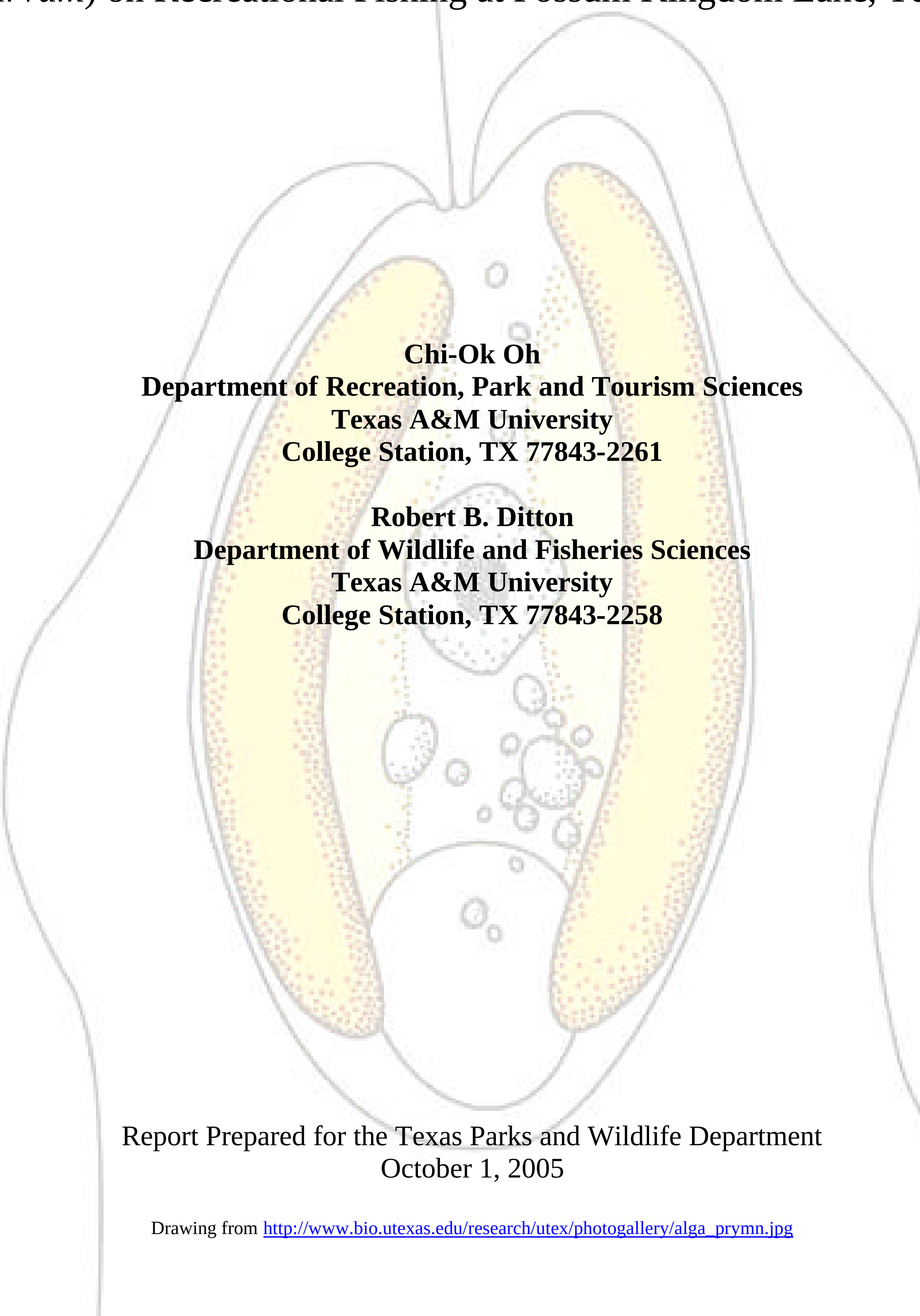
Estimating the Economic Impacts of Golden Alga (*Prymnesium parvum*) on Recreational Fishing at Possum Kingdom Lake, Texas



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Report Prepared for the Texas Parks and Wildlife Department
October 1, 2005

Drawing from http://www.bio.utexas.edu/research/utex/photogallery/alga_prymn.jpg

PWD RP T3200-1168 10/30/2005

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HD-630

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Acknowledgements

This project could not have been completed without the assistance of several individuals. First, we acknowledge the funding support for this project by the Texas Parks and Wildlife Department and the continuous communication and support by Dr. Dave Sager. Second, we acknowledge the assistance of Julia Belknap, a Ph.D. student in the Department of Recreation, Park, and Tourism Sciences with initial start-up and field work. Julia made sure we had a good understanding of the problem from her fieldwork. We appreciate the time and effort of all of the local people who helped educate us on the nature of the problem and its economic impact on the local area. Third, we appreciate the immediate response from Linda Pedro, Research Specialist in the Texas Comptroller's Office in Austin; she provided us with quarterly sales tax data for the SIC categories and years we wanted. Finally, we appreciate the dedication of our student worker staff, especially Leah Gohmert and Roxanna Nelson for their day-to-day involvement in various ways. We thank each of you for your contributions to our research project. Any errors of omission or commission are solely our responsibility.

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Estimating the Economic Impacts of Golden Alga (*Prymnesium parvum*) on Recreational Fishing at Possum Kingdom Lake, Texas

Executive Summary

In January through July 15, 2001, there was a confirmed outbreak of golden alga (*Prymnesium parvum*) at Possum Kingdom Lake (PKL) in Texas. The event was followed by two additional confirmed golden alga events at the PKL. As various fish populations at the lake have been affected and catchability (or perceived catchability) has been reduced, we expected recreational fishing at the lake by non-residents and residents alike to decrease and the regional economy (Palo Pinto, Stephens, and Young counties) to be impacted negatively.

