) in the hatchery.

If water is to be pumped from an aquifer to supply the facility, a survey of the aquifer and its contents may be necessary. The U.S. Geological Survey or the New Mexico State Engineer's Office may be able to provide this information, as well as some general information concerning the output of wells in the area. Other well owners in the area may be able to give you a better indication of potential well outputs and the quality of the aquifer.

If the water to be used will come from surface water sources, it is important to determine the seasonal supply and quality of those sources. It is also necessary to determine the abundance of wild fish in these sources and the methods to be used to prevent their entry into the planned facility.

In New Mexico, rights to the use of water must be obtained by application to the State Engineer. In order to obtain water rights in New Mexico, potential users must show that they are diverting the water, putting it to beneficial use, and not impairing the rights of other water users. Additionally, to appropriate water (obtain water rights) there must be water available. Water supplies in New Mexico are limited. It may be necessary to purchase water rights from other users. These rights are an additional expense that must be considered in the overall business plan.

Soil Quality

Soil is an important factor to consider when constructing an outdoor aquaculture facility. A facility constructed to rear fish in earthen ponds or raceways requires a soil composed largely of clay (minimum clay content of 20%) because clay soils hold water and prevent seepage better than other soil types.

A soil analysis should be conducted to determine the trace metal concentration, pesticide concentration, and other chemical components that may affect fish. Soil analyses can be obtained from a commercial testing laboratory. Contact the testing laboratory before sampling to ensure that proper collection and shipping procedures are followed.

Facilities using cement raceways or tanks are not as dependent on soil type. However, it may be necessary to construct effluent settling ponds. Depending on the water rights you have and applicable discharge laws, this settling pond may need to be constructed to hold water with little or no loss to seepage. Again, a clay soil may be needed.

Pond liners may be used to avoid the requirement for specific soil types. Pond liners are an additional expense and may require specialized installation. These costs must be analyzed carefully to ensure the operation can support the additional expenses.

Topography

Topography is another factor to consider when analyzing a potential site. Some facilities, particularly hill ponds, can be constructed in areas of rolling hills. However, many facility types require relatively flat ground with a slope of no more than 2 to 3%.

Available Support Services

Aquaculture requires certain support services that may not be available at all locations in New Mexico. Some of these services include construction services familiar with aquaculture, electrical service, all-weather access roads, fish feed and fertilizer suppliers, equipment repair and supply services, product markets, structures on the site (barns, homes, etc.), fish disease diagnostic facilities, qualified staff, and fingerling (see **Glossary**) suppliers.

A site may meet all of the biological and design criteria but may be located in a place that has no available support services. It may therefore be necessary to pass over this location in favor of a less desirable site with greater access to these services.

Permits

Each state has different requirements for constructing and operating fish culture facilities. Permits for effluent discharge, water rights, building, propagation of game fish, and health must be obtained from the controlling state agencies. Depending on your facility and operational plans, additional permits may be necessary. In New Mexico, for example, it is illegal to import and rear live tilapia. An "Applications for Importation of Exotic Species" may be made to the New Mexico Game and Fish to rear species prohibited in the state.

FISH SPECIES IN NEW MEXICO AQUACULTURE

Fish species can be divided into three general categories based on preferred water temperature: 1) coldwater species, 2) coolwater species, and 3) warmwater species. Due to its climatic variability, New Mexico has species from all three categories. The culture techniques used to rear each of these species are different: coldwater species are most frequently cultured at high densities in raceways, warmwater species are traditionally raised in ponds at slightly lower densities, and coolwater species are cultured in either system at varying densities. The following is a list of species with aquaculture potential and availability in New Mexico. Aquaculture status and methods of culture for each species are briefly described.

Coldwater Species

Kokanee salmon (landlocked sockeye salmon) are found in seven waters within the state. Salmon are usually spawned in the fall or winter. Eggs are incubated in vertical tray incubators (see **Glossary**). Parr, or fry, are held in troughs with flowing water and fed artificial feeds. Feed-trained parr, or fingerlings, are moved to raceways and fed artificial feeds for rearing to market size. Stocking density for grow-out depends on fish size, water temperature, rate of water flow, desired growth rate, and water quality. Kokanee salmon can be reared in the saline water resources found in New Mexico.

