A TIME SERIES APPROACH TO ESTIMATING THE ECONOMIC IMPACTS OF EXOGENOUS EVENTS ON A LOCAL ECONOMY

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Abstract.—Achieving the economic impacts associated with recreational fishing depends considerably on the maintenance of high-quality fishery resources. As fishing quality declines at a lake, anglers are likely to divert their activity to other water bodies reachable at similar travel cost. In 2001, a series of the abrupt events, namely, an outbreak of harmful algal blooms, occurred at Possum Kingdom Lake in Texas. As various fish populations at the lake were affected and catchability reduced, we sought to estimate the *negative impacts* of the golden algae events as an illustration of estimating damage assessment. Using a time series intervention analysis, we demonstrated that inserted interventions had negative economic impacts. The intervention time series method provided a useful tool for analyzing the influence of external events on various time series of interest. Further, other approaches were suggested for monitoring recreational fishing activity and understanding related economic impacts at recreational fishing lakes.

1.0 INTRODUCTION

Recreational fishing is big business in the United States. About 1,842,000 individuals (residents and non-residents) participated one or more days per year in freshwater fishing and spent an estimated $750,870,000 overall per year in the state of Texas in 2001 (U.S. Fish and Wildlife Service and U.S. Bureau of the Census 2003). Recreational fishing is also an important part of the state's tourism industry with local economic impacts as anglers are lured from one region of the state to another to pursue their activity (see, e.g., Anderson et al. 2003, Thailing & Ditton 2000) or as out-of-state anglers and their expenditures are attracted to high-quality recreational fishing in Texas (see, e.g., Chen et al. 2003). However, maintaining direct and indirect economic impacts associated with recreational fishing depends entirely on maintaining high-quality fishery resources (high catch per unit of effort and all of the factors that play a role in this including water quality, water quantity, habitat, stocking levels, etc). If fishing quality declines at a particular lake in a measurable way, anglers may divert their activity to other water bodies reachable at similar travel cost, which can result in major economic consequences for local businesses in the original area.

This situation happened to some extent starting in January through July 15, 2001 when there was a confirmed outbreak of golden algae (Prymnesium parvum) at Possum Kingdom Lake (PKL) in Texas. This algal species is normally found in estuarine areas and produces a toxin fatal to fish when it becomes the dominant algal species in a water body. According to the Texas Parks and Wildlife Department (TPWD), at least 200,027 fish, including many large highly sought after game fish, died during this period (TPWD 2005). From January 1, 2003- April 21, 2003, there was another confirmed golden algae bloom at PKL, resulting in a further loss of an estimated 1,475,212 fish killed (TPWD 2005). Another other event, which happened in the spring of 2005, was not incorporated in the study due to its ongoing process.

As various fish populations at the lake are affected and catchability (or perceived catchability) is reduced, we would expect recreational fishing activity at the lake by non-residents (who are more likely to make substitution choices elsewhere) and residents alike to decrease. Accordingly, we would expect reduced angler expenditures, which will impact the various sectors of the tourism economy in the three-county local study area (i.e., Palo Pinto, Stephens, and Young counties).

There is usually little opportunity to implement studies of external events with negative consequences and their economic impacts. Accordingly, most efforts to estimate the associated negative economic impacts are often "guesstimates" at best because appropriate data were not collected before, during, and following the events. In addition, the potential presence of confounding factors should be recognized from the outset. Typically, an anecdotal information approach appears to be used most often, primarily for helping the media to understand and report harmful algal bloom (HAB) events and their effects. Typically, some casual observations or unscientific “surveys” are made immediately after the event based on a limited number of observations and then extrapolated to the population of business owners in the region.

In the absence of a feasible study design for estimating economic impacts, the best way to assess the economic impacts of exogenous events on a local economy may be through an empirical modeling process using a time-series approach. While a time series approach typically makes use of either single (i.e., univariate) or multiple time-series variables (i.e., multivariate), a univariate approach has been adopted most often due to the ease of modeling involved and limited data availability for using a multivariate approach (Enders 1995). Accordingly, the negative economic impacts of golden algae at PKL or other HABs can probably best be estimated with a univariate approach, namely, by detecting the irregular variations or patterns of economic variables as a result of the event.