The purpose of the study was to estimate the extent of economic impact associated with the algal events using three different time-series secondary data sets. First, data for sales tax and county level gross sales were obtained for five tourism-related SIC code categories (grocery stores, eating and drinking places, retail stores not else classified, hotels and motels, and miscellaneous amusement and recreation services) for the three county study area for the period starting with the first quarter of 1986 to the second quarter of 2004. Second, data for the number of visitors to PKL State Park were provided by TPWD for the period of September 1996 to January 2005. Third, monthly gross sales for recreational fishing related items were obtained for the years 1998- 2004 from the local store concession operating at the PKL State Park.

To examine the impacts of the 2001 and 2003 golden alga events, intervention analysis was used. ARIMA (AutoRegressive Integrate Moving-Average) models were used to test the effects of exogenous interventions. Using an intervention time-series modeling methodology with economic impact assessment, three intervention components (the 9-11 terrorist attacks and two algal blooms) were inserted to estimate the economic impacts of each event.

The Texas Parks and Wildlife Department funded this research project with additional funding support from the Texas Agricultural Experiment Station.

Economic Impact Losses

- From the first golden alga event in 2001, total economic impact was estimated as a loss of $2.8 million, equivalent to about 5% of total output in the three counties in the PKL study area.
- For comparison purposes, the 9-11 terrorist attacks on the U.S. and the second golden alga bloom were followed by economic losses of $2.2 million and $1.1 million, respectively.

State Park Visitation

- The algal blooms in 2001 explained a 57% reduction in the number of visitors to PKL State park or about 4,793 per month.
- The 9-11 terrorist attacks had a negative impact of 1,489 visitors.
- The algal bloom in 2003 resulted in a reduction of 1,615 visitors.

Concessionaire Sales

- The 2001 and 2003 algal blooms explained sales declines of $9,658 and $22,318, respectively for the business.
- Interestingly, the 9-11 terrorist attacks indicated a positive impact on sales of $52,234, likely the result of people staying closer to home.

The intervention time-series method provided a reliable tool for analyzing the influence of external events on various time series of interest. TPWD damage assessment values can be added to what we have reported here to more fully understand event impacts. It was impossible for us to focus our research exclusively on recreational fishing in the study area due to a lack of information specifically on recreational fishing. Also, there is no SIC code devoted exclusively to the recreational fishing business. Instead, we focused on outdoor recreation-related tourism as reflected by the SIC codes used. The total economic impact of golden alga at PKL might have been higher had other data and understandings been available to us regarding angler use of the lake, their willingness-to-pay above trip costs (consumer’s surplus) and their expenditures for fishing by category. Our results are likely reflective of recreational fishing since other recreation activities were not *directly* impacted by golden alga events. However, there is some likelihood that potential visitors who participate in other activities have been impacted.

In light of what anglers "know" about fishing at PKL, many are likely substituting other lakes in the region as fishing destinations that can be accessed at similar cost and yield the same level of angling satisfaction available previously at PKL. This pattern is also likely to continue to do so until their perceptions of PKL fishing change. What can be done to better understand/ offset these effects?

- First, fishing at PKL needs to get as much good press and media coverage as possible. The coverage should be truthful and devoted to all types of fishing at PKL.
- Second, it is in the best interest of the local area to encourage the TPWD-Inland Fisheries to institute an annual creel intercept survey at PKL. Because the TPWD does not conduct creel intercepts at each and every lake in Texas, some type of cost sharing arrangement may be necessary.
- Third, when recreational fishing makes a full recovery at PKL, an angler survey should be completed using the creel intercept as a sampling frame as has been done previously at a number of other lakes in Texas. In the meantime, a survey of anglers in the Dallas- Ft.Worth Metroplex would be useful for understanding the distribution of current and previous angling activity by anglers residing in this region, and what the competition is for PKL in terms of other lakes available at a similar cost

Other Texas lakes known for their recreational fishing and tourism activity have much to learn from the PKL case. It is not just enough to say that recreational fishing is important to the local economy. A creel intercept survey as well as other types of data should be collected on a regular basis to ascertain recreational fishing use of the lake by month as well as use trends over time. This will allow for understanding the extent of impacts of various possible exogenous events (golden alga, oil spills, contaminants, drought, increased gasoline prices, etc.) on recreational fishing activity and related expenditures. Such a data base is a principal requirement for being in the tourism business and needs to be up and operational at all major Texas fishing lakes prior to any other such events so effects can be fully understood and remediation justified.

Estimating the Economic Impacts of Golden Alga (*Prymnesium parvum*) on Recreational Fishing at Possum Kingdom Lake, Texas

Introduction

Fishing in freshwater in Texas is big business. 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, for example, Thailing and Ditton 2000 and Anderson et al. 2003) or as out-of-state anglers and their expenditures are attracted to high quality recreational fishing in Texas (see, for example, Chen et al. 2003). However, the maintenance of the direct and indirect economic impacts associated with recreational fishing currently enjoyed by various lake regions in Texas depend entirely on the maintenance of a 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 or is perceived as declining, 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 happened to some extent starting in January through July 15, 2001 when there was a confirmed outbreak of golden alga (*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 (Texas Parks and Wildlife 2005). Similar events have occurred in two of the winters since. From January 1, 2003- April 21, 2003, there was another confirmed golden alga bloom at Possum Kingdom Lake resulting in a further loss of an estimated 1,475,212 fish killed. (http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/ga/blooms.phtml).

According to the golden alga bloom expanded status reports available on the TPWD webpage (http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/ga/status2.phtml#brazos), there were additional golden alga events in the winter and spring of 2005.

As various fish populations at the lake are affected and catchability (or perceived catchability) is reduced (as reflected in TPWD increases in minimum size for largemouth bass and a reduced bag limits for striped bass), 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 this to result in reduced angler expenditures which will impact the various sectors of the tourism economy in the three-county local study area (Palo Pinto, Stephens, and Young Counties).

