Forecasting Models for Harvest of River Otter in Louisiana

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Abstract: Although thousands of river otters (*Lontra canadensis*) are harvested every year in Louisiana, no formal management plan exists for the species. As a first step toward development of such a plan, we described general trends and associations between number of otters harvested and pelt price and number of licensed trappers during 1957–2004. We also applied time series analysis to develop forecasting models for river otters harvested. Although number of otters harvested was stationary, trends were detected in number of licensed trappers and pelt price. The early 1980s appear as a point of inflection in number of licensed trappers and pelt price, with a declining trend after that time in both. Lagged cross-correlation between number of otters harvested and licensed trappers was significant, as was the case between number of licensed trappers and pelt price. An autoregressive model including number of otters harvested at time t-1 and t-5 was identified as a suitable model to forecast number of otters to be harvested at time t. The simplicity of the model suggests that it could be a valuable forecasting tool for wildlife management agencies in Louisiana.

Key words: forecasting, furbearer, harvest, *Lontra canadensis*, Louisiana, river otter, time series, trapping

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Harvest practices may have important effects on dynamics of a population such as being the primary source of mortality (Jonzen et al. 2003). Thus, the identification and quantification of those effects becomes relevant given their implications on management and conservation of a species. However, many of the harvested mammalian species are very elusive or secretive (Feldhamer et al. 2003, Novak et al. 1987), and data on their dynamics and the impact of harvesting is seldom available (Caughley 1977). When no direct data are available, a description of the dynamics of harvest through time and ability to forecast number of animals that will be harvested may represent one of the first steps toward development of a sound management plan for that species.

The river otter (*Lontra canadensis*) is among the most elusive furbearer species (Melquist and Hornocker 1983, Melquist and Dronkert 1987, Melquist et al. 2003). It also is highly valued in the fur market (Melquist and Dronkert 1987, Tarver et al. 1987, Melquist et al. 2003,), particularly in Louisiana, where otters have been an important resource for more than a century (St. Amant 1959). Although thousands of otters are harvested every year in the state during the regular trapping season (20 November–31 March) (Linscombe and Kinler 1985, Scognamillo 2005) , no formal management plan exists for otters in Louisiana, and because research on otter populations in Louisiana has been limited (Beck 1977; Chabreck et al. 1982, 1985; Ensminger and Linscombe 1980; Fleming et al. 1985; Linscombe and Kinler 1985; Shirley et al. 1988), the consequences of harvesting its populations are poorly understood.

Considering that temporal dynamics of river otter harvest have important implications for river otter management and conservation, our goal was to describe temporal patterns of variables associated with river otter harvesting and to develop a forecasting model that could be used by state wildlife managers to estimate number of otters to be harvested during future trapping seasons.

Methods

We analyzed harvest data for river otters collected by the Louisiana Department of Wildlife and Fisheries (LDWF) using time series methodology. A complete time series for 1957–2004 existed for number of otters harvested, number of licensed trappers, and otter pelt price. We considered time series for 1957–2003 for all the analyses and model development, and data from the 2004 trapping season was used as an out-of-range sample for model forecast evaluation.

Because much of the theory developed to analyze time series assumes stationarity, which implies that the mean and variance of a time series are constant over time and that the structure of the series depends only upon relative position in time of two observations (Kendall and Ord 1990), non-stationary time series need to be transformed into stationary series prior to analysis. We used time plots and sample autocorrelation function (sACF) to detect non-stationarity (Chatfield 2001). We considered a time series as representing a non-stationary process if its sACF approached zero 'very slowly' with the lag (Wilson 2001); e.g., the sACF of a sta-

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tionary time series will reach zero at lags $k = 1–4$, while the sACF of a non-stationary series will reach zero at lags $k \geq 5$. Analysis of sACF is commonly used to detect non-stationarity, but because of the subjectivity of this approach, we also used Augmented Dickey-Fuller (ADF) test (Brocklebank and Dickey 2003, Enders 2004) as a formal statistical tool even though it has been noted that this kind of test generally has poor power (Chatfield 2001). Non-stationary time series were detrended by differentiation (Chatfield 2001).

To identify associations between number of otters harvested and trapper participation at different lags and between pelt price and number of otters harvested, we estimated cross-correlation coefficients between pairs of time series (Kendall and Ord 1990, Chatfield 2001). Because the cross-correlation function is not an even function (i.e., correlation at positive lags, $+k$, differs from correlation at negative lags, $–k$), the value of the lag which gives the maximum cross-correlation provides some indications on which series is 'leading' the other (Gottman 1981, Chatfield 2001). For instance, a positive correlation at positive lags between number of licensed trappers, as the reference time series, and nominal price indicates that past pelt prices are correlated to present number of licensed trappers, or that an increase in the otter pelt price will be followed by an increase in number of licensed trappers k years after. Because we wanted to check for lagged dependencies, we removed dominant autocorrelation structures in the time series before cross-correlation was estimated (Brocklebank and Dickey 2003, p. 170).