The purpose of this study was to demonstrate the effectiveness of a time series approach, namely, intervention analysis, for estimating the negative economic impacts of exogenous events on the economy of the adjacent study area. In particular, study objectives were to estimate the extent of economic impact of the outbreak and continued presence of golden algae at PKL on the local three-county area during a particular time period. Additionally, we sought to suggest a protocol of approaches for monitoring recreational fishing activity and related economic impacts at PKL and for recreational fishing lakes elsewhere in the future.

2.0 METHODS

2.1. Data Collection

Due to a lack of necessary primary data prior to exogenous events, time-series secondary data were most desirable for situations like this one. Two time-series secondary data sets with coverage of relevant variables were acquired from the Texas Comptroller of Public Accounts (TCPA) and TPWD. Data for county-level gross sales and state tax on total expenditures were obtained from TCPA. We used five tourism-related SIC code categories for the three-county study area for the period starting the first quarter of 1986 to the second quarter of 2004. The SIC codes included the expenditure amounts at grocery stores, eating and drinking places, retail stores not else classified, hotels and motels, and miscellaneous amusement and recreation services. The original SIC codes used were adjusted to the IMPLAN codes for the economic impact analysis. Tourism and recreation related expenditures were adjusted to 2001 levels using the Dallas-Fort Worth consumer price index (U.S. Bureau of Labor Statistics 2005). Data for the number of visitors to PKL State Park were provided by TPWD from September 1996 to January 2005. The number of visitors was expressed in natural logarithms. The log transformation is beneficial in that it is easier to manage a log-transformed variable when the variance was proportional to change in the series level (McCleary & Hay 1980).

2.2. Economic Impact Assessment

The economic impact of recreation and tourism-related activities reflected in gross sales in five SIC-code categories in the three counties adjacent to PKL were further estimated using a regional Input-Output (I-O) model. An I-O model presents a comprehensive representation of the economic structure of a region and facilitates the identification of interrelationships among economic sectors. Thus, regional I-O models provide detailed and relevant information on consequences of expenditures on regional economies (Baaijens et al. 1998).

The economic impacts of recreation and tourism-related activities are best described in terms of changes in the amount of total output. Other estimates such as labor income and value added, which may provide information not incorporated here, were excluded intentionally from further analysis because they varied the same as the variable we used. Total output was used to estimate the degree of the interdependence of sectors; the larger the output multiplier, the greater the interdependence of the sector on the rest of the regional economy. To be as accurate as possible in analyzing the various economic impacts on the local or regional level, we used the I-O modeling developed by IMPLAN, a modeling technique designed for economic impact analysis (Minnesota IMPLAN User's Manual 1997).

2.3. Intervention Model Approach

To examine the impacts of the 2001 and 2003 golden algae outbreaks, intervention analysis was used. This was considered a useful model for evaluating the influence of an external event (or events) on the behavior of a time series (Enders et al. 1990). Intervention analysis is a two-step process. The initial step begins with the identification of a suitable model (typically ARIMA [AutoRegressive Integrated Moving-Average] models) that represents the pre-intervention periods (McCleary & Hay 1980). Then, the identified model is re-estimated using the full sample to test the effects of exogenous interventions on the level of time series. Interventions can be represented as "binary variables which indicate the absence of the state prior to the event and the presence of the state during and after the event" (McCleary & Hay 1980, p.143). Thus, a binary vector (or dummy variable) is introduced into the model to take into account the effect of an exogenous intervention. By comparing the level of post-intervention time series to that of pre-intervention series, the statistical significance of the effect can be assessed.

This model developed by Box and Tiao (1976) can be written as

$$Y_t = f(I_t) + N_t$$

where Y_t is an observed time-series and the function, $f(I_t)$ is the intervention component of the model. And, N_t represents the effect of other factors, which can typically modeled by the ARIMA component. Thus, while $f(I_t)$ explains the deterministic component between an intervention (or interventions) and the time series, N_t describes the stochastic process of the time series around the $Y_t = f(I_t)$ (McCleary & Hay 1980).