Some changes occur gradually such as improved highway access and higher densities at lakes. Consequently, they are more difficult to understand while other changes are more recognizable as connected with particular abrupt events. These events generally have starting and ending points. Events can be positive or negative. When fishing tournaments or groups of tournaments are held at a lake, it has been possible to estimate the direct and indirect economic impacts on the counties surrounding the lake using angler survey results together with IMPLAN software to estimate the extent of positive impacts directly associated with these short term events). Likewise, other events such as oil spills, rainy weather, hurricanes, droughts, and red tide can have negative consequences on the local area and regional economies. Some of these have starting and ending points whereas some continue for longer periods of time and their affects may linger longer after the event has subsided.

It is generally easier to study events with positive economic impacts because the data base that is necessary to determine the extent of the positive impact is readily available and often considered during event planning process. Accordingly, where recreational fishing tournaments are being planned at Sam Rayburn Reservoir, for example, researchers are able to conduct a survey of tournament anglers to supplement the data collected during tournament registration by the organizers (e.g., Anderson et al. 2002). Generally, all of the information needed to identify direct economic impacts (angler expenditures during the event in the local and regional area) is available. Once the data are manipulated with the IMPLAN software, it is possible to ascertain indirect and induced economic impacts as well as total economic impacts when direct and indirect impacts are taken together.

Usually, there is little if any planning for the contingency of events with negative consequences and their economic impacts. Accordingly, most efforts to estimate these negative economic impacts associated are often “guesstimates” at best because appropriate data were not collected before, during, and following the events. Second, the potential presence of confounding factors should be recognized from the outset. In identifying whether an oil spill had a significant impact on visitation on the Texas coast (Freeman et al. 1985) assumed that other factors (i.e., gasoline availability and price) may have had just as much influence on the results as the oil spill. Focusing on one highly visible event, according to Freeman et al. (1985), may lead to misleading results.

Several previous studies of large natural or human-caused events and their economic impacts were instructive to our efforts. First, as Adams et al. (2000) pointed out, no studies with the exception of one by Lipton (1998) have attempted to *measure* the economic consequences of harmful algal bloom (HAB) events. He attempted to measure the economic impacts of Pfiesteria outbreaks in the Chesapeake Bay region. Reported economic losses in terms of reduced seafood sales and reductions in party and charter boat fishing totaled about $43 million. Most have sought to *estimate* the economic consequences of harmful algal blooms (Jensen 1975; Kahn and Rockel 1988; Todd 1995; Evans and Jones 2001). A wide variety of estimation methods have been used previously ranging from anecdotal observations of lost seafood sales, clean-up costs, reductions in recreation activity, reductions in tourism expenditures, etc. to input-output analyses that seek to understand the economic impact of events on incomes, expenditures, and jobs in the local or regional economy. Also, welfare analyses are useful for understanding how a HAB event has affected the supply and demand for water-based recreation activities, thereby changing individuals’ willingness-to-pay for these activities. This presupposes that some measures of consumer surplus from prior to the HAB event are available for assessing the true economic effect of the HAB. As Adams et al. (2000) pointed out, each of the various methods used to date have particular data requirements.

The anecdotal information approach appears to be used most often, primarily for helping the media to understand and report 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, consequently, extrapolated to the population of business owners in the region. A similar but more useful approach is to conduct a survey of industry representatives using a stratified sample and then extrapolating to the population level. This latter approach was used by Lipton (1998) to measure the economic effect of a Pfiesteria outbreak in the Chesapeake Bay region. This approach focused on the direct effects in the seafood and recreational fishing sectors without dealing with the indirect effects of the HAB on other industries with ties to seafood and recreational fishing. Likewise, individuals may avoid the local area where the HAB has occurred but go elsewhere in the area, or choose not to go fishing in the local area but enjoy other tourism attractions in the local area. These effects are not accounted for at all with anecdotal information. Also, these effects may be positive or negative for the local economy but they are typically overlooked by individuals trying to come up with a "magic number" that represents the extent of economic impact.

The economic impacts of golden alga at PKL or other HABs can probably best be described in terms of changes in total output as a result of the event. An input-output model provides a holistic view of the economic structure of a region and facilitates understanding of the interrelationships among its economic sectors. Such an analysis provides a change in county-level economic activity (i.e., recreational fishing expenditures) associated with a decrease in activity in a particular sector of activity (i.e., recreational fishing) resulting from the golden alga event or other HAB. It is essentially the same as looking for an increase in county-level expenditures associated with an increase in fishing tournament activity as per the earlier Sam Rayburn Lake example. With an input-output matrix, the changes in from losses/gains, respectively, in fishing-related businesses would be multiplied across the entire county and regional economy. Accordingly, changes in market-related activities such as expenditures, income, employment, and economic output are measured. Thus, declines in fishing-related sales lead to declines in other economic sectors in the local and regional economy as well as state wide for that matter. The total economic impact would include all of these interrelated decreases in economic activity. IMPLAN, a modeling technique designed for the purpose of economic impact assessment provides a flexible technique for analyzing a wide variety of economic impact situations. The IMPLAN system constructs a model which produces a set of local and regional multipliers for individual counties or groups of counties. These multipliers account for the structure of the regional economy and identify which industries are impacted and how they are interrelated to other industries.

The purpose of this study is to estimate .the extent of economic impact of the outbreak and continued presence of golden alga at Possum Kingdom Lake (PKL) on the local three-county area. In particular, study objectives are to: 1) expand county-level time series state sales tax data (pre- and post-golden alga outbreak) to total expenditures to understand changes in direct expenditures in the study area over time, 2) use an input-output model to estimate the extent of indirect and induced economic effects of the golden alga outbreak on the study area for selected recreation and tourism sectors and demonstrate interrelationships among sectors, and 3) suggest a protocol of approaches for monitoring recreational fishing activity and related economic impacts at PKL and other recreational fishing lakes in the future.

