A COMPUTERISED PROCESSING AND ANALYSIS SYSTEM FOR DISEASE MONITORING USING SLAUGHTERHOUSE CONDEMNATION DATA

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INTRODUCTION

The primary function of meat inspection is to protect the public health, but it has an additional economic duty in that there must be no unnecessary condemnation of the valuable commodity. In recent years, however, more attention has been paid to another important aspect of meat inspection. Accurate meat inspection data can provide statistics which can be utilised for animal disease control purposes (Gracey, 1986). Farm surveys have been carried out to determine the prevalence of animal diseases in different countries. However, not all disease prevalences can be obtained from a study of the picture in selected farms. Indeed, the abattoir is the only place where certain disease conditions can be evaluated. Thus extensive meat inspection data, if retrievable, can provide an economic method of accurately investigating and monitoring many important production diseases (McIlroy et al., 1987).

This paper describes a computerised information retrieval system for slaughterhouse condemnation data relating to specific disease conditions in the cattle, sheep and pig populations of Northern Ireland since 1969. Examples of the use of the system to evaluate trends in diseases and the influence of weather on the occurrence of disease are provided.

MATERIALS AND METHODS

In 1969, a computerised data processing system was established to collect and collate information on the specific cause and location of condemnations in cattle, sheep and pigs in all slaughterhouses throughout Northern Ireland (Stewart, 1969). Individual records of condemnations for each species are collated onto specially designed forms on a weekly basis. An example of one of the abattoir condemnation collation forms for cattle is given in Fig 1. The input values in individual cells on the form are logged directly onto a micro VAX computer. The data processing system consists of a relational database utilising fourth generation language tools running on this micro VAX computer. Monthly summary reports of slaughterhouse condemnation data are produced and distributed manually to all interested parties. The format of the monthly report consists of a matrix with rows (m) detailing the designated reasons for condemnation and columns (n) corresponding to the specific carcase area or organ affected. An example of the type of information recorded for sheep is given in Table 1. Individual cells within the matrix record the monthly total within each category for each species. The total number of each species slaughtered is also recorded.

TABLE 1
Reasons for condemnations in sheep slaughtered in Northern Ireland and the carcase area affected

Rows (m)	Columns (n)
Abscesses & Pyaemia	Whole carcase
Arthritis	Side
Bruising etc	Fore quarter
Contamination	Hind quarter
Decomposition	Head
Emaciation	Tongue
Fever	Other carcase portions
Insufficient bleeding	Pairs of lungs
Nephritis & Nephrosis	Plucks
Oedema	Heart
Parasitic conditions	Stomach
Pericarditis etc	Intestine
Peritonitis etc	Spleen
Pleurisy & Pneumonia	Whole liver
Tumours	Kidneys
Uraemia	Other

The data processing system was initiated and has been subsequently managed for purely administrative purposes. However, no database retrieval software exists for statistical and epidemiological analysis. Furthermore, no routine archiving of the data onto backing storage is performed and retrospective data are therefore only available in the form of the hardcopy reports.

In 1986, a system was set up to enable statistical and epidemiological analysis of the slaughterhouse condemnation data. The system has been described in detail by McIlroy et al. (1988). The monthly summary reports were logged onto a VAX 6320 super mini-computer via the central data processing unit of Biometrics Division. The information was transferred in duplicate directly from the hardcopy reports and validated by a "key-to-disc" program, running on Sperry-Univac equipment. The VAX 6320 computer incorporates a virtual memory enhancement system and has available 32 megabytes of main memory, 5 gigabytes of hard-disk backing storage and a 1600 b.p.i. magnetic tape unit for routine archiving. The system supports over 60 visual display terminals.

The main software available for data analysis is a suite of specially written FORTRAN 77 programs which enable routine interactive, complex time series analysis of the database. These programs, which are menu-driven, are specifically structured to facilitate the flexible analysis of time series data. A key feature contained within this suite of programs is the ability to merge the variables held in the slaughterhouse condemnation database with corresponding meteorological variables. This is achieved using an index file structure and enables multivariate analysis of the overall integrated database system.

An additional function of the suite of programs is the ability to extract data from the database and construct files suitable for analysis by the statistical software package, GENSTAT. This package enables basic statistical summaries of data and also more advanced statistical analysis such as generalised analysis of variance and multiple regression. Tabular and graphical output of any analyses is available on distributed VT220 terminals, an HP2686A laser printer and an HP7475A graph plotter.