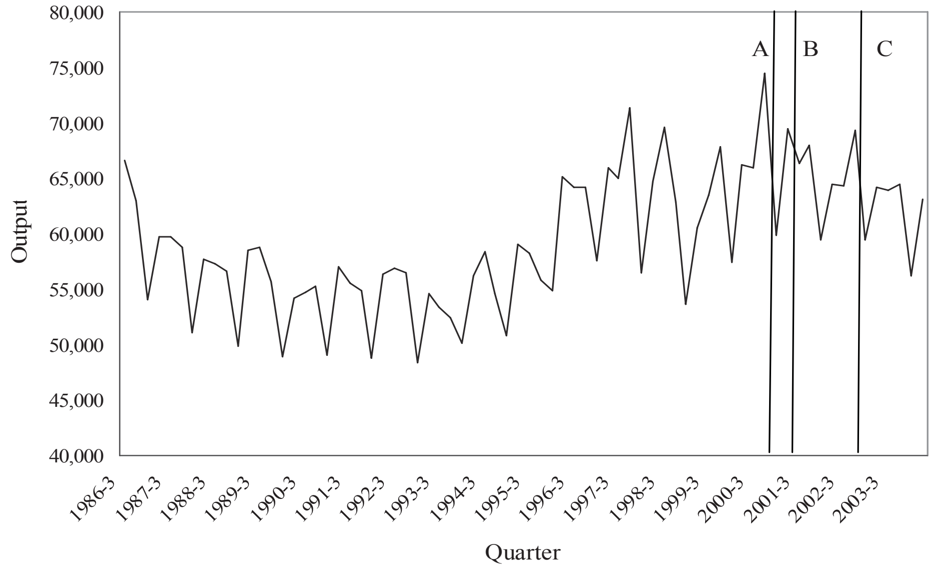
2.4. Noise Component (N_t)

The general principle of Box-Jenkins ARIMA modeling for the noise component involves the following steps: model identification, estimation, and diagnostic checking (Ender 1995, Johnston & DiNardo 1997). In the identification stage, the data are initially transformed to make them stationary. More specifically, differencing was performed to remove trend, and seasonal differencing was performed to remove seasonality. A tentative model was then determined by examining the autocorrelation function (ACF), which is a computation of the correlation of the observed series with consecutive lags of that series and partial autocorrelation function (PACF), a computation of the partial correlation of the observed series with consecutive lags of that series. Using the graphical inspection of ACF and PACF of the pre-intervention time series, a tentative model can consist of autoregressive (AR) or moving average (MA) components only, or both AR and MA components together. The parameters of AR and MA indicate weights attached to successive lags of the current and preceding observations and of random shocks, respectively.

After the specification of the tentative model with parameter estimation (i.e., calculation of the coefficients) has been derived, diagnostic checks of the model were performed to ensure all coefficients were significant and within the bounds of stationarity for the AR coefficients or invertibility for MA coefficients, and that residuals did not differ from white noise. White noise indicates that each value in the sequence has a mean of zero, a constant variance, and is serially uncorrelated (Enders 1995). Finally, to test the goodness of fit of the model to the data, we used two different model-selection criteria: Akaike's Information Criterion (AIC) and Schwartz's Bayesian Criterion (SBC).

