Aquaculture Development Potential in Arizona - A GIS Based Approach

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ABSTRACT

Arizona aquaculture production in 2000 was 680 metric tons. Finfish including tilapia, bass, trout and catfish accounted for 590 metric tons, while other culture organisms, primarily marine shrimp rounded out production. The continued success of the aquaculture industry in Arizona is dependent on the success of individual farms. By increasing the chances of success through the proper selection of species, location and culture practices, failure in aquaculture and therefore a negative association can be avoided.

A GIS-based model enabling extension personnel, land-use managers, farmers and other interested persons to evaluate potential aquaculture sites in Arizona has been developed. The primary objective of the project was to synthesize readily available data into a model capable of predicting locations in which aquacultural development could be economically and environmentally viable. Data layers included in our model can be grouped into the following categories:

- Site Suitability
- Water Quality
- Land Ownership
- Infrastructure

To test the model's predictive power, existing aquaculture farms were marked on a map generated by the model. Of the 31 farms depicted on the map, 21 occur in areas predicted to have suitable slope and sufficient soil clay content. Of the 10 that occur in areas not predicted as suitable, 5 have the correct slope, 3 have suitable soils and only 2 have neither.

Further testing included the generation of species specific (tilapia, trout, bass, catfish and marine shrimp) maps with the locations of exiting operations plotted. Of the five models tested, marine shrimp farms were most likely to occur in areas predicted as suitable by the model (67% correct). Trout farms were least likely to have their sites predicted as suitable by the model (27%). Bass, catfish and tilapia farm locations were predicted accurately 65%, 57% and 62% of the time, respectively.

BACKGROUND

Interest in aquaculture in the state of Arizona is on the rise. Currently, there are over 30 licensed aquaculture operations in Arizona, including finfish producers, marine shrimp producers, research/educational facilities and distributors. Arizona aquaculture production in

2000 was 680 metric tons. Finfish including tilapia, bass, trout and catfish accounted for 590 metric tons, while other culture organisms, primarily marine shrimp, rounded out production (Toba and Chew 2001).

The Arizona aquaculture industry has weathered many startups and sadly almost as many failures. The lack of a strong industry and the high, new-farm failure rate can be a deterrent to those farmers and investors interested in entering into new projects. Efforts must be made, therefore, to ensure that present and future aquaculture ventures will be successful.

Geographical Information Systems or GIS have been described as "an integrated assembly of computer hardware, software, geographic data and personnel designed to efficiently acquire, retrieve, analyze, display and report all forms of geographically referenced information geared towards a particular set of purposes" (Nath et al. 2000). Kapetsky et al. (1990) demonstrated that a GIS could be used to identify potential areas for aquaculture development on a statewide scale. Using their work as a model, and considering the rising interest in aquaculture in Arizona, we believe that a GIS based model of aquaculture development potential for the state would be a valuable planning tool.

Proper selection of species, location and culture practices can greatly improve the success rate of new aquaculture ventures. Unfortunately, owing to the small industry presence in the state and the long history of more traditional agriculture production, many extension personnel in Arizona are presently ill equipped to answer aquaculture related questions. The primary objective of this project, therefore, was to develop a GIS based model capable of predicting areas in Arizona that would be suitable for aquaculture development and expansion, in hopes of reducing the likelihood of a new venture failing due to improper site selection.

MODEL DEVELOPMENT

Our model was designed to enable extension personnel, land-use managers, farmers and other interested persons who may be unfamiliar with the specific requirements of aquaculture to evaluate potential farm sites in Arizona for aquaculture development and expansion. Existing data sets were collected from a variety of independent sources and synthesized to meet the needs of this project. Each data set contains specific information, that, while important, does not necessarily give the viewer all of the necessary information to evaluate a potential site for aquaculture development. It is not until you are able to evaluate all of the data sets together that relationships and patterns emerge.

Seven individual models were produced, one corresponding to each of the five most common Arizona aquaculture species (bass, catfish, marine shrimp, tilapia and trout) and two general models, designed to offer more flexibility in site selection. These non-species specific models allow the database to be queried by user-defined limits placed on the various parameters of the model and/or location (coordinates or city name). All data contained in the model were manipulated using ArcView GIS 3.2 (Environmental Systems Research Institute, Inc., Redlands, CA).

Data incorporated into the model were chosen to address some specific concerns facing a new aquaculture venture. Due to the complex construction needs of recirculating and raceway aquaculture facilities, model parameters were selected for inclusion based on the construction of an outdoor, pond-based production system. Therefore, altering these hypothetical design parameters could significantly influence the applicability of the data contained in this model.

Data sets selected were grouped into four major areas, site suitability, water quality, infrastructure and land ownership (Table 1).