Linear autoregressive integrated moving-average models (ARIMA models; Box and Jenkins 1970, Wilson 2001) were used to describe and forecast number of otters harvested. ARIMA modeling methodology has three steps (i) identification of the model, (ii) estimation of parameters, and (iii) forecasting. We followed these three steps using the procedure PROC ARIMA in SAS/ETS (SAS. 2003, v. 9.1). The Q-statistic (Box et al. 1994, Ljung and Box 1978) in the identification step, which is generated using the autocorrelation coefficients, was used to test the null hypothesis that the time series represented a purely random process; i.e., that the process was uncorrelated. Plausible ARIMA models to describe and forecast number of harvested otters were identified by analyzing the sACF and sample partial autocorrelation function (sPACF) for this time series. This last function, sPACF, measures correlation at lag k after removing the effects of associations at lower lags (Gottman 1981). Once the set of plausible models was identified, parameters were estimated for each model in the set. In the estimation step, the Q-statistic was calculated on the model residuals and was used to test the null hypothesis that these residuals were random or white noise (as generally named in the time series literature; see Gottman 1981, Chatfield 2001, Wilson 2001). Among all the models that showed residuals as white noise, which indicated a good fit of that particular model to the data, we selected the model that minimized the Akaike's Information Criterion (AIC) (Burnham and Anderson 2002) as the final model to describe and forecast number of otters harvested. Given the relatively small sample size, no test was performed on the forecasting capability of the model (Chatfield 2001); however, we used the residual (observed value–forecasted value) for the 2004 trapping season as an indicator of forecasting accuracy of selected models.

To assess potential effects of number of licensed trappers and pelt price on forecast of number of otters to be harvested, we also considered Transfer Function models (Box and Jenkins 1970, Chatfield 1980). If ARIMA models can be viewed as univariate models, Transfer Function models can represent the logical multivariate extension where the time series of interest is related to one or more other time series. Modeling methodology follows the same three steps described for ARIMA models. To forecast number of otters harvested one trapping season ahead, we included number of licensed trappers and pelt price as explanatory variables in the model. We followed the same criteria for model selection used for ARIMA models; i.e., transfer function model with the lowest AIC was used for forecasting. All tests $\alpha = 0.05$.

Assuming that real pelt price-a pelt price adjusted by the cost of many of the major commodities a trapper needs to buy could be a better descriptor of effect of pelt price on number of otters harvested and number of licensed trappers than the nominal pelt price, we created this new variable by dividing nominal pelt price by consumer price index (Bureau of Labor Statistics 2004) and included it in analyses.

Results

For comparison purposes, a time plot for nominal pelt price was overlaid with time plots for number of otters harvested and licensed trappers. Number of otters harvested did not show a clear trend when considered for the whole period (Fig. 1), whereas number of licensed trappers and pelt price showed different trends when broken down into different time periods. Time plots for nominal price and real price (Fig. 2) showed a decline in otter pelt price during the 1980s and an increasing trend from the early 1990s until 2003. Number of licensed trappers showed an increasing trend before 1980 and a continuous decline since that year (Fig. 3). Number of otters harvested was considered to be stationary during the period analyzed as suggested by the sACF (autocorrelation curve reached zero at lag $k \approx 4$, Fig. 4) and the ADF test (ADF = -3.65, $P = 0.03$). The sACF for number of licensed trappers and pelt price suggested presence of trend (autocorrelation curve reached zero at lag $k \approx 8$), as it was also indicated