Markets for salmon are nationwide. The U.S. farmed salmon industry, based in Maine and Washington, has grown to around 12,000 tons (live weight) per year in Maine (roughly $78 million) and some 8,000 tons in Washington state (roughly $52 million). This is only a small fraction of the salmon consumed in the United States. Small producers, therefore, will have to compete with large coastal producers and will need to differentiate their product(s) from the coastal product(s) and/or develop reliable niche markets.

Rainbow trout are found throughout New Mexico. Culture methods for rainbow trout are similar to those used to rear kokanee salmon. Fish are spawned in the fall or winter, eggs are incubated in vertical tray incubators, and raceways are used to grow out fingerlings. Water quality and quantity requirements also are similar to those of kokanee salmon. Techniques for rearing brown trout, brook trout, and lake trout are similar to those for rainbow trout. Trout, like salmon, can be cultured in New Mexico's saline water.

Markets for rainbow trout are nationwide. Large quantities of food-sized rainbow trout are raised in Idaho, California, South Carolina, and Pennsylvania. In 2008, over 53 million tons of trout, mostly rainbow, were grown in the U.S., with a value of $79.7 million. Small producers will need to develop niche markets and differentiate their product(s). Markets for stocking rainbow trout in private sportfish ponds also exist.

Coolwater Species

Striped bass, white bass, and hybrid striped bass are reared either in raceways or, more commonly, in ponds. Domesticated broodstock have not been developed. Broodfish must be captured from the wild and induced to spawn via hormone injection (see **Glossary**). In New Mexico, anecdotal evidence indicates brood striped bass may be available from Elephant Butte Reservoir.

Hybrid striped bass (commonly known in New Mexico as wipers) are a cross between striped bass and white bass. Hybrid striped bass are raised in ponds at stocking rates between 3,000 and 4,000/ac. Higher stocking rates are used for the fry-to-fingerling grow-out phase. Aeration and artificial feeds are used for intensive production. Striped bass and hybrid striped bass can be reared in saline water.

A growing market is developing for hybrid striped bass as foodfish (see **Glossary**). A strong market also exists for fingerling striped bass, white bass, and hybrid striped bass for stocking in sportfish ponds.

Northern pike can be found in eight waters in New Mexico. They are highly valued as a sportfish. Culture of this fish has been conducted primarily by state and federal hatcheries for stocking public waters. However, interest in intensive culture of this species as a foodfish has grown and appears to be possible.

Broodstock are normally collected from the wild and spawned in the hatchery, either naturally or by hormone injection. Eggs are incubated in vertical tray incubators, and fry are transferred to tanks or troughs for feed training. Feed-trained fingerlings are then transferred to raceways for grow-out to market size.

Due to the culture status of this species, no consistent market is known. Fingerlings can probably be sold to state and federal agencies for stocking and mitigation purposes (i.e., to replace stocks lost due to human activities). Based on the demand by anglers for this species, a foodfish market probably exists.

Yellow perch are found in the impoundments of the major drainages of New Mexico. The species is a prized sportfish. Yellow perch culture is limited primarily to state and federal hatcheries. Intensive culture techniques have been developed, but foodfish markets for this species appear to be limited to the north-central U.S.; this region supports a commercial fishery in the Great Lakes for yellow perch.

Intensive culture techniques for yellow perch require natural spawning, stripping (see **Glossary**), or induced spawning broodstock. Eggs are incubated in vertical tray incubators and fry are cultured to fingerlings in fertilized ponds. Eighty percent of fingerlings greater than one inch in length can be trained to accept artificial feeds. Market size (0.33 lb) can be obtained in 12–15 months depending on temperature and photoperiod.