A typical terminal session proceeds on a menu-driven, interactive basis. Authorised research workers are prompted, via the FORTRAN 77 program, to select from the slaughterhouse condemnation database the variable under current investigation. The corresponding matrix file for the variable selected from disk consists of the monthly condemnation percentage of the total number of animals slaughtered. The user is then prompted to select from a menu a specific statistical analytical procedure. The system analysis will normally proceed using individual monthly values of any selected variable. However, there is an option available at this stage to compute average combinations of months (eg, bi-monthly, quarterly etc) and automatically store these in a new file for further analysis. Files of running averages for monthly condemnations of data can also be constructed for analysis.

During a preliminary analysis of the selected variable, the annual condemnation prevalence is usually computed and displayed in graphical and tabular format, the former facilitating the visual assessment of any trend over the time series. Hardcopies of these output files are available on the graph plotter and laser printer, respectively.

The next stage in the analysis normally involves the computation of average monthly prevalences in individual years and over all years.

This facilitates the detailed analysis of any seasonality pattern of the variable under investigation. Output files are again available in both tabular and graphical format. If seasonality patterns and/or statistically significant trends are identified, an option is available in the menu to perform complex statistical detrending and deseasonalisation techniques on the original time series. The resultant filtered series are automatically stored in a new file for additional comparative analysis with other variables. Correlograms are routinely produced by the system in both graphical and tabular format and used to assess the stationarity of the detrended, deseasonalised series.

When the preliminary analysis of the slaughterhouse condemnation variable has been completed, the research worker is prompted to select any individual or linear combination of variables from the meteorological database. The selected meteorological variable is also subjected to the same preliminary analysis and a file containing the resultant filtered series produced. After all preliminary analyses of relevant slaughterhouse condemnation and meteorological variables have been performed, the research user would normally select from the menu the option to cross correlate selected variables. The user is prompted to select whether cross correlations are to be performed on data recorded at coincident time intervals or data lagged at any time interval from one to twenty-four months. All subsequently computed correlation coefficients are again available in both tabular and graphical formats. The latter facilitates the visual assessment of any associations occurring between variables, on a routine interactive basis. This is especially important in the systematic, exploratory analysis of complex epidemiological interactions between variables in the integrated database.

An additional menu option availab is the ability to rank years in ascending order, depending on t overall mean value of a meteorological variable prevailin Years can then be grouped, typical into two categories, high and lo depending on prevailing weath conditions. The average month percentages of any slaughterhou condemnation variable are comput for each selected group of year These overall monthly averages c be compared statistically, using paired t-test, after the arcsi root transformation has be performed on the data. A final me option is the possibility o transferring any created files in the statistical software packag GENSTAT, for advanced statistic analyses.

RESULTS AND DISCUSSION

The importance of slaughterhou condemnation data as an effecti method of disease surveillance in population has been recognised Northern Ireland for many year Thus Gracey (1960), reporting on t disease incidence during the mid-5 in 600 randomly selected farm considered concurrent slaughterhou condemnation data essential t obtain an accurate assessment of t disease prevalence in the overa population. This extensive surve which was one of the first to conducted in any country, w initiated and administered by t Department of Agriculture f Northern Ireland.

Slaughterhouse condemnation data h been used in many countries t evaluate the epidemiological aspec of animal diseases. Most surve have been conducted on an ad h basis on specific disease syndrom (Penny and Mullen, 1975). Mo recently, routine analysis of dynamic database of slaughterhou condemnation data has been perform in Sweden and Denmark. The Swedi system has been used in veterin preventive medicine programmes a in epidemiological investigation However, the slaughterhou condemnation data is restricted pigs and available only from a limited number of slaughterhouses (Backstrom and Bremer, 1978). The Danish system is again restricted to pigs but collates data from the majority of slaughterhouses involved in the slaughtering of pigs in Denmark (Willeberg, 1980). This system has also been used in veterinary preventive medicine programmes and epidemiological investigations and also has the ability to monitor the disease status of individual farms presenting animals for slaughter.

The availability of data on a monthly basis since 1969 for each condemnation variable has enabled the formation of a large database for the investigation of diseases in the total population of cattle, sheep and pigs. The special features of the software described previously enables the systematic performace of advance time series analysis. The creation of a flexible, interactive FORTRAN program to perform such analysis on a routine basis is considered essential for exploratory research.