Methods

If we had known the golden alga infestations or events were coming, we could have designed an effective means for understanding their social and economic impacts. But as is often the case with red tide events (e.g., Evans and Jones 2001; Adams et al. 2000), oil spills (e.g., Bell 2002; Chapman et al. 1998; Freeman et al. 1985), and other such temporal exogenous events, available data sets are often less than desirable for analysis purposes.

Data Collection

Three different time-series secondary data sets with coverage of relevant variables were acquired from various entities including the Texas Comptroller of Public Accounts (TCPA), Texas Parks and Wildlife Department (TPWD), and a local concessionaire operating a store at the Possum Kingdom Lake State Park. 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. Thus, these SIC codes included the expenditure amounts of grocery stores, eating and drinking places, retail stores not else classified, hotels and motels, and miscellaneous amusement and recreation services (Table 1). The original SIC codes used were adjusted to the IMPLAN codes for the economic impact analysis (Table 1). Data for the number of visitors to Possum Kingdom Lake (PKL) State Park were provided by TPWD from September 1996 to January 2005. Finally, monthly gross sales of recreational fishing related items (i.e., the retailed amount of baits and licenses) were obtained from a local store concession operating within the Possum Kingdom State Park for the years of 1998-2004. The latter two variables (i.e., number of visitors to PKL State Park and state park concessionaire monthly gross sales) used here besides county-level gross sales and state tax were 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 (i.e., variable) level (McCleary and Hay 1980). In addition, tourism and recreation related expenditures and gross sales of a local were adjusted to 2001 levels using by the Dallas-Fort Worth consumer price index (U.S. Bureau of Labor Statistics 2005).

Table 1. Original SIC and IMPLAN Codes Related to Tourism Expenditures

Original SIC code		IMPLAN code	
Grocery Stores	541	Food & Beverage Stores	405
Eating & Drinking	581	Food Services & Drinking Places	481
Retail Stores	599	General Stores not else classified	410
Hotel & Motel	701	Hotel & Motel	479
Recreation Services	799	Other amusement -gambling & recreation	478

Economic Impacts Assessment

The economic impact of recreation and tourism related activities reflected in five SIC-code gross sales in three counties adjacent to PKL were further estimated using a regional Input-Output (I-O) model. One of the benefits for the use of I-O model in economic impact analyses is its comprehensiveness and flexibility (Briassoulis 1991). An

I-O model presents a comprehensive representation of the economic structure of a region (or regions) 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).

Various multipliers dealing with output, income, government revenue, employment, and imports can be derived from I-O analysis (Fletcher 1989). Total economic impacts were calculated from the sum of direct, indirect, and induced impacts in the local region (defined as the three counties surrounding the PKL). Direct impacts include the amount of expenditures (i.e., bait costs, lodging, and food and beverages) that occur as a direct consequence of anglers' trip-related activities in the local region (surrounding PKL). This new money remains in the local economy by generating secondary effects. Indirect impacts imply that beneficiaries from direct expenditures spend part of their receipts on the purchase of trip-related products and services from local suppliers. Moreover, induced impacts are generated from the circulation of wages and salaries paid by the employers of directly and indirectly related industries. The additional ripples of indirect and induced impacts are created in a circular cycle and contribute to total economic impacts.

The economic impacts of recreation and tourism-related activities are described in terms of changes in the amount of total output and the number of total people employed. Other estimates such as labor income and value added were excluded intentionally from further analysis because of the same directional movements along with the variables 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. Employment indicated the number of jobs generated from the additional production. Employment included full-time and part-time jobs. 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 the purpose of economic impact analysis (Minnesota IMPLAN User's Manual 1997). IMPLAN is a computer-based input-output system that provides a flexible technique for analyzing a wide variety of situations and problems (Uysal et al. 1992; Minnesota IMPLAN User's Manual 1997).

Intervention model approach

To examine the impacts of the 2001 and 2003 golden alga outbreaks, intervention analysis is a well-known 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 and Hay 1980). And 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 and 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 and Hay 1980).

Noise component (N_t)

The general principle of Box-Jenkins ARIMA modeling involves the following steps: model identification, estimation and diagnostic checking (Ender 1995; Johnston and DiNardo 1997). In the identification stage, the data are initially transformed to make them stationary. More specifically, differencing is performed to remove trend, and seasonal differencing is performed to remove seasonality. A tentative model is 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 are performed to ensure that all coefficients are significant and within the bounds of stationarity for the AR coefficients or invertibility for MA coefficients, and that the residuals do 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). Ideally, the model with smaller values for AIC and SBC as well as with fewer parameters is preferred (Newbold and Bos 1994).

Intervention (I_t)

Once a successful ARIMA model is identified, an intervention component (or components) can be 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 and 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 transfer functions that specifies the dynamic transference from the independent effect of the input series (I_t) on the dependent output series (Y_t). Thus, transfer functions can capture intervention responses into a model to depict the dynamic transfer from the intervention to the dependent time series (Box and Tiao 1975; Wood 1988).

Given the abrupt onset of the 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 are captured by the transfer function, $\frac{wB}{1-dB}$ where w is the parameter estimate of an intervention and d is the dampening rate of the interventions. B is the backshift operator such that $BY_t = Y_{t-1}$. Due to complexity of model interpretability with higher order transfer functions, zero and first-order transfer functions are commonly used. The parameters of the full impact assessment model are 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) are satisfied, impact parameters can be tested for statistical significance and the entire model interpreted (McCleary and Hay 1980).

Empirical analysis

The methods described above were used to construct impact assessment models using three different variables. The data were first plotted to scrutinize any irregular variations or patterns of the series (Figure 1 through 4). Three hypothesized interventions were then inserted into each time series variable: Golden Alga blooms in 2001, the 9-11 Terrorist Attacks in 2001, and Golden Alga blooms in 2003. The ARIMA modeling requires a substantial number of data observations for the identification and estimation process. The pre-intervention observations in each time series before the first incident of Golden Alga blooms (January 2001) were used for the initial construction of the ARIMA model. To check stationarity of each time series, both augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used. Although detailed results were not reported here (for more details, contact the first author), 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 the seasonal fluctuations.