Walleye are found in the impoundments of the major drainages of New Mexico. Walleye are a prized sportfish and foodfish. Walleye culture requires collecting pre-spawning adults from the wild and stripping eggs in a hatchery facility. Eggs are incubated in McDonald jars (see **Glossary**). Fry can be stocked in fertilized ponds for growth to fingerlings or offered artificial feeds immediately while held in troughs. Poor survival (>30%) can be expected when artificial feeds are used for rearing fry. Foodfish culture is limited by fingerling survival.

Markets for this fish may be available, but little market research exists. Fingerlings may have great value for stocking sportfish ponds and possibly for mitigation purposes.

Smallmouth bass are present in most of the major drainages in New Mexico. Smallmouth bass culture is restricted primarily to fingerling production. Spawning is most frequently conducted in ponds. Gravel nests are placed around the edge of the broodfish pond and spawning occurs naturally. Fry are collected before swimming up off the nest and transferred to fertilized nursery ponds. Fingerlings are harvested in approximately thirty days at a size of one to two inches. Intensive smallmouth bass culture using artificial feeds is possible but has not been shown to be economically feasible.

Fingerling smallmouth bass are a valued commodity in some states for stocking sportfish lakes. Other market opportunities may be found in mitigation projects.

Warmwater Species

Channel catfish are found throughout New Mexico. Aquaculture of this species is conducted in many states in the U.S., including Texas and Arizona. Channel catfish are spawned by placing spawning cans in broodstock ponds. Eggs are collected from the cans and incubated in paddlewheel troughs (see **Glossary**). Fry are stocked in fertilized nursery ponds and fed artificial feeds through grow-out. Research conducted in New Mexico indicates saline water found in the state can be used to rear catfish.

Market size for channel catfish is one pound. In the Southeast where catfish culture is conducted on a large scale, the break-even price (i.e., the price to cover all costs) is approximately $0.55/lb. Strong markets exist nationwide for channel catfish, but large production from the Southeast means other producers must differentiate their product(s) and find niche markets.

Largemouth bass are one of the most highly sought after sportfish in the U.S. They are present in all of the major drainages of New Mexico except the Tularosa Basin. Production is limited to fingerlings due to difficulties in training largemouth bass to artificial feeds. Like smallmouth bass, largemouth bass are spawned in ponds. Fry are removed and stocked in fertilized ponds for culture to two to three inches.

Fingerlings are usually sold to private pond owners for sportfishing. Additional markets may include state and federal agencies. Prices for fingerling largemouth bass are high. Prices for larger fish increase significantly, but losses to cannibalism also are high, limiting production.

Bluegill are found throughout New Mexico. They are traditionally used as a forage base for largemouth bass in sportfish ponds. Fingerlings are produced through natural spawning in ponds. Bluegill can be easily trained to accept artificial feeds.

Fingerling bluegill are marketed to private pond owners. Little market is available for food-sized bluegill. Potential may exist to rear bluegill as foodfish, but little research has been conducted in this area.

White crappie are found throughout New Mexico except in the Tularosa Basin. At this time, crappie culture is limited to fingerling production. Research, however, has shown that crappie can be trained to pelleted feeds suitable for use in grow-out to foodfish.

Broodfish are collected from the wild and may be spawned naturally in ponds or by stripping in the hatchery. Eggs collected by stripping are incubated in McDonald jars. Fry from either spawning method are reared in fertilized ponds to a minimum size of one inch. Feed training can be initiated at this time with grow-out culture in ponds or raceways. Significant care should be taken when transferring or transporting crappie because they are highly sensitive to any handling.

Markets are available for fingerling crappie. A foodfish market is not yet feasible due to the difficulty in rearing large numbers in intensive systems.

Crayfish, or crawdads, are found throughout New Mexico in irrigation ditches, rivers, and ponds. They are cultured extensively in shallow ponds in Louisiana and Texas. Crayfish are frequently double-cropped with more traditional agricultural crops (e.g., rice).