An example of the importance of identifing disease trends is given in Fig 2. This Figure demonstrates the annual average prevalence of liver condemnations in pigs due to cirrhosis. Such cirrhotic lesions are almost invariably associated with the migration of the larval stage of the economically important pig nematode Ascaris suum during the production period. The annual increase in the prevalence of this disease is very highly statistically significant ($p<0.001$). It was previously accepted that this condition was adequately controlled by modern management methods and prophylactic anthelmintic treatment. It is clearly apparent from the computer analysis of the database that this supposition is erroneous. These important findings are being used to stress the continued necessary use of strategic control measures to the pig industry in Northern Ireland. Assessing and reporting the efficacy of any control measures implemented will form the basis of future analysis of this economically important condition of pigs.

The importance of identifying and quantifying the seasonality pattern of a disease is demonstrated in Fig 3. This Figure shows the recorded average monthly prevalence of pleurisy and pneumonia in sheep since 1969 to 1988 inclusive. Such lesions are indicative of pneumonia during the production period. A distinct pattern is evident with the maximum prevalence of lung condemnations occurring in the early spring and the minimum in the summer. Notably, this pattern was found to be consistent for all years. This pattern suggests that weather conditions are important in the occurrence of such lesions. This possibility was examined by cross correlating the prevalence of pleurisy and pneumonia at slaughter with all relevant weather variables, lagged at different time intervals. Statistically significant correlations were found with several lagged weather variables. The most highly significant correlation between the prevalence of pleurisy and pneumonia in sheep was found with the combined weather variables, rain and windchill, lagged by two months ($p<0.001$). This demonstrates that high rain and windchill conditions prevailing within a particular time interval may precipitate the occurrence of pneumonia in sheep. Such a disease incident is subsequently reflected in the prevalence of lung condemnations due to pleurisy and pneumonia, in slaughterhouses throughout Northern Ireland, two months later.

The facility to categorise years for individual variables is also demonstrated by lung condemnations due to pleurisy and pneumonia in sheep. The 18 years under investigation were ranked in ascending order, depending on the mean value of the annual rain and windchill prevailing. The years were then categorised into two groups, high and low rain and windchill years. The average monthly values for each group are shown in Fig 4. The mean prevalence of lung condemnations due to pleurisy and pneumonia for the low rain and windchill group was 0.28%. The corresponding mean for the high rain and windchill group was 0.63%. The standard error of the difference of the means of these two groups was 0.003. After the arcsine root transformation had been carried out and a paired t-test performed, a very highly significant difference between the mean values for each group was found ($p<0.001$). The practical significance of this important finding is that, in years when the degree of rain and windchill was high, the level of pleurisy and pneumonia in the sheep population of Northern Ireland more than doubled.

These research findings are of great practical importance to sheep production in Northern Ireland, an area with high rain and windchill prevailing between September and April. Notably, the majority of the sheep population are not provided with any form of shelter during this period and are thus continuously exposed to prevailing adverse weather conditions. This may substantially increase their susceptibility to the detrimental effects of rain and windchill and thus increase the risk of the occurrence of pneumonia.

The results of this important research, which have been published recently (McIlroy et al., 1989), strongly suggest that sheep should be protected from the combined effect of these two adverse weather conditions which commonly prevail in Northern Ireland during the winter months.

Another practical example of the value of analysing the combined database of slaughterhouse condemnation and meteorological data has been the formulation of a new mathematical model which accurately forecasts the prevalence of fasciolosis (liver fluke) in Northern Ireland. Fasciolosis is a serious economic disease of cattle and sheep with a worldwide distribution. In the annual control of the disease, it is highly desirable that the issue of specific veterinary advice on the strategic use of control measures, such as the use of modern, flukicidal drugs, should be based on precise forecasts of the levels of risk of the disease. The monthly prevalence of liver condemnations due to fasciolosis in sheep has been used in the investigation of the epidemiology of this important disease of production. The prevalence of liver condemnations due to fasciolosis was computed as a percentage of the total number of sheep slaughtered on a monthly basis and a distinct seasonality pattern was found which was consistent from year to year. The average monthly prevalence of fasciolosis (with corresponding standard errors) in sheep in Northern Ireland from 19 to 1988 is demonstrated in Fig 5. The minimum prevalence was invariably recorded in July and August with the maximum levels being achieved throughout the winter period. In view of the consistent and distinct seasonal pattern in the prevalence of this disease and the known dependance for its development on previously occurring favourable weather conditions (Soulsby, 1982) a meaningful fasciolosis year was defined. Each fasciolosis year was defined as commencing in August and terminating in the following July. The average prevalences for each of the eighteen fasciolosis years available from the abattoir pathology database were computed and are demonstrated in Fig 6.