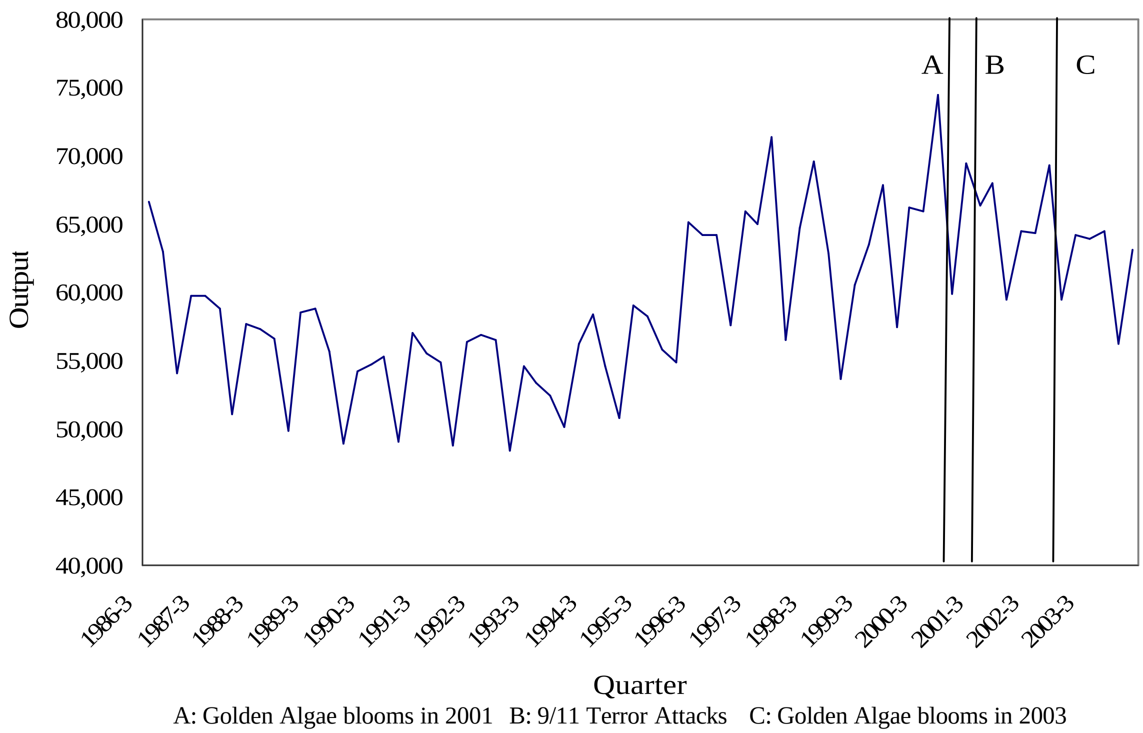

Figure 1. Total Economic Output in the Three-county PKL Study Area, 1986 – 2004

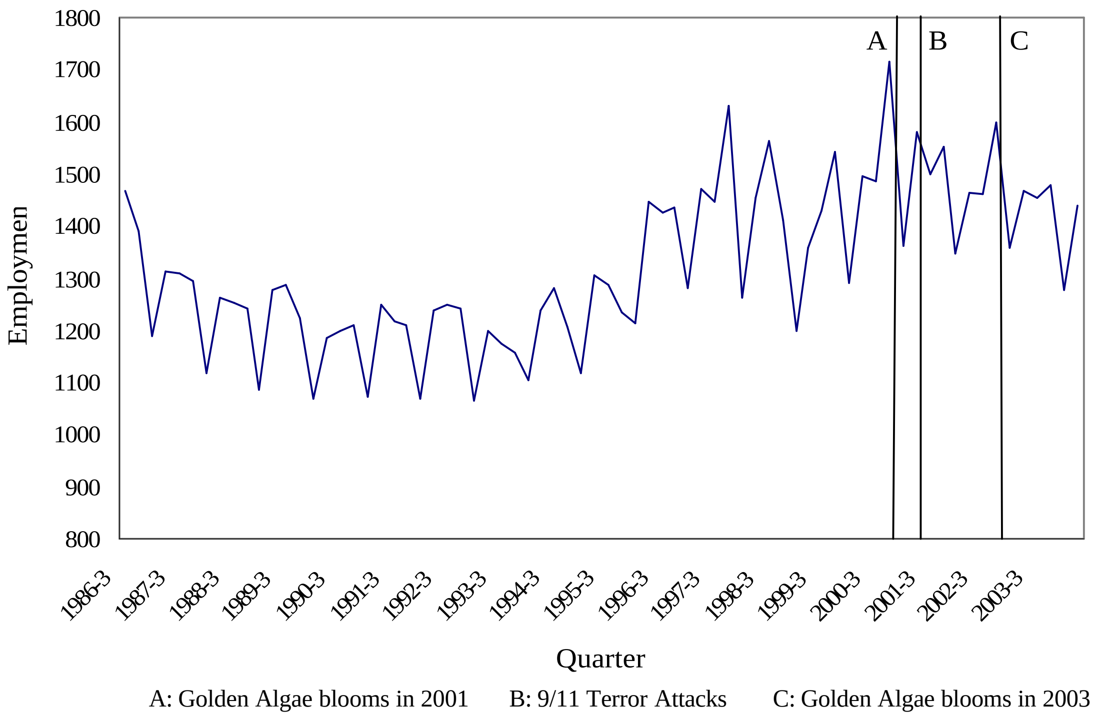

Figure 2. Employment in the Three-county PKL Study Area, 1986 – 2004

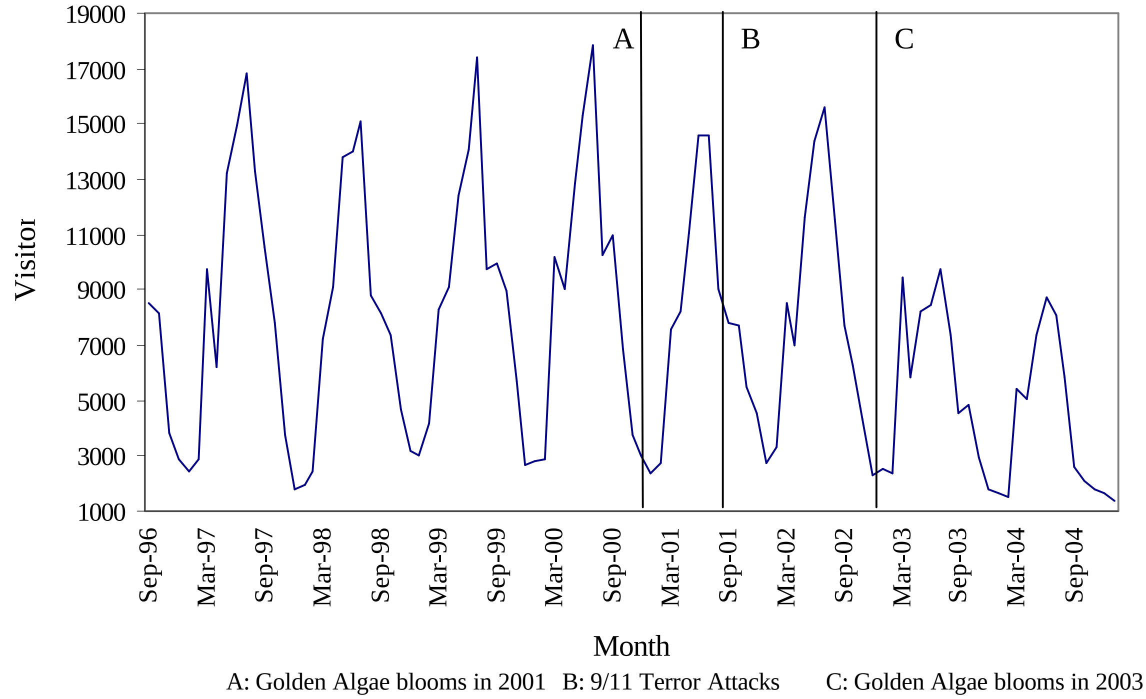

Figure 3. Number of Visitors to PKL State Park, 1996 - 2005

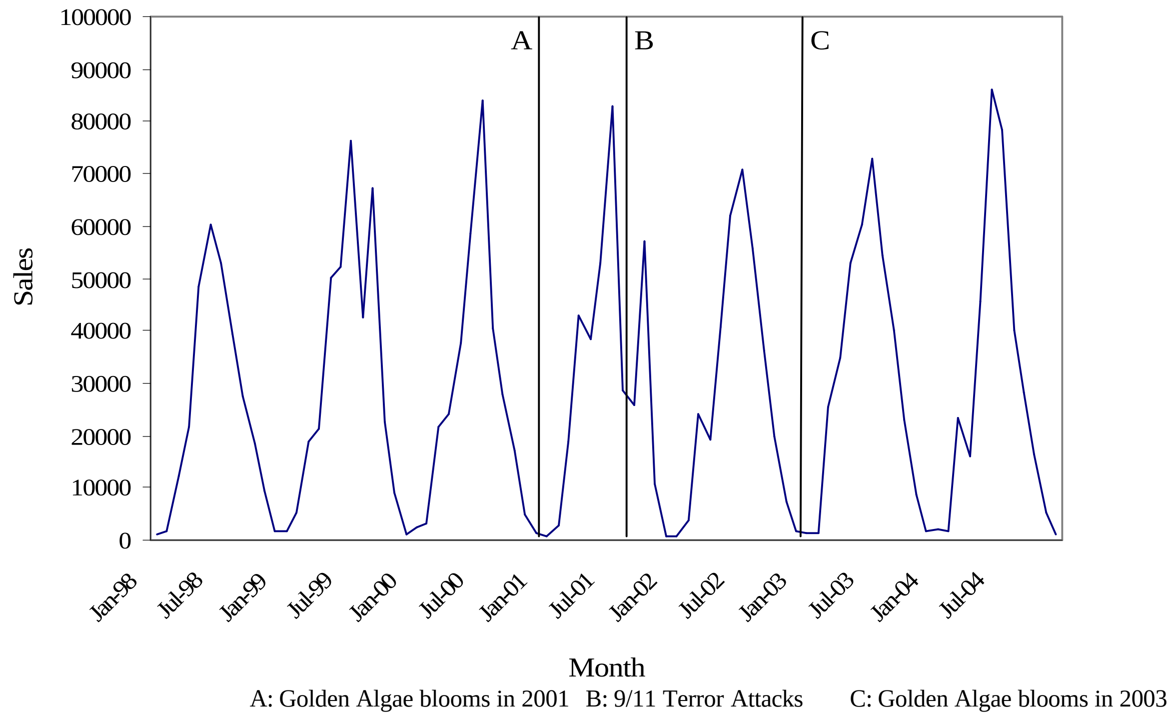

Figure 4. State Park Concessionaire Monthly Gross Sales, 1998 – 2004

Once a tentative 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 but statistically acceptable impact assessment model was generated (McCleary and Hay 1980). The Ljung-Box Q-statistic was used to test whether the residuals have a mean of zero, constant variance, and are serially uncorrelated (i.e., white noise).