Crayfish are spawned in the culture pond, and offspring are allowed to grow on natural or artificial forage to a marketable size, with the brood crayfish remaining in the pond. Harvesting is conducted with baited traps.

Markets for crayfish exist in many areas of the U.S., but competition from Louisiana and Texas producers will make product differentiation and niche marketing important to any New Mexico producer.

NON-NATIVE, NON-INDIGENOUS SPECIES WITH AQUACULTURE POTENTIAL IN NEW MEXICO

New Mexico has a large number of fish species with aquaculture potential. There are also several non-native, non-indigenous (or exotic) aquaculture species with proven potential that could be raised in New Mexico. These species include tilapia, the Chinese carps, and penaeid shrimp. This section will discuss, in general terms, the culture methods and markets for these exotic species.

It is important to note that culture of exotic species in New Mexico is controlled by the New Mexico Department of Game and Fish. An "Application for Importation of Exotic Species" must be made to and accepted by the Department before importing or beginning culture of any non-native, non-indigenous species.

Tilapia is the common name applied to three genera of fish in the family Cichlidae. The species that are the most important for aquaculture include the Nile tilapia, the Mozambique tilapia, and the blue tilapia. Tilapia are similar in appearance to bluegill. They were imported from Africa to many parts of the world. Production of tilapia is centered in the southern U.S., the Caribbean, and Central America. In the U.S., tilapia are also cultured in colder climates using indoor recirculating systems or geothermal spring water.

Tilapia are warmwater fish. They are disease resistant and tolerant of poor water quality, and they grow well in most aquaculture systems. Culture methods ranging from open ponds to cages to water recirculating systems have been used to successfully rear tilapia. Tilapia have also been cultured successfully in saline water. They are also the species of fish most commonly grown in both hobby and commercial aquaponics systems.

Tilapia will reproduce in most aquaculture systems. Reproduction is both a benefit and a hindrance to production of this species. It is a benefit because fingerling production is simplified. It is a hindrance because tilapia spawn frequently. The high spawning frequency slows growth, and the increased fish mass due to the fry in the culture unit leads to stunting in the population.

Markets for tilapia are growing worldwide. U.S. tilapia production grew from more than 2,000 metric tonnes (live weight) in 1991 to over 9,000 mt in 1998. Producer markets are available in niche markets or, if production is large enough, in larger outlets.

Chinese carps are, as their name implies, native to Asia. Carps traditionally cultured include bighead carp, silver carp, common carp, grass carp, and mud carp. In China, where these fish were first cultured, all carp species are reared together in a single pond. This system of culture is called "polyculture." Polyculture yields can be higher than those obtained in monoculture systems. Polyculture of carp with other species, including tilapia, has been successful.

The Chinese carps are warmwater to coolwater species. Reproduction is induced by hormone injection, and eggs are incubated in McDonald jars or zug jars (see **Glossary**). Fry are reared in fertilized ponds. Artificial feeds can be used to rear these fish to foodsize in ponds. Carp can also be cultured in raceways with artificial feed.

Markets for foodsize carp are limited to ethnic markets in large cities. Interest in canning bighead carp to compete with canned tuna has developed and may prove to be a viable market. Larger markets for foodsize carp in the U.S. are limited by consumer dislike for the large number of bones found in the flesh of carp. Grass carp, however, are a high-value fish. Grass carp are used to control aquatic weeds in many ponds and lakes throughout the U.S. This use has created an increasing market for grass carp.

Penaeid shrimp are cultured in Texas, Central and South America, Japan, Thailand, and along the coast of Asia. In Texas, penaeid shrimp are cultured along the Gulf coast and in west Texas. West Texas shrimp culture uses saline groundwater from the Permian Basin to supply grow-out ponds.

Penaeid shrimp are cultured in warmwater ponds. Post larvae (PLs) are stocked into ponds and fed artificial feeds. Spawning is usually conducted in more controlled environments (e.g., indoor tanks). U.S. shrimp culture, therefore, is divided into two parts: hatchery and grow-out. Hatchery operations supply PLs to producers worldwide, while grow-out facilities provide foodsize shrimp to the worldwide market.