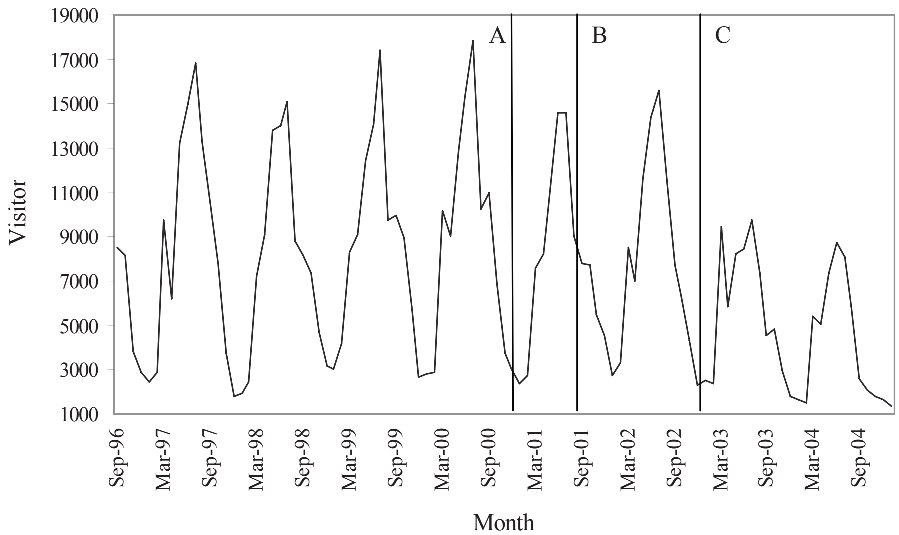
2.5. Intervention (I_t)

Once a successful ARIMA model was identified, an intervention component (or components) was added in the form of a binary variable. In contrast to the experimental construction of ARIMA model, specification of the intervention component should be executed based on *a priori* ideas (McCleary & Hay 1980). Thus, because an intervention is considered an exogenous input time series with the pre-specified onset of an event that disturbs the dependent time series in a bivariate model approach, the function of I_t is called a transfer function which specifies the dynamic transference from the independent effect of the input series (I_t) on the dependent output series (Y_t). Thus,



A: Golden Algae blooms in 2001   B: 9/11 Terrorist Attacks   C: Golden Algae blooms in 2003

Figure 1.—Total Economic Output in the Three-county PKL Study Area, 1986-2004.



A: Golden Algae blooms in 2001   B: 9/11 Terrorist Attacks   C: Golden Algae blooms in 2003
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Figure 2.—Number of Visitors to PKL State Park, 1996-2005.

transfer functions can capture intervention responses into a model to depict the dynamic transfer from the intervention to the dependent time series (Box & Tiao 1975, Wood 1988).

Given the abrupt onset of interventions like algal blooms, intervention processes of dynamic realization can be either temporary or permanent, depending on the duration of the interventions. Thus, the effects of the interventions were captured by the transfer function, $\frac{\omega B}{1 - \delta B}$, where ω is the parameter estimate of an intervention and δ is the dampening rate of the interventions. *B* is the backshift operator such that $BY_t = Y_{t-1}$. The parameters of the full impact assessment model were then estimated based on the tentative ARIMA model identified. When all required conditions (e.g., significant coefficients, white noise residuals, and bounds of system stability) were satisfied, impact parameters were tested for statistical significance and the entire model interpreted (McCleary & Hay 1980).

3.0 EMPIRICAL ANALYSIS

The data were first plotted (Figures 1 and 2) to scrutinize any irregular variations or patterns of the series. Three hypothesized interventions were then inserted into each

Table 1.—The impact of golden algae blooms on total output in the three-county study area

Model Component	Parameter	Coefficient	t- value	
Golden Algae Blooms in 2001	ω_{01}	-2,816,402.0	-1.315	
9-11 Terrorist attacks	ω_{02}	-2,208,659.2	-0.864	
Golden Algae Blooms in 2003	ω_{13}	-1,091,767.6	-0.464	
	AR lag 1	0.6930	6.330	
	Seasonal AR lag 4	-0.5940	-4.004	
	Seasonal AR lag 8	-0.3550	-2.321	
	AIC	1,970.94	SBC	1,983.30
	Q Statistics	Lags	Significance	
		16	0.124	

time-series variable: Golden Algae blooms in 2001, the 9-11 Terrorist Attacks in 2001, and golden algae blooms in 2003. The 9-11 terrorist attacks were inserted due to the significant economic impacts on the tourism industry nationwide (Lee et al. 2005). The pre-intervention observations in each time series before the first incident of golden algae blooms (January 2001) were used for the initial construction of the ARIMA model. To check stationarity of each time series, augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used. Although detailed results are not reported here, the results generally indicated that non-stationarity was present before differencing each time series and became stationary after the first differenced series of the variables. Significant AR and MA factors were utilized further to support that the residuals were white noise as well as seasonal differencing with seasonal fluctuations.