Parameter estimates and diagnostic statistics for total output are represented in Table 2. Due to almost identical estimation results for total economic outputs, estimates of employment were not reported here. 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 $\frac{w_0}{1-d_1}$ as the first order transfer function. However, when d 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 d, which determines the rate at which the process returns to its pre-intervention equilibrium level (McCleary and Hay 1980). After having tested the first order transfer functions at the outset, the zero order transfer functions seemed to be more appropriate to measure each effect of the intervention components. Table 2 illustrates the estimated impacts of the intervention events on the total output variable. Following the golden alga blooms in 2001, there was a zero order decrease of $2.8 million in total economic output calculated from five tourism-related SIC codes. Compared to the average total economic output computed from the pre-intervention periods, the amount decrease is equivalent to a change in about 5% of total output. Not only did they show the directional consistency with our priori expectations, but the intervention components were also statistically significant at 10% of one-tailed test. After the 9-11 terrorist attacks in 2001, the parameter estimate of w_{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 w_{13} indicating -$1,091,768, the golden alga blooms in 2003 had a negative impact (decline) on total economic output of 1.9% despite its non-significance.

Table 2. The impact of golden alga blooms on total output in the three-county study area

Model Component	Parameter	Coefficient	t- value	
Golden Alga Blooms in 2001	w_{01}	-2,816,402.0	-1.315	
9-11 Terrorist attacks	w_{02}	-2,208,659.2	-0.864	
Golden Alga Blooms in 2003	w_{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	

Table 3 presents parameter estimates and diagnostic statistics for the number of visitors to PKL State Park. Various examination 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 is not straightforward any more. Therefore, because the parameter w_0 is not directly interpretable in the logarithm transformation, it is more convenient to work with the term, $e^{(w_0)}$ 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 from McCleary & Hay, 1980): Percent change = $(e^{(w_0)} - 1) \times 100$.

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 alga 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, however, the zero order transfer functions were more suitable for the other two interventions (i.e., 9-11 terrorist attacks and the golden alga 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 = $\frac{w_1}{1-d_1}$ = -0.854.

When this result was translated into percent change, we found that the algal blooms in 2001 explained 57% reduction of the number visitors. As the pre-intervention mean for the time series variable was approximately 8,344 visitors per month, this percent change represents a total reduction of approximately 4,793. The parameter estimate of w_{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% reduction in the number of visitors or about 1,489 visitors. Likewise, the parameter estimate of w_{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 in the number of visitors to PKL State Park of about 1,615 visitors.

Table 3. The impact of golden alga blooms on the number of visitors to PKL State Park

Model Component	Parameter	Coefficient	t- value	
Golden Alga Blooms in 2001	w_{11}	-0.2287	-1.620	
	d_{11}	0.7323	2.196	
9-11 Terrorist attacks	w_{02}	-0.1951	-1.475	
Golden Alga Blooms in 2003	w_{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	

Table 4 illustrates parameter estimates and diagnostic statistics for the monthly gross sales for the PKL on-site store concessionaire. Using ARIMA $(3,1,0)(1,1,0)_{12}$ for a noise component, all three intervention components were specified with the zero order transfer functions. For the impact assessment model identified, all parameters were adequately estimated and diagnostic statistics were acceptable (Table 4). The same calculation process used previously was also implemented here due to the logarithm transformation of the original time series. Based on the parameter estimate (w_{11}), -0.4349, the effect of the initial algal blooms in 2001 was estimated to be the sales drop by $9,658 despite its non-significance at 10%. However, the other two intervention components were significant[†]. In particular, the 9-11 terrorist attacks was associated with a considerable increase in monthly gross sales (183.2%), corresponding to the sales increase of $52,234. The positive effect of 9-11 terrorist attacks was opposite to what was expected *a priori*. However, unlike the extensive negative impacts of 9-11 terrorist attacks on air transport passenger demand due to increased terrorism risk (Lee et al. 2005), it can be reasoned that the effects of greater terrorism risk or perceived risk on short-distance recreational trips to nearby destinations primarily by automobiles were

[†] 9-11 terrorist attacks were significant at 15% of two-tailed test because of the unexpected sign.

likely to be minimal and even possibly positive. Finally, a negative impact of the second algal bloom event in 2003 was reported as expected. The parameter estimate of w_{13} indicates a sales drop by 79%, reflecting a sales loss of $22,318.

Table 4. The impact of golden alga blooms on monthly gross sales

Model Component	Parameter	Coefficient	t- value	
Golden Alga Blooms in 2001	w_{11}	-0.4349	-0.839	
9-11 Terrorist attacks	w_{22}	1.0411	1.508	
Golden Alga Blooms in 2003	w_{13}	-1.5698	-1.928	
	AR lag 1	-0.5887	-3.943	
	AR lag 2	-0.3694	-2.271	
	AR lag 3	-0.2950	-2.072	
	Seasonal AR lag 12	-0.4349	-3.104	
	AIC	215.40	SBC	229.33
	Q Statistics	Lags	Significance	
		20	0.688	

Discussion

In the following paragraphs, we provide 1) a summary of economic impact losses in recreation and tourism-related sales, visitation to the PKL State Park, and sales by the PKL concessionaire, 2) a review of other possible approaches for estimating the economic losses associated with the algal blooms, 3) limitations of our research, 4) a review of actions that can be taken in the PKL area to overcome the impacts experienced their in recent years, and 5) a review of potential actions that can be taken at other lakes with important recreational fisheries to make sure they have a sufficient data base to help justify mitigation efforts.