Markets for shrimp are worldwide. Shrimp are the most popular seafood eaten in the United States. It represents over 25% of the nation's annual per capita seafood consumption (seafoodhealthfacts.org, 2010). Declining wild stocks are increasing the demand for farm-raised shrimp. In turn, the increased demand for farm-raised

Table 2. Temperature Ranges for Cultivating Various Aquaculture Species		
Aquaculture Species	**Temperature Range (°F)**	**Optimal Temperature Range (°F)**
Kokanee salmon	33–70	50–59
Rainbow trout	33–78	50–60
Brown trout	33–78	48–60
Northern pike	33–80	40–65
Striped bass	35–90	55–75
Channel catfish	33–95	70–85
Largemouth bass	33–95	55–80
Smallmouth bass	33–90	50–70
Bluegill	33–95	55–80
Goldfish	33–95	45–80
Penaeid shrimp	68–95	74–90

shrimp has increased the demand for PLs. Indoor intensive recirculating aquaculture systems (also known as zero-exchange) and aerobic systems operate with minimum water requirements, an issue of paramount importance in arid states such as New Mexico. These systems allow for the production of significant yields of fresh marine shrimp without the need for a coastal environment.

WATER TEMPERATURE REQUIREMENTS FOR NEW MEXICO FISH SPECIES

New Mexico has a wide array of climatic conditions: mountains, deserts, and river valleys. The aquaculture species to rear in New Mexico, then, are dependent on climatic conditions at the proposed site.

Table 2 outlines the overall and optimal temperature ranges of selected aquaculture species. A map dividing the state into regions defined by estimated monthly average water temperature and estimated growing season is provided (Figure 1). Water temperatures were determined using measurements collected by the U.S. Geological Survey and the Army Corps of Engineers on the reservoirs they control in New Mexico. Average temperatures, therefore, may be cooler in the summer months and warmer in the winter months than those observed in a small, shallow aquaculture pond. However, the observations will provide an indication of water temperatures that can be expected in each region. Each region is also briefly described in terms of its aquaculture potential, and a list of possible aquaculture species for the region is given.

Region Description And Potential Aquaculture Species List

Region 1 encompasses the northern portion of New Mexico. The growing season and temperatures are best suited to coldwater species: kokanee salmon, rainbow trout, and other trout species. Some coolwater species (e.g., northern pike) may also be cultured in the southern portion of this region. The region has significant water resources with good potential for aquaculture development.

Region 2 covers the middle portion of the state. The temperatures and growing season are best for coolwater species: striped or hybrid striped bass, walleye, yellow perch, and others. Some warmwater species can also be cultured in the southern reaches of this region (e.g., channel catfish). The majority of New Mexico's population is found in this area, and it may therefore be difficult to obtain water resources. Some saline water resources are available in the region.

Region 3 includes the area around Santa Rosa where artesian springs produce an abundant and constant flow of 61°F water. The region, therefore, is best suited to coolwater species: striped and hybrid striped bass, northern pike, yellow perch, and others. The constant water temperature provides a year-round growing season.

Region 4 is situated in and around the Gila National Forest. Water temperature and growing season are most appropriate for coldwater species: kokanee salmon and trout. However, limited private land ownership and the presence of the endangered Gila trout in the area may limit aquaculture development.

Region 5 includes the southern and most of the eastern portion of New Mexico. This region is best suited to the culture of warmwater species: channel catfish, largemouth bass, bluegill, crayfish, and possibly penaeid shrimp. Significant saline water resources can be found throughout this region.

Note: Variation will occur in each region depending on exact location. The map and information given here should only be used as a guide. Each proposed aquaculture site must be analyzed independently.

EXPECTED YIELDS FOR AQUACULTURE SYSTEMS IN NEW MEXICO

Yield of an aquaculture system is limited by a series of factors. As each of these factors is overcome by the appropriate management technique, yields increase until the next limiting factor is reached. Yield of an aquaculture system, therefore, depends on the level of management intensity.