Site Suitability

The primary data sets describing site suitability were the slope of the land and the soil properties. These are important when considering the feasibility of constructing an outdoor pond system. Average slopes were calculated and used in the site evaluation. An average slope of <8% was considered suitable. Similarly, soil clay contents between 15 and 50% were chosen as suitable for pond construction. Slope data and soil property data were obtained from the State Soil Geographic (STATSGO) Data Base, maintained by the U. S. Department of Agriculture, Soil Conservation Service.

Water Quality

Surface water sources are often not available in the arid southwest. Therefore, in Arizona aquaculture operations commonly require the use of groundwater. The water quality database used was the Groundwater Site Inventory Database (GWSI), published by the Arizona Department of Water Resources. Specifically, water temperature, pH, alkalinity and total dissolved solids data were used, as each commonly cultured species has specific water quality concerns (Table 2). Water quality requirements are species specific, so were modeled accordingly. Total dissolved solids affect primarily the culture of marine shrimp farms and were not included in the other species' maps. With the exception of a few locations in the state, water pH was adequate for aquaculture, so only pH extremes are indicated in the models.

Infrastructure

Infrastructure data are important to the assessment of potential aquaculture sites because they address the operational viability of a new farm. It is certainly beneficial to have easy access to an adequate labor pool, local markets and power delivery systems, but the obstacle that their absence presents can be overcome in innumerable ways. Locations of roads and interstates, power transmission lines, railroads and towns with their respective populations are presented in this GIS model primarily for reference (Table 1). Infrastructure data were obtained from the Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) database and the Arizona Land Resource Information System (ALRIS) database.

Each individual that uses this model will likely have their own ideas as to what infrastructure is necessary and which is not. Unfortunately there is no easy formula that can predict the success of a new aquaculture venture based on the existing infrastructure to help make siting decisions. Therefore, specific infrastructure limitations that could exclude otherwise suitable areas for aquaculture development were not built into the model as in the case of the water quality, slope and soil clay content data. Our hope is to present this information so that decision makers will be better informed.

Land Ownership

Land ownership data was also obtained from the ALRIS database. Ownership has been summarized into three categories: private, government or reservation. Government owned land comprises both state and federal holdings, including parks, monuments, military bases, etc. With few exceptions this land is closed to development. There are instances where federal lands have been leased for private use, namely cattle ranching, however, we are not currently aware of any private aquaculture or other confined animal feeding operations being built and/or operated on leased federal lands.

Private land is considered any land owned by individuals or corporations, and as such is seen as a possible location for aquaculture development. Reservation land is owned by one of the many Native American tribes in Arizona. While this land is not available for sale, there are at least two established fish farms that have been built on land leased from one of the tribes. Additionally, a few of the tribes have expressed an interest in developing aquaculture projects of their own.

MODEL TESTING

Species-specific models were tested against the extant aquaculture facilities in the state. Maps corresponding to each of Arizona's five commonly cultured species were generated with the currently licensed farms plotted on each. Of the five models tested, marine shrimp farms were most likely to occur in areas predicted as suitable by the model (67% correct). Bass, catfish and tilapia farm locations were predicted accurately 65%, 57% and 62% of the time, respectively. Trout farms were least likely to have their sites predicted as suitable by the model (27% correct). Figure 1 summarizes this information.

Given the low degree of accuracy obtained from the trout model, a closer look at the GIS model seems natural. When you keep in mind, however, that one major assumption we made in building the model was that parameters included were chosen specifically for the construction of a hypothetical, pond based culture system, this lower level of accuracy for trout is understandable. Two factors were quickly singled out. First, trout are much more likely to be raised in raceways than in a pond based system and secondly, trout are commonly cultured in areas that have more hilly terrain. These two factors alone (soil clay content and slope) would make many real world trout farm sights be overlooked by our GIS model.

CONCLUSIONS

Overall, the GIS based model was 56% accurate in its ability to predict the locations of licensed farms. We believe that this is largely due to the fact that the farms were plotted based on the city in which they are licensed, not the actual farm locations (latitude and longitude) and we feel that the model's accuracy would be significantly greater had farms been plotted by their actual locations. Latitude and longitude data are not currently available for all of the licensed farms in Arizona, so it was decided that plotting farm locations should done using one consistent method. Future refinement of the model will include a more accurate 'test' of the models.

To offer one example, a farm that we have a strong collaborative relationship with is known to be approximately 16 km north of the location at which our model has 'plotted' the location. This particular farm falls just to the south of the predicted area on the map generated by the GIS model. Had this farm been plotted by its coordinates instead of its mailing address, it would fall directly in the area predicted by our model, increasing the accuracy.

Regardless, the results do suggest that this model has sufficient predictive power to help extension personnel, land-use managers, farmers and other interested persons who may be unfamiliar with the specific requirements of aquaculture to evaluate potential farm sites in Arizona for aquaculture development and expansion. It is important to keep in mind that the goal of this model is not to eliminate the need to make a site visit prior to the initiation of an aquaculture project, but rather to help refine the search area by eliminating those areas that are grossly inadequate. Arming interested individuals with this tool can potentially reduce the failure of new aquaculture ventures by improving site selection and thereby improve the success of the aquaculture industry in Arizona.