The detailed mathematical methods used in the formulation of the new forecasting model have been described in detail by Goodall et al. (1989). A wide variety of autoregressive integrated moving average (ARIMA) processes were fitted to the time series of the annual prevalence of fasciolosis. Such ARIMA processes were investigated using the methodology described by Box and Jenkins (1968). The most suitable ARIMA process for the annual fasciolosis time series, as determined by the criterion of Akaike (1978), was found to be a first order Markov process. The proportion of variation accounted for by fitting the Markov process was 67%.

The annual time series was further analysed by ranking fasciolosis years into ascending order depending on the level of all possible weather conditions prevailing. This process involved computing the average monthly value of all individual weather variables and all possible linear combinations of such monthly values over the entire time series. The eighteen fasciolosis years were then categorised into two groups, high and low, depending on the weather conditions being above or below the medium value of the entire time series. The average monthly prevalences of liver condemnations for the years within each group were computed. The computed values were subjected to the arcsine root transformation and a paired t-test used to compare the mean values for each of the two groups. Using this procedure, five weather variables were associated with very highly significant differences ($p<0.001$) in the annual prevalences of fasciolosis as determined by specific liver condemnations. These five weather variables were mean temperature, wind and rain for the months, June, July, August (summer), and mean temperature and wind for the months March, April, May (spring). The inclusion of these five weather variables in a multiple regression model yielded a very highly significant multiple correlation coefficient of 0.95 ($r^2 = 90\%$). The fitted values from this new model and the observed values for individual fasciolosis years are shown in Fig 7 and clearly indicate the establishment of an accurate system for determining the annual prevalence of this economically important disease.

The forecasts are made at the end of August when all of the slaughterhouse and meteorological components of the model are available. The accurate forecasts can therefore be made at a time when strategic preventative measures for the control of the disease over the ensuing fasciolosis year can be effectively implemented. The new computer system can be used to forecast accurately the annual risk of fasciolosis in any region of the world where information on the previous years prevalence, as determined by specific slaughterhouse condemnation data, and the relevant temporal meteorological conditions are available (McIlroy et al., 1989).

CONCLUSIONS

This computerised data analysis system encorporates a large database of slaughterhouse condemnation variables and meteorological variables. The entire population of the three major production species slaughtered in all slaughterhouses throughout Northern Ireland is being monitored on an ongoing basis. The customised software enables systematic time series analysis of condemnation variables and also their cross correlation with concurrent meteorological data. The software also facilitates the investigation of complex epidemiological interactions and permits the accurate assessment of the cost of many disease syndromes to animal production in Northern Ireland. The system is established on a permanent basis and routine reports are issued to all interested parties concerned with profitable animal production.

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LEGENDS FOR FIGURES

Figure 1. Slaughterhouse condemnation data collation form for cattle.

Figure 2. The annual prevalence of liver condemnations in pigs due to cirrhotic lesions.

Figure 3. The overall average monthly prevalence of lungs condemned due to pleurisy and pneumonia in sheep from 1969 to 1988.

Figure 4. The overall average monthly prevalence of lungs condemned due to pleurisy and pneumonia in sheep in years when the prevailing rain and windchill was either high or low.

Figure 5. The average monthly prevalence of liver condemnations due to fasciolosis in sheep.

Figure 6. The average annual prevalence of fasciolosis in sheep.

Figure 7. The observed and predicted annual prevalence of fasciolosis in sheep.

Week Ended: ____________

↑	I		*		*	I	*		N/L

CATTLE

WED. / SAT.