Aquaculture systems can be managed at levels ranging from no management to intensive management. No management, or extensive culture, entails stocking fish into a pond and allowing fish to feed on natural forage in the water. Yield obtained from this system is limited by the food supply in the water. The next level of management intensity entails feeding formulated, complete feeds. Yields with feeding will increase significantly over those obtained in the extensive culture system. Adding aeration to the feeding system will overcome low oxygen

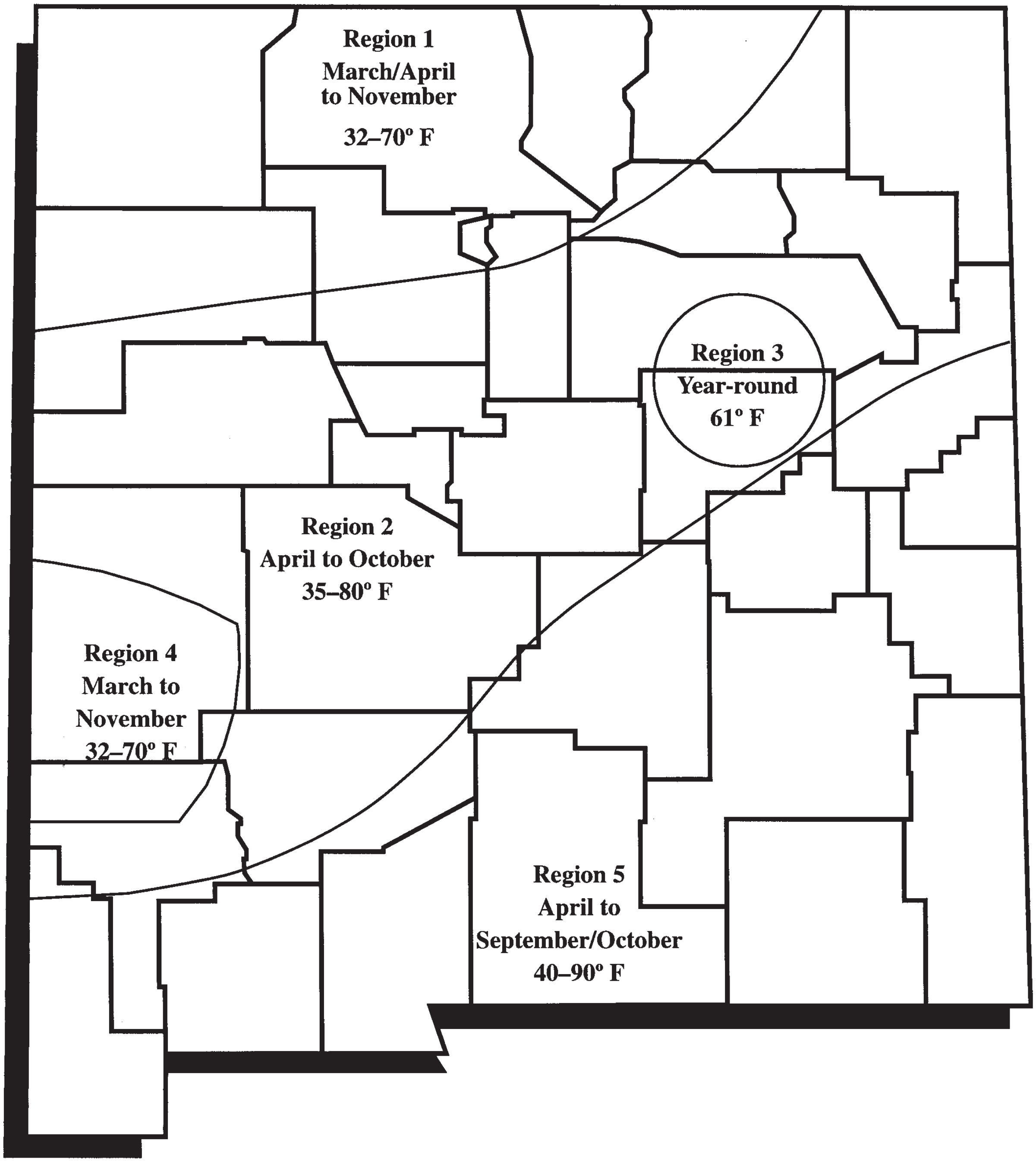

Figure 1. Map of estimated growing season and average maximum and minimum water temperatures for distinct regions in New Mexico.