Using the intervention time-series model approach as well as 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 alga bloom in 2001, total economic impact was estimated as a loss of $2.8 million, equivalent to about 5% 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 alga bloom seemed to explain a negative loss of $1.1 million. However, the last two impacts were not supported by statistical significance at .10. On the number of visitors to PKL State Park, all three interventions had significantly negative impacts. Using the identified best model of ARIMA $(||4||,1,1)(0,1,1)_{12}$, the algal blooms in 2001 explained a 57% reduction of the number of visitors, equivalent to approximately 4,793 per month. The 9-11 terrorist attacks had a negative impact of 1,489 visitors. The algal blooms in 2003 resulted in a reduction of 1,615 visitors. Finally, for the PKL on-site store concessionaire, ARIMA $(3,1,0)(1,1,0)_{12}$ was identified as the best model. The first algal blooms in 2001 explained a sales decline of $9,658 and the second algal blooms in 2003 had a negative impact on sales of $22,318. Surprisingly, the 9-11 terrorist attacks indicated a positive impact on the sales of $52,234, likely the result of people staying closer to home.

The intervention time-series modeling used here provides a reliable tool for analyzing the influence of an external event or events on the behavior of a time-series variable employed. Although this method was used mainly for estimating regional economic impacts using three variables, other methods such as damage assessment (e.g., Kopp and 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 insight for the better decision-making had additional data been available.

There are other data collection approaches and data that could be useful as well for ascertaining impacts on recreational fishing activity and expenditures as well. First, as suggested by Adams et al. (2000), a "local agency/citizenry/industry-based information monitoring system" could be useful. Such a system would rely on data collecting by local people before the event, immediately at the onset of the event as well as immediately following the event. This approach has been used previously to understand the impacts of various events on local economies and relies on a personal interview format (Adams 1995; Restrepo et al. 1982; Lipton 1998). A variation of this approach would have business operators involved in the recreational fishery, for example, collect data on a continuous basis with daily observations to account for daily changes in the event and its impacts. For restaurants and hotels, and bait shops, this would involve daily tabulations of sales and number of customers as well as cancellations. Second, having traffic counters positioned effectively to provide a monthly record of traffic to the lake in question as well as at boat launch ramps. Besides providing traffic counts and a record of visitation, it would also be useful for establishing seasonality of use patterns (Perales and Jackson 1998). Third, where recreational fishing is one of the most important industries on local lakes, these communities must have and maintain a local response handbook detailing which activities that should be carried out during an event to reduce the adverse effects on the local tourism industry. This effort would begin with a risk assessment of all potential hazards for each respective lake and an assessment of the extent of recreational fishing activity and related expenditures.

Unfortunately, it was impossible for us to focus our research on recreational fishing alone in the study area due to a lack of information specifically on recreational fishing. There was no SIC code devoted exclusively to the recreational fishing business. Accordingly, we focused on outdoor recreation-related tourism as reflected by expenditure data available in the SIC code categories chosen. The total economic impact of golden alga at Possum Kingdom Lake might have been higher had other data and understandings been available to us regarding angler use of PKL, their willingness-to-pay above trip costs (consumer's surplus) and their expenditures for fishing by category. Our results are likely mainly reflective of recreational fishing since other recreation activities were not *directly* impacted by golden alga events but there is some likelihood that potential visitors thought other activities could have been impacted.

Our results are conservative in that we only used 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 (To see a discussion of this more, please see Ditton and Hunt 2001). These are not the "sky-high" multipliers often used for understanding the economic impact of tourism activity.

It takes considerable time for a lake to develop a good reputation for its fishing quality but it can be lost quickly with a golden alga event or anything else that diminishes (or is perceived by anglers as diminishing) fishing quality there. Because of continuing publicity about golden alga events at PKL including the ongoing research program, the lake continues to be viewed in a negative light. Furthermore, other lakes in the Dallas-Ft. Worth area have established and maintain continuing efforts that seek to attract anglers to their area. Previous studies conducted by the TPWD show that 11.8% of licensed freshwater anglers in the state of Texas reside in the Dallas- Ft. Worth area (Anderson and Ditton 2004). In light of what anglers "know" about fishing at PKL, many are likely substituting other lakes in the region that can be accessed at similar cost and yield the same level of angling satisfaction available previously at PKL. They are also likely to continue to do so until their perceptions of PKL fishing change. What can be done to offset these effects? First and foremost, fishing at PKL needs to get as much good press as possible. Emphasis needs to be on being truthful and be devoted to all species available at PKL, not just the featured species of large mouthed bass and striped bass. Second, it is in the best interest of the local area to encourage the TPWD-Inland Fisheries to institute an annual creel intercept at PKL. It is not clear as to the extent one was available there previously, but sampling appears to have been discontinued when the first golden alga event occurred. Without TPWD creel intercept data, there is no independent record of catch and effort (CPUE), removals by species, and record of fishing pressure (increasing or decreasing) at PKL. Without creel intercept data, it is next to impossible to characterize what is occurring with the PKL fishery and how it may be changing over time. The lake and the people who depend on it to make their living are at a disadvantage by not having such data available. Because the TPWD cannot conduct creel intercepts at each and every water body in Texas, it may be necessary for the Chamber of Commerce or some other regional body to cost-share such a study with the TPWD. Third, when recreational fishing makes a full recovery, an angler survey should be completed using creel intercepts as a sampling frame as has been done previously at several other recreational fishing lakes in Texas (Ditton and Hunt 2001). This will provide a baseline on fishing participation at PKL and will enable a complete economic impact analysis of the recreational fishery there for whatever purpose (see for example, such an analysis at Lake Fork (Chen et al 2003) and Sam Rayburn (Anderson, et al. 2003)) With insights to the number of anglers fishing at PKL by quarter, number of days fishing at the lake, and expenditures by economic sector, it should be possible to estimate the economic impact of recreational fishing at PKL in good times and bad. Without creel survey data and an in-depth study of angler use of the PKL and their expenditures, it was not possible to *directly* ascertain the economic impacts of one or more golden alga events.

Because of the extensive economic impact of recreational fishing and other outdoor recreation activities at other major Texas lakes, what types of data should be collected there on a regular basis so as to ascertain use trends and extent of impacts associated with exogenous events such as golden alga 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 alga, oil spills, contaminants, drought, etc. to provide a basis for remediation efforts.

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