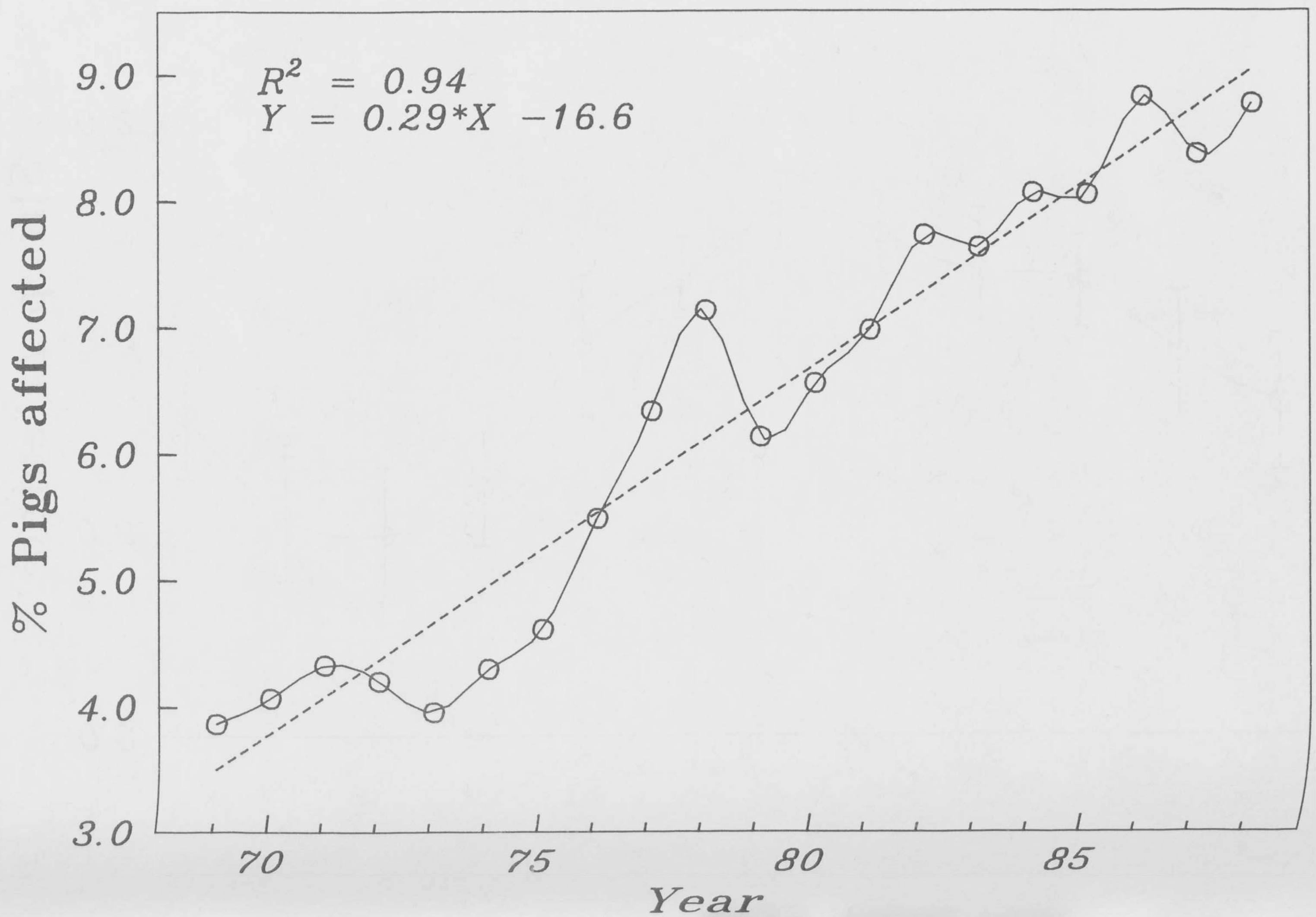
TOTAL | | Home / Export

REASON FOR CONDEMNATION	Code	Carcases	PART CARCASES				OFFALS										Others (b)	TOTAL
			Sides	Fore-quarters	Hind-quarters	Other Portions	Heads	Tongues	Pairs of Lungs	Hearts	Stomachs	Intestines	Spleens	Livers Whole	Livers Part	Kidneys		
ABSCESSES AND PYAEMIA	01	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
ACTINO-BACILLOSIS	02	A		C		E	F	G	H	J	K	L	M	N	P		R	S
ARTHRITIS	03	A	B	C	D	E											R	S
BRUISING, ETC.	04	A	B	C	D	E	F	G									R	S
CIRRHOSIS	05													N	P		R	S
C. BOVIS	06	A					F	G	H	J	K	L	M	N	P	Q	R	S
CONTAMINATION	07	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
DECOMPOSITION	08	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
EMACIATION	09	A	B	C	D	E												S
FASCIOLIASIS	10	A												N	P			S
FEVER AND SEPTICAEMIA	11	A																S
INSUFFICIENT BLEEDING	12	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
NEPHRITIS AND NEPHROSIS	13	A														Q	R	S
OEDEMA	14	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
PARASITIC CONDITIONS	15	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
PERICARDITIS, ETC.	16	A				E			H	J								S
PERITONITIS, ETC.	17	A	B		D	E					K	L	M	N	P	Q	R	S
PLEURISY AND PNEUMONIA	18	A	B	C		E			H	J								S
TUBERCULOSIS	19	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
TUMOURS	20	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
URAEMIA	21	A																S
OTHERS (a)	22	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
TOTALS	23	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S

SPECIFY OTHERS: (a) REASONS: ____________ (b) PARTS/OFFALS: ____________

←N/L

Signed ____________ V.O./P.H.I.


R² = 0.94
Y = 0.29*X −16.6
% Pigs affected
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