Once an initial ARIMA model was identified, the compound impact assessment models, each with three intervention components, were implemented after inserting each intervention individually. Despite white noise residuals in the ARIMA model with the pre-intervention period (i.e., the noise component), the full impact assessment model was not acceptable if residuals were different from white noise. The model-building procedure was done repeatedly until a parsimonious and statistically acceptable impact assessment model was generated (McCleary & Hay 1980). The Ljung-Box Q-statistic was used to test whether the residuals have a mean of zero, have constant variance, and are serially uncorrelated (i.e., white noise).

Parameter estimates and diagnostic statistics for total output are represented in Table 1. For the time series variable of total economic output in the three-county study area, ARIMA (1,1,0)(2,1,0)4 appeared to be the best model. All parameters were statistically significant and acceptable. Diagnostic checks with Q statistics at different lags also supported that the residuals were not different from white noise. While ignoring the noise component, the new equilibrium level is the pre-intervention mean plus $\frac{\omega_0}{1-\delta_1}$ as the first order transfer function. However, when δ is near zero (i.e., statistically non-significant), the total amount of change as a result of the intervention can be measured with the zero order transfer function. The difference between the zero order and first order transfer function is the value of δ, which determines the rate at which the process returns to its pre-intervention equilibrium level (McCleary & Hay 1980). After having tested the first order transfer functions at the outset, the zero order transfer functions seemed to be more appropriate for measuring each effect of the intervention components.

Table 1 illustrates the estimated impacts of the intervention events on the total output variable. Following the golden algae blooms in 2001, there was a zero order decrease of $2.8 million in total economic output calculated from five tourism-related SIC codes.

Table 2.—The impact of golden algae blooms on the number of visitors to PKL State Park

Model Component	Parameter	Coefficient	t- value	
Golden Algae Blooms in 2001	ω_{11}	-0.2287	-1.620	
	δ_{11}	0.7323	2.196	
9-11 Terrorist attacks	ω_{02}	-0.1951	-1.475	
Golden Algae Blooms in 2003	ω_{13}	-0.2187	-1.630	
	AR lag 4	-0.5631	-5.058	
	MA lag 1	-0.5465	-5.654	
	Seasonal MA lag 12	-0.4730	-3.815	
	AIC	98.83	SBC	115.76
	Q Statistics	Lags	Significance	
		16	0.087	

Compared to the average total economic output computed from the pre-intervention periods, the amount decrease is equivalent to a change in about 5 percent of total output. Not only did the estimated impacts show the directional consistency with our *a priori* expectations, but the intervention components were also statistically significant at 10 percent of one-tailed tests. After the 9-11 terrorist attacks in 2001, the parameter estimate of ω_{02} indicates that there was an immediate zero-order decline of total economic output by about $2.2 million. Additionally, with the parameter estimate of ω_{13} indicating -$1,091,768, the golden algae blooms in 2003 had a negative impact on total economic output of 1.9 percent despite its non-significance.

Table 2 presents parameter estimates and diagnostic statistics for the number of visitors to PKL State Park. Various examinations using autocorrelation functions such as ACF, PACF, and IACF and the associated Ljung-Box Q statistics showed that ARIMA $(||4||,1,1)(0,1,1)_{12}$ was the best model. By working in the time series with logarithm transformation, the interpretation of the model parameters was not straightforward any more. Therefore, because the parameter ω_0 was not directly interpretable in the logarithm transformation, it was more convenient to work with the term, $e^{(\omega_0)}$ which can be decoded as the ratio of the post-intervention series level to the pre-intervention series level (McCleary & Hay 1980). This ratio can be further transformed into the percent change in the expected value of the process as a result of the intervention (See more on this in McCleary & Hay 1980): Percent change = $(e^{(\omega_0)}-1)\times 100$. The percent change of the first order transfer function can be calculated in a similar manner. Although the impacts of two interventions (i.e., 9-11 terrorist attacks and golden algae blooms in 2003) on total economic output were not significant previously, all three interventions had a significant (at 10% of one-tailed tests) and negative impact on the number of visitors to PKL State Park.