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Table 1. Data categories included in the development of the GIS model and the specific data sets comprising each category.

Data Category	Data Used
Site Suitability	Land slope
	Soil clay content
Water Quality	Temperature
	Alkalinity
	pH
	Total dissolved solids
Infrastructure	Interstates
	Roads
	Towns w/population
	Power lines
	Railroads
Land Ownership	Private
	Government
	Reservation

Table 2. Water quality parameters included in the GIS model and the acceptable ranges for each of the common aquaculture species grown in Arizona.

	Species				
Water Parameter	**Trout**	**Tilapia**	**Bass**	**Catfish**	**Shrimp**
Temperature (˚C)	10 - 15	26 - 31	25 - 30	26 - 30	21 - 32
pH	6 - 9	6 – 9	6 - 9	6 - 9	6 - 9
Alkalinity (mg/L)	40 - 140	40 - 140	40 - 140	40 - 140	40 - 140
Total Dissolved Solids (ppt)	N/A	N/A	N/A	N/A	>0.5

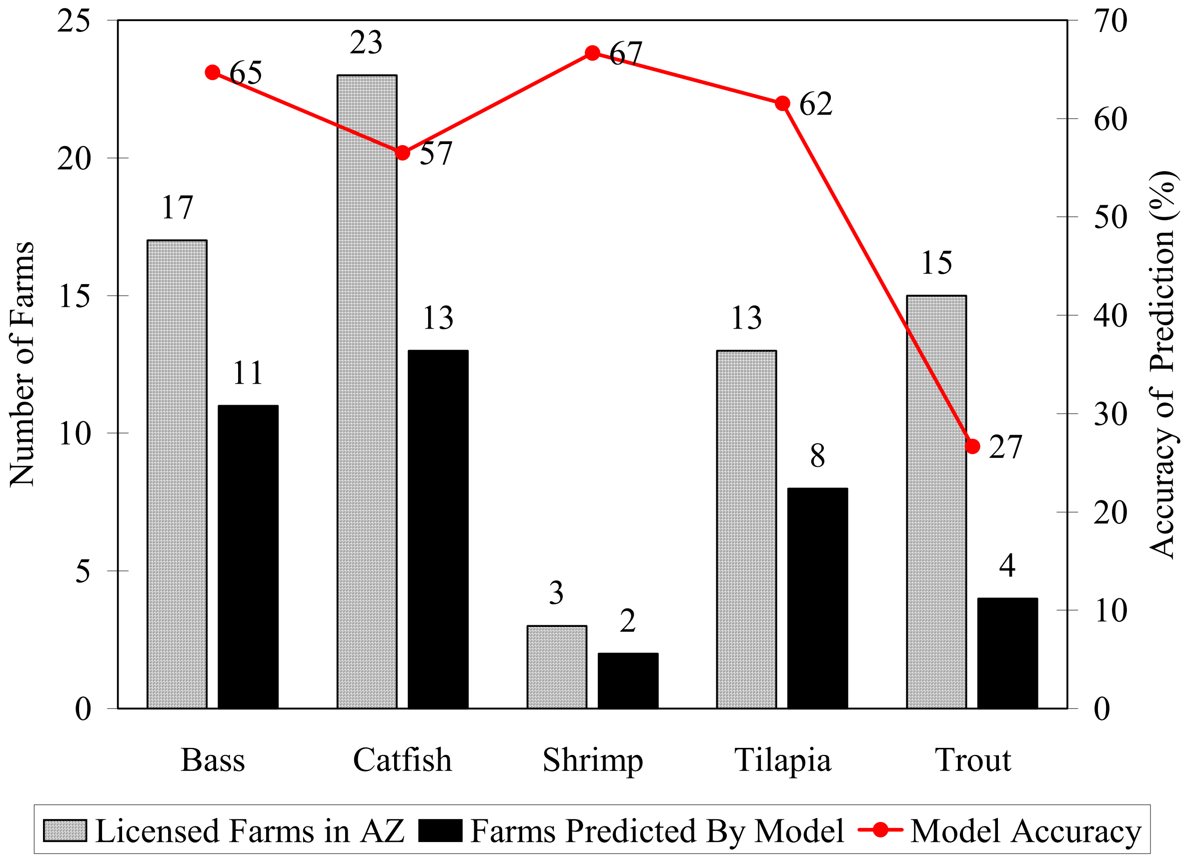

Figure 1 Graph depicting the accuracy of the five, species specific GIS models developed, showing the number of extant aquaculture facilities, the number of farms that fall in the 'predicted' area and the accuracy of each model.