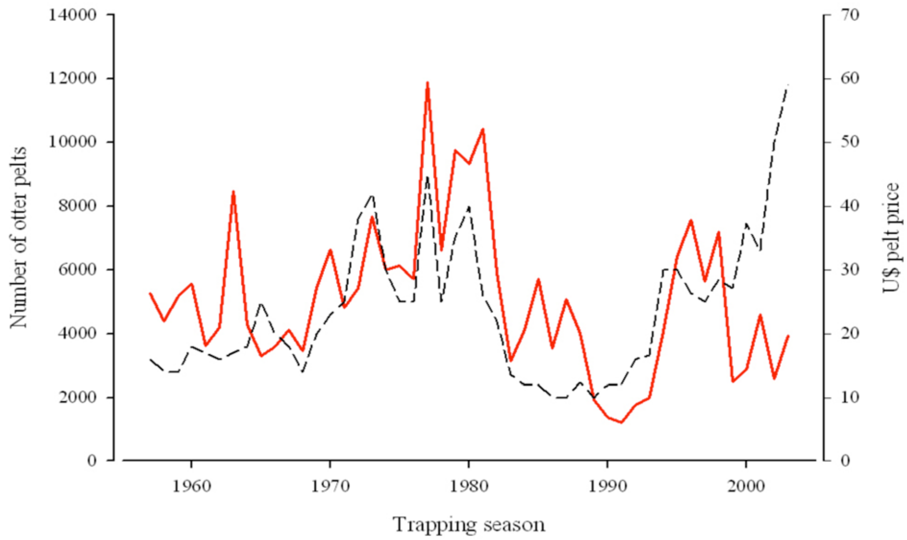

Figure 1. Time plot of number of otters harvested (continuous line) and nominal otter pelt price (dashed line) in Louisiana during trapping seasons 1957–2003. (Source: Louisiana Department of Wildlife and Fisheries).

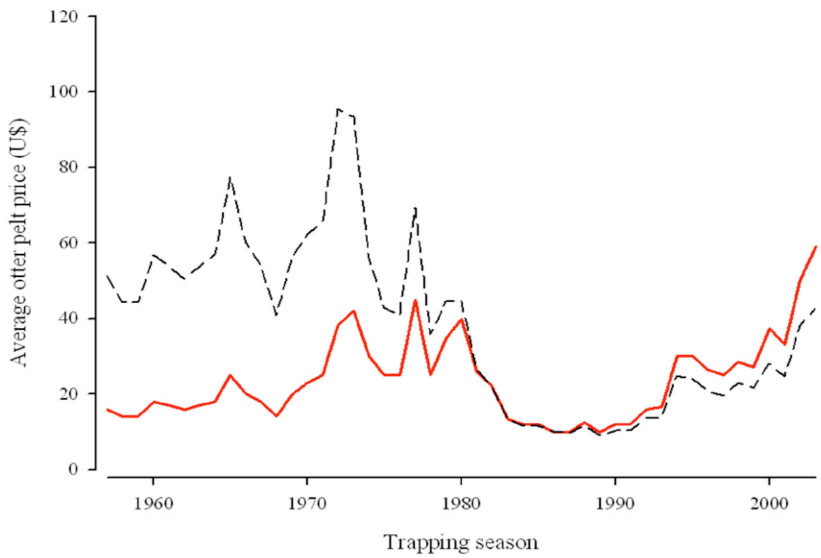

Figure 2. Nominal otter pelt price (continuous line) and real otter pelt price (dashed line) paid in Louisiana during 1957–2003. (Source: Louisiana Department of Wildlife and Fisheries).

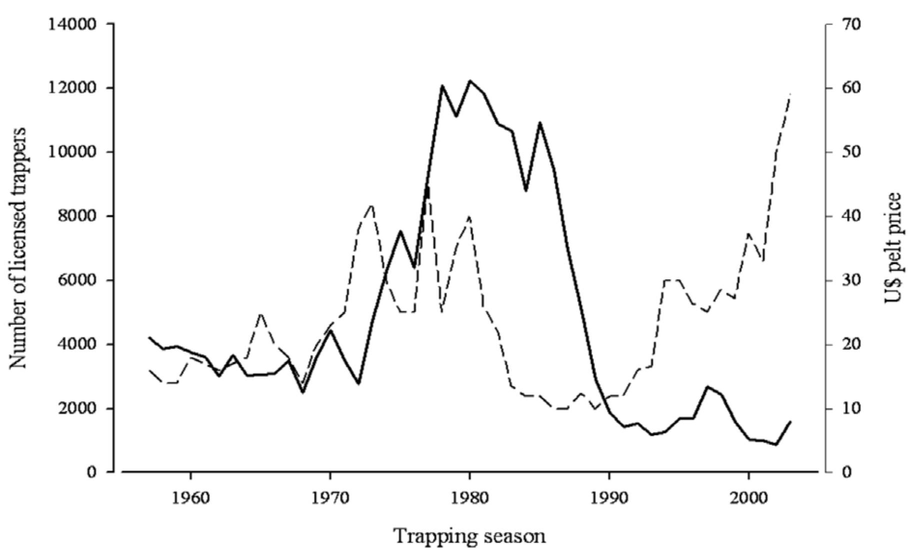

Figure 3. Number of licensed trappers (continuous line) and nominal otter pelt price (dashed line) in Louisiana during trapping seasons 1957–2003. (Source: Louisiana Department of Wildlife and Fisheries).