Note: Temperature variation due to elevation changes in each region is not reflected.

Table 3. Expected yields for aquaculture systems.				
Species	Extensive (lb/ac)	Complete Feed (lb/ac)	Complete Feed and Aeration (lb/ac)	Complete Feed, Aeration, and Water Exchange (lb/ft^3)
Channel catfish	54	3,570	5,800	6
Striped bass	67	1,560	4,450	3
Rainbow trout	89	1,785	4,460	6
Penaeid shrimp	<446	1,070–1,740	3,570–19,540	0.5

content in the water and allow for a further increase in yield. Finally, yields can be increased through intensive management of the aquaculture system. Here, complete feeds are used, aeration is applied, and poor water quality is overcome by flushing water through the system. Yield and management input will be high at this intensive level of culture.

Different levels of management can be observed in aquaculture situations seen throughout New Mexico. Extensive culture is exemplified by private sportfish ponds stocked at a low level and used for private fishing. Pond culture of fish with feeding, and occasionally aeration, is practiced at the Dexter National Fish Hatchery in Dexter, NM. The intensive level of culture is observed at state hatcheries, where rainbow trout are cultured in raceways with complete feeds and continuous water flow.

Yields given in Table 3 represent averages obtained from research at various locations. Yields in New Mexico will vary depending on water quality and the culture system used. These yields, however, can be used as a basis for planning.

AQUACULTURE SUCCESSES, FACILITIES TO VISIT, AND PUBLICATIONS

Aquaculture has been very successful in many states in the U.S. Mississippi is probably the best known example of successful aquaculture development. However, states closer to New Mexico also have developed strong aquaculture industries.

Texas has a diversified aquaculture industry throughout most of the state, producing catfish, crayfish, sportfish fingerlings, and marine shrimp. Aquaculture in Texas is a $20 million dollar industry that is projected to reach $1.5 billion.

Arizona is another state close to New Mexico that has taken advantage of aquaculture to strengthen its agricultural sector. Arizona's industry produces catfish, trout, sportfish fingerlings, tilapia, and crayfish. One focus in Arizona is integration of aquaculture and traditional irrigation farming. Farms devoted strictly to aquaculture, however, are seen in Arizona.

Aquaculture Facilities To Visit In New Mexico

New Mexico has two federally operated hatcheries and six state-run hatcheries.

Federal Fish Hatcheries

Dexter National Fish Hatchery and Technology Center
P.O. Box 219
Dexter, NM 88230
(575) 734-5910
(Specializes in the culture of endangered species in ponds and raceways.)

Mescalero National Fish Hatchery
P.O. Box 247
Mescalero, NM 88340
(575) 671-4401
(Rear rainbow trout in raceways.)

State Fish Hatcheries

Glenwood State Fish Hatchery
Box 67
Glenwood, NM 88039
(575) 539-2461
(Rear rainbow trout in raceways.)

Lisboa Springs State Fish Hatchery
Route 2, Box 61
Pecos, NM 87552
(505) 757-6360
(Rear rainbow trout in raceways.)

Parkview State Fish Hatchery
P.O. Box 7
Los Ojos, NM 87551
(575) 588-7307
(Rear rainbow trout in raceways.)

Red River State Fish Hatchery
P.O. Box 410
Questa, NM 87556
(575) 586-0222
(Rear rainbow trout in raceways.)

Rock Lake State Fish Hatchery
HCR 69, Box 58
Santa Rosa, NM 88435
(575) 472-3690
(Rear rainbow trout in raceways.)