While the first order transfer was identified for the initial algal blooms in 2001, the zero order transfer functions were more suitable for the other two interventions (i.e., 9-11 terrorist attacks and the golden algae blooms in 2003). Using the first order transfer function, the asymptotic change in log level of the algal blooms in 2001 was:

Total demand change = $\frac{\omega_1}{1-\delta_1}$ = -0.854. When this result was translated into percent change, we found that the algal blooms in 2001 explained a 57% reduction in visitor number. As the pre-intervention mean for the time series variable was approximately 8,344 visitors per month, this percent change represented a total reduction of approximately 4,793. The parameter estimate of ω_{02} from the 9-11 terrorist attacks in 2001 indicated there was an immediate zero-order decline. When the estimate, -0.195, was converted into the percent change, the terrorist attacks were accompanied by a 17.7 percent reduction in visitor numbers or a decline of about 1,489 visitors. Likewise, the parameter estimate of ω_{13} indicated a negative impact of the algal blooms in 2003 on the number of state park visitors (a decline of 19.6%). Accordingly, this reflected a drop of 1,615 PKL State Park visitors.

4.0 DISCUSSION

Using the intervention time-series model approach with economic impact assessment, three intervention components including two algal blooms were inserted to estimate the economic impacts of each event. Initially, the variable of total economic output was generated from the I-O model to provide a holistic depiction of the economic structure in the region. ARIMA (1,1,0)(2,1,0)4 was identified as the best model to fit into the data generation process. From the first golden algae bloom in 2001, total economic impact was estimated as a loss of $2.8 million, equivalent to about 5 percent of total output in the three counties around PKL. While there was a negative impact of $2.2 million after the 9-11 terrorist attacks, the second golden algae bloom seemed to explain a negative loss of $1.1 million. However, the last two impacts were not supported by statistical significance at .10. All three interventions had significantly negative impacts on the number of visitors to PKL State Park. Using the identified best model of ARIMA (||4||,1,1)(0,1,1)12, the algal blooms in 2001 explained a 57 percent reduction in the number of visitors, equivalent to approximately 4,793 visitors per month. The 9-11 terrorist attacks had a negative impact of 1,489 visitors while the algal blooms in 2003 resulted in a reduction of 1,615 visitors.

Since its initial development by Box and Tiao (1976), the intervention time-series modeling approach has provided a reliable means for analyzing the influence of one or more external events on the behavior of a time-series variable employed. Although this method was used here mainly for estimating regional economic impacts using three variables, other methods such as damage assessment (e.g., Kopp & Smith 1993) could also have been used concurrently to incorporate other often overlooked information. Combining the concept of consumer surplus (i.e., willingness to pay above recreationists' expenditures), for example, with a damage assessment from the fish kill associated with the algal blooms also could have provided economic valuation insight beyond economic impact estimations. It is well known that the market value associated with natural resources is not the only value sacrificed once resources are impacted. The comprehensive deliberation of total values estimated from both market and nonmarket sides collectively could have provided additional insights for better decision-making had additional data been available.

Our results are conservative in that we used only the five categories typically used to analyze outdoor recreation. Other SIC codes could have been appropriate for investigation if evidence provided support for doing so. Likewise, IMPLAN multipliers vary by expenditure area and are reflective of the extent of business activity within and between business sectors (For a further discussion of this, please see Ditton & Hunt 2001).

Because of the extensive economic impact of recreational fishing and other outdoor recreation activities at other major Texas lakes, the question remains: what types of data should be collected on a regular basis so as to ascertain use trends and extent of impacts associated with exogenous events such as golden algae blooms and any declines in public use of water bodies and associated infrastructure? If recreational fishing is a significant economic activity, or thought to be, there needs to be a data base available to ascertain the extent of fishing activity and expenditures and to ascertain the impacts of all possible exogenous events such as golden algae, oil spills, contaminants, drought, etc. to provide a basis for remediation efforts.

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