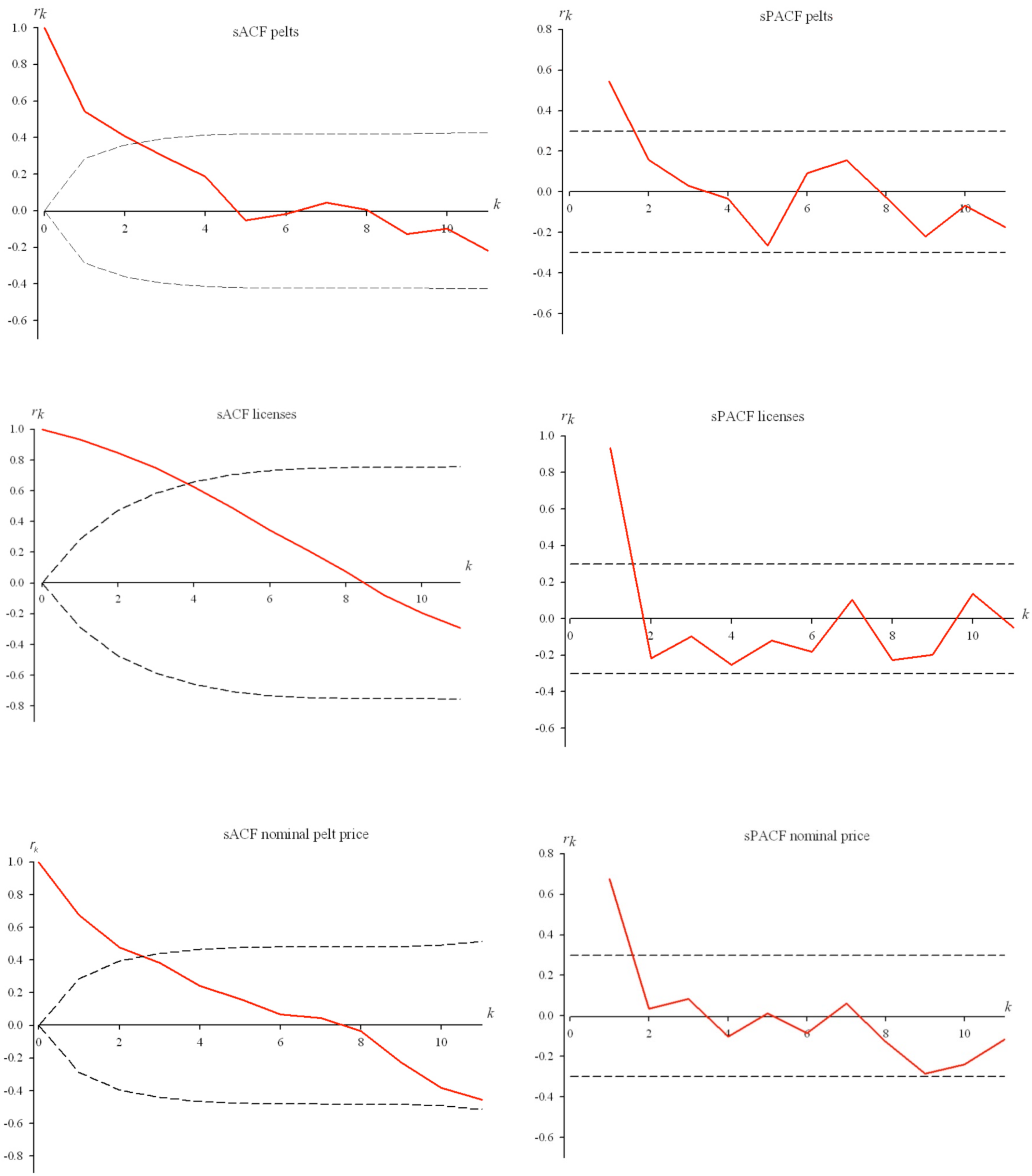

Figure 4. Sample autocorrelation function (sACF) (left) and sample partial autocorrelation function (sPACF) (right) for time series number of otter pelts harvested (top), number of licensed trappers (center), and otter pelt price (bottom) in Louisiana during 1957-2003. Dashed lines indicate 95% confidence interval, *k* represents lag, and *rk* correlation coefficient at lag *k*. Values considered significant if falling outside 95% CI.

by the ADF test (licensed trappers, ADF = –1.08, P = 0.92; pelt price, ADF = –1.53, P = 0.80). Number of licensed trappers and pelt price were detrended by differenciation to meet stationarity assumption required for further analysis.

Cross-correlograms for number of licensed trappers and otters harvested indicated that past number of otters harvested was positively correlated with present number of licensed trappers (significant positive correlation at positive lags k = 3–6 , Fig. 5a) while the only significant cross-correlation between pelt price and number of otters harvested was positive at lag k = 0 (Fig. 5b). Two significant positive cross-correlations at lags k = –1 and –6 indicated that nominal pelt price series led number of licensed trappers (Fig. 5c). No significant ($P < 0.05$) correlations were detected between number of licensed trappers and real pelt price.

Seven ARIMA models were developed to describe number of otters harvested based on the analysis of its sACF and sPACF: a) first-order autoregressive model, AR(1); b) fifth-order autoregressive model with alternate parameters, AR(1,5); c) first-order moving averages model, MA(1); d) fourth-order moving averages model, MA(4); e) fifth-order moving averages model, MA(5); and two mixed model, f) ARMA (1,4) and g) ARMA (1,5). Moving average models MA(4) and MA(5), and mixed models were included in the analysis in an attempt to capture the almost significant peak observed in the sPACF at lag k = 5 for number of otters harvested (Figure 4, top right).

Autoregressive model AR(1,5) had the lowest AIC and for that reason it was selected for forecasting. This model forecasted 5415 otters to be harvested in 2004 (residual = 298, 95% CI: 1570–9261). The equation describing this model was:

$$OTTER_t = 5115 + 0.6\,(OTTER_{t-1} - 5115) \\ -0.26\,(OTTER_{t-5} - 5115) + \text{error}$$

where $OTTER_t$ is number of otters harvested at time t, $OTTER_{t-1}$ is number of otters harvested at time t–1, and $OTTER_{t-5}$ represents number of otters harvested at time t–5.

Seven transfer function models were evaluated based on analysis of sACF and sPACF for number of otters harvested. Transfer function model AR(1) with detrended time series licensed trappers and nominal price as regressors was selected for forecasting based on its AIC. Model equation was:

$$\text{AR(1)}: 4973 + 0.57\,(OTTER_{t-1} - 4973) \\ -0.56\,\nabla LIC - 61.57\,\nabla NPRICE$$

where $OTTER_{t-1}$ represents number of otters harvested at time t-1, and ∇LIC and $\nabla NPRICE$ represent the first difference of the series number of licensed trappers and nominal price respectively. This model forecasted 5398 otters to be harvested in 2004 (residual= 315, 95% CI: 1782–9015).

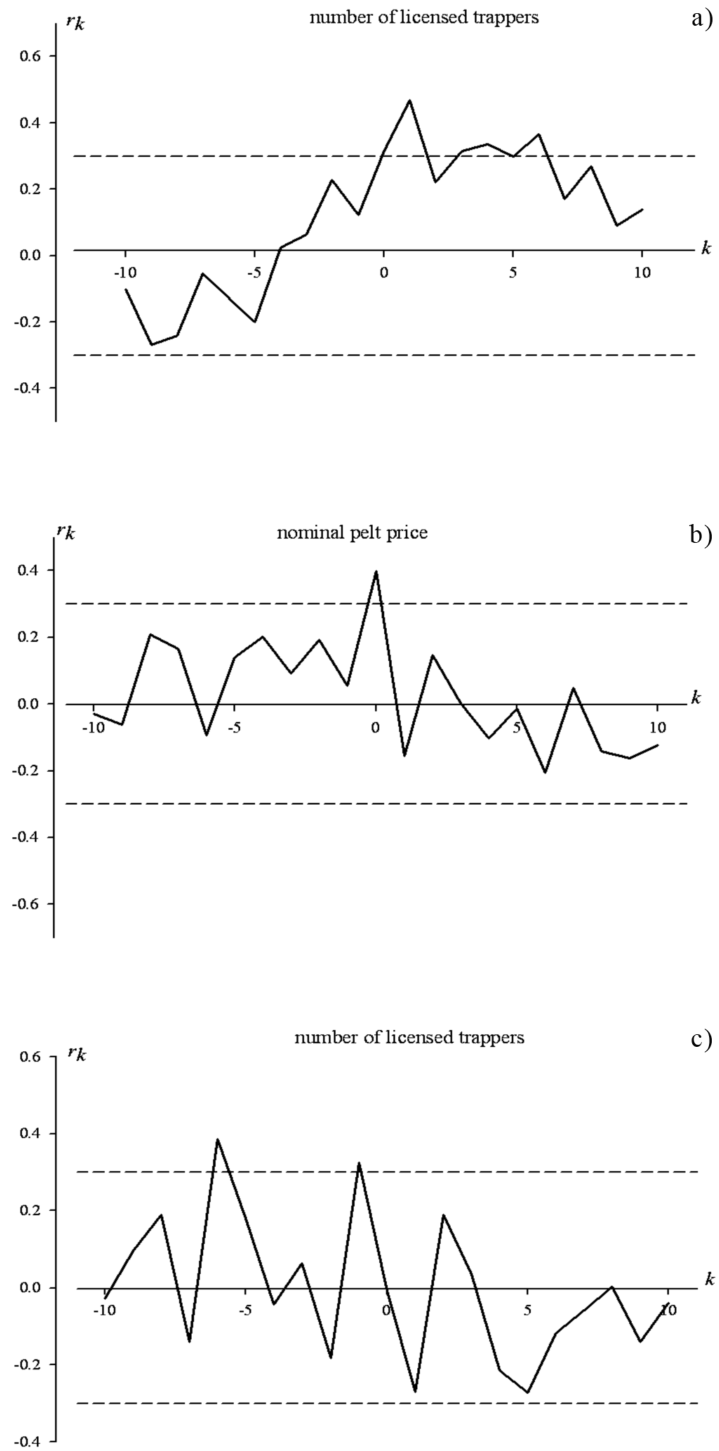

Figure 5. Cross-correlogram for number of otter pelts harvested in Louisiana during 1957–2003 and number of licensed trappers (a) and nominal pelt price (b). Diagram c represents correlogram between number of licensed trappers and pelt price. Dashed lines indicate estimated 95% confidence interval. k :lag, r_k = correlation coefficient at lag k. Values considered significant if falling outside 95% CI.

Discussion

Many considerations are required to select the appropriate model to be used as a forecasting tool, with data accessibility being one of the most critical. The ARIMA model AR(1,5), which had the best performance in terms of residual magnitude, does not require other variables or values from the present trapping season to forecast number of otters to be harvested, a characteristic that indicates that this model could be considered as a valuable tool for the management of river otters in Louisiana. The equation that describes this model and that could be used by state wildlife managers in Louisiana to forecast number of otters harvested is:

$$OTTER_t = \bar{x}_{otter} + 0.6\,(OTTER_{t-1} - \bar{x}_{otter}) - 0.26\,(OTTER_{t-5} - \bar{x}_{otter})$$

where $OTTER_t$ represents number of otters expected to be harvested the current trapping season (time *t*), $\bar{x}_{otter}$ is mean number of otters harvested during the period being analyzed, $OTTER_{t-1}$ represents number of otters harvested at time *t*–1, and $OTTER_{t-5}$ is number of otters harvested at time *t*–5. A 95% confidence interval can be estimated by $OTTER_t \pm 1.96$ SE (SE: standard error).

The performance of the transfer function model AR(1) with number of licensed trappers and nominal price as additional regressors was similar to the ARIMA model AR(1,5) as it had a narrower 95% confidence interval and a slightly larger residual. Although a narrow confidence interval is a desirable property, this transfer function model required present number of licensed trappers and pelt price to forecast number of otters harvested, and these values are usually only available at the end of each trapping season. For that reason, this model may not represent a suitable tool for managers who are interested in estimating number of otters to be harvested at the beginning of the trapping season.

It is important to consider that length of the time series used to detect patterns and associations, and to develop forecasting models is critical, with the longest time series offering the best opportunity to identify better models. Confidence intervals for forecasted values are intrinsically wide in time series forecasting, and they become wider as more years are forecasted. Longer time series also will improve accuracy of the forecast. As more data becomes available, time series should be re-analyzed, and the proposed model should be adapted to new findings.

Besides the benefits that a forecasting model could bring to a management plan for otters in Louisiana, results from this study related to association and/or trends among other harvest related variables also could represent a valuable contribution. Time plots for nominal and real pelt price suggest that otter fur had a greater real value before the 1980s than it has had in more recent years, which may have had some effects on recruitment of new trappers to the trapping activity. Although the nominal price has been increasing for the last 15–18 years, the real price does not represent for trappers what it did in the early 1970s, when each pelt was worth twice as much as it was in 2003 for the trapper's economy.

The international fur trade market suffered a significant transformation in the mid-1980s with the rise of the animal rights movement (Finsen and Finsen 1994). This transformation certainly had an impact on pelt price and trapping activity, which is clearly depicted by a decreasing number of licensed trappers since that time in Louisiana. This trend in number of trappers is concurrent with a nationwide decline in number of people involved in furbearer trapping, which has been related to lack of trapper recruitment, a general decline in pelt prices among all furbearer species, and an increase in anti-trapping sentiment (Armstrong and Rossi 2000).

Given the decline in number of licensed trappers and the relatively lower value of otter pelts in recent years, one would expect a decline in number of otters harvested. However, number of otters harvested remained stationary. We hypothesize that this stationarity could be a consequence of the relatively high value of river otter pelts in the fur market compared to other species. The relatively high value of otter pelts compared to other furbearer species in Louisiana (St. Amant 1957, Linscombe and Kinler 1985) could have led active trappers to target this species more in recent years. This change in trapper attitude could be the reason why otter harvest has remained relatively stable, although number of trappers has been declining since the early 1980s.

Another possibility for the stationarity detected in number of otters harvested is that this stationarity resulted from an increase in otter catchability (defined as the probability of catching an otter). Otter catchability could be higher in response to increased otter population abundance, perhaps due to a decline in number of trappers (Caughley 1977). With all other variables constant, a trapper supposedly could catch more otters if he/she had more interest in catching one (i.e., setting more traps) or if there were more otters that could potentially be caught (i.e., same number of traps, but otters are more abundant). With no data available on trapping effort or trapper's attitude in Louisiana, it is unclear whether the stationarity in number of otters harvested is a consequence of an increase in abundance of otters with no changes in harvest effort or due to a renewed interest of trappers in river otters considering the sustained high price of otter pelts compared to other furbearer species. Regardless of the actual process(es) involved, it seems reasonable to assume that the dramatic decline in number of licensed trappers must have positively affected abundance of river otters in Louisiana at some level (Caughley 1977) independently of whether active trappers have an increased interest in the species in recent years.

Cross-correlation analysis identified associations existing between number of otters harvested, number of licensed trappers, and pelt price. As mentioned before, the significant positive correlation at positive lags in Figure 5a indicated that present number of licensed trappers was correlated to past number of otters harvested, suggesting that any changes in number of otters harvested will be followed by changes in the same direction in number of licensed trappers. This association could be explained assuming that a string of successful or unsuccessful trapping seasons could encourage new people to participate or quit trapping activities during the next few trapping seasons (Berryman 1991). Cross-correlation also indicated that the association between number of otters harvested and pelt price could be purely contemporaneous. This suggests that no time series lead the other and that average pelt price paid in any of the previous trapping seasons does not affect number of otters harvested during present or future trapping seasons. This non-lagged effect of pelt price on number of otters harvested agrees with the lack of association between these two variables identified in the extensively studied time series representing lynx fur returns from the Hudson's Bay Company (Brand and Keith 1979, Royama 1992).

The cross-correlogram representing the association between pelt price and number of licensed trappers indicated that changes in pelt price may positively affect future number of licensed trappers or, in other words, that an increase/decline in pelt price would be followed by an increase/decline in number of licensed trappers one and six years from the trapping season being considered in the pelt price time series. It has been suggested that beaver pelt price also may have some effect on trapper participation in the following trapping season (Runge 1999, Runge et al. 2000). Although a one-year positive effect of pelt price on number of licensed trappers can be expected (assuming that a high pelt price at a particular trapping season will make trappers return to this activity the following year), a direct effect of the current pelt price on number of trappers six years into the future is more difficult to explain. However, an indirect association could be identified by hypothesizing that this delayed effect of pelt price on number of licensed trappers could result from combined effects of the contemporaneous cross-correlation between number of otters harvested and pelt price and the six-year lagged cross-correlation between number of otters harvested and number of licensed trappers.

Finally, even though harvest data for otters in Louisiana has been kept by the LDWF almost without interruption since 1914, it was in 1977 when the LDWF began requiring fur buyers and dealers to record directly from trappers not only the species and approximated date an animal was caught, but also the parish where that animal was trapped. At the time of the publication of this study, the time series describing number of otters harvested per parish was too short for analysis; however, as this database grows and as spatial distribution of harvest related variables is incorporated into this database, the possibility of developing spatially explicit forecasting models will become more real. State agencies are encouraged to standardize and intensify data collection on otters or other species being harvested, considering characteristics of the animals being caught (i.e., sex, age, reproductive status) and trapping effort. Building a database with this kind of information could create the possibility of making inferences about otter population trends based on harvest data. Future research on ecology and dynamics of otters in Louisiana will further contribute to the performance of this model.

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Literature Cited

Armstrong, J. B. and A. N. Rossi. 2000. Status of avocational trapping based on the perspectives of state furbearer biologists. Wildlife Society Bulletin 28:825–832.

Beck, D. 1977. Pesticides and heavy metal residues in Louisiana river otter. Master's Thesis. Texas A&M University, College Station.

Berryman, A.A. 1991. Can economic forces cause ecological chaos? The case of the Northern California Dungeness crab fishery. Oikos 62:106–109.

Box, G.P. and G.M. Jenkins. 1970. Time series analysis, forecasting and control. San Francisco: Holden-Day.

———, ———, and G.C. Reinsel. 1994. Time series analysis, forecasting and control. Prentice-Hall, Englewood Cliffs, New Jersey.

Brand, C.J. and L.B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. Journal of Wildlife Management 43:827–849.

Brocklebank, J.C. and D.A. Dickey. 2003. SAS for forecasting time series. SAS Institute, Inc. Cary, North Carolina.

Bureau of Labor Statistics. 2004. U.S. Department of Labor. Bureau of Labor Statistics. Consumer Price Index. http://stats.bls.gov/cpi/home.htm

Burnham, K.P. and D.R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Second Edition. Springer-Verlag, New York, New York.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley & Sons. New York.

Chabreck, R., J. Holcombe, G.L. Linscombe, and N. Kinler. 1982. Winter food of river otters from saline and fresh environments in Louisiana. Proceedings Annual Conference of the Southeastern Assocation of Fish and Wildlife Agencies, 36:373–383.

———, T. Edwards, and G.L. Linscombe. 1985. Factors affecting the distribution and harvest of river otters in Louisiana., Proceedings Annual Conference of the Southeastern Assocation of Fish and Wildlife Agencies, 39:520–527.

Chatfield, C. 1980. The analysis of time series : an introduction. Chapman and Hall, New York.

———. 2001. Time-series forecasting. Chapman and Hall/CRC London, UK.

Enders, W. 2004. Applied econometric time series. Wiley & Sons, Inc.

Ensminger, A. and G.L. Linscombe. 1980. The fur animals, the alligator, and the fur industry in Louisiana. Louisiana Department of Wildlife and Fisheries Bulletin, 109. Baton Rouge.

Feldhamer, G.A; B.C. Thompson, and J.A. Chapman. 2003. Wild mammals of North America: biology, management, and conservation. Second Edition. The Johns Hopkins University Press. Baltimore, Maryland.

Finsen, L. and S. Finsen. 1994. The animal rights movement in America. Twayne Publishers. New York.

Fleming, W.J., C.M. Bunk, G. Linscombe, N. Kinler, and C.J. Stafford. 1985. PCBs, organochlorine pesticides, and reproduction in river otters from Louisiana. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 39:337–343.

Gottman, J.M. 1981. Time series analysis. A comprehensive introduction for social scientists. Cambridge University Press. Cambridge, UK.

Jonzen,N., E. Ranta, P. Lundberg, V. Kaitala, and H. Lindén. 2003. Harvesting-induced population fluctuations? Wildlife Biology 9:59–65.

Kendall, M. and J.K. Ord. 1990. Time Series. Third Edition, Oxford Press, UK.

Linscombe, R.G. and N. Kinler. 1985. Fur harvest distribution in Louisiana. Pages 187–199 *in*: C.F. Bryan, P.J. Zwank, and R.H. Chabreck, editors. Proceedings of the Fourth Coastal Marsh and Estuary Management Symposium. Louisiana State University, Baton Rouge.

Ljung, G.M. and G.E. Box. 1978. On a measure of lack of fit in time series models. Biometrika 65:297–303.

Melquist, W.E. and A.E. Dronkert. 1987. River otter. Pages 627–641 *in*: Wild furbearer management and conservation in North America. Ministry of Natural Resources. M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Ontario, Canada.

——— and M.G. Hornocker. 1983. Ecology of river otter in west central Idaho. Wildlife Monographs 83.

———, P.J. Polechla, and D. Toweil. 2003. River otter. Pages 708–734 *in* Wild mammals of North America: biology, Management, and conservation. G. A. Feldhamer, B. C. Thompson, and J.A. Chapman editors. Second Edition. The Johns Hopkins University Press. Baltimore, Maryland.

Novak, M, J.A. Baker, M.E. Obbard, and B. Malloch, editors. 1987. Wild furbearer management and conservation in North America. Ministry of Natural Resources. Ontario, Canada.

Royama, T. 1992. Analytical population dynamics. Chapman and Hall, New York.

Runge, M.C. 1999. Design and analysis of a model for adaptive harvest management of beaver (*Castor canadensis*). Ph. D. Dissertation. Cornell University, Ithaca, New York.

———, M.C. Gotie, D.H. Streeter, and A.N. Moen. 2000. A time series for beaver pelt price. Northeast Wildlife 55:1–10.

SAS. 2003. SAS user's guide: SAS/ETS version 9.1. SAS Institute Inc. Cary, North Carolina.

Scognamillo, D.G. 2005. Temporal and spatial harvest patterns of river otter in Louisiana, and its potential use as a bioindicator species of water quality. Ph. D. Dissertation. Louisiana State University, Baton Rouge.

Shirley, M.G., G.L. Linscombe, N.W. Kinler, R.M. Knaus, and V.L. Wright. 1988. Population estimates of river otters in a Louisiana coastal marshland. Journal of Wildlife Management 52:512–515.

St. Amant, L.S. 1959. Louisiana wildlife inventory and management plan. Louisiana Wildlife and Fisheries Commission.

Tarver, J, G.L. Linscombe, and N. Kinler. 1987. The fur animals, the alligator, and the fur industry in Louisiana. Louisiana Department of Wildlife and Fisheries Bulletin, 109. Baton Rouge.

Wilson, G.T. 2001. Univariate time series: autocorrelation, linear prediction, spectrum, and state-space model. Pages 25–52 *in* D. Pena, G.C. Tiao, and R.S. Tsay, editors. A course in time series analysis, Wiley Series in Probability and Statistics. New York.