Seven Springs State Fish Hatchery
Mountain Route, Box 66
Jemez Springs, NM 87025
(575) 829-3740
(Rear rainbow trout in raceways.)

Demonstration facility for intensive, zero-exchange heterotrophic shrimp culture system:
New Mexico State University Leyendecker Farm
Las Cruces, NM 88003
Contact: Dr. Tracey Carrillo, (575) 646-3125

Aquaculture Facilities To Visit In Other States

Texas A&M Mariculture Port Aransas
Contact: Dr. Addison L. Lawrence, Project Leader
1300 Port Street
Port Aransas, TX 78373
(361) 749-4625
(Researches a variety of aquaculture technologies.)

Aquaculture Publications

Trade Journals, Newspapers, and Magazines

Aquaculture Magazine
203 S St. Mary's Street, Ste. 160
San Antonio, TX 78205
(210) 229-9036; www.aquaculturemag.com
(Relays scientific findings to industry. Also publishes an annual buyer's guide to aquaculture products.)

Aquaculture News
http://www.seafoodsource.com/news/aquaculture
(Covers breaking news articles that pertain to the global aquaculture industry.)

The Catfish Journal
1100 Highway 82 E, Suite 202
Indianola, MS 38751
(601) 956-6702; www.catfishfarmersofamerica.com
(Focuses mainly on the catfish industry and related market and government developments. Published by the Catfish Farmers of America.)

Fish Farming International
U.S. Office
701 Dexter Ave. N, Ste. 410
Seattle, WA 98109
(206) 282-3474; http://fishfarminginternational.com
(Covers international fish farming.)

Fish Farming News
PO Box 600
Deer Isle, ME 04627
(800) 989-5253; http://fish-news.com/ffn/

Trout Talk
PO Box 1647
Pine Bluff, AR 71613
(870) 850-7900; www.ustfa.org/trout-talk/
(Official publication of the United States Trout Farmers Association.)

Scientific Journals

Aquaculture
www.journals.elsevier.com/aquaculture/

Aquacultural Engineering
www.journals.elsevier.com/aquacultural-engineering/

Journal of Aquatic Animal Health
www.tandfonline.com/loi/uahh20

Journal of the World Aquaculture Society
http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1749-7345

North American Journal of Aquaculture
www.tandfonline.com/loi/unaj20

GLOSSARY

Fingerlings. Fish ranging in size from one inch to eight inches.

Foodfish. Fish large enough to be sold for consumption. Food size is species specific, but generally ranges from 0.75 to 1.5 pounds.

Fry. Fish ranging in size from newly hatched to approximately one inch.

Induced spawning. A method to spawn fish that requires injecting hormones into the fish to bring about ripeness of the gametes.

McDonald jar. A device used to rear fertilized fish eggs. The jar is approximately eighteen inches tall and six to eight inches in diameter. The bottom of the jar is rounded. A center tube allows water entering the jar to be released on the rounded bottom. Fertilized eggs are placed in the bottom of the jar. Fry are allowed to exit the jar with the flow via a spout located at the top of the jar. Fry exiting the jar typically enter aquaria or troughs.

Paddlewheel trough incubator. A device used to rear fertilized fish eggs. This device consists of a trough, hardware cloth baskets, electric motor, and a shaft with paddles. Eggs are placed in the trough in baskets. Paddles are located between baskets and are turned on the shaft by the motor to maintain well-oxygenated water near the eggs.

Stripping. A procedure to remove eggs or sperm from fish. A fish is held and gentle pressure is applied to the sides of the fish in order to release gametes.

Vertical tray incubator. A device used to rear fertilized fish eggs. The incubator consists of stacked trays that hold eggs. Water enters the incubator at the top and passes downward through each successive tray.

Zug jar. A device used to rear fertilized fish eggs. The jar has steep sides (>45°) and water enters via a valve at the bottom. Fertilized eggs are placed in the bottom of the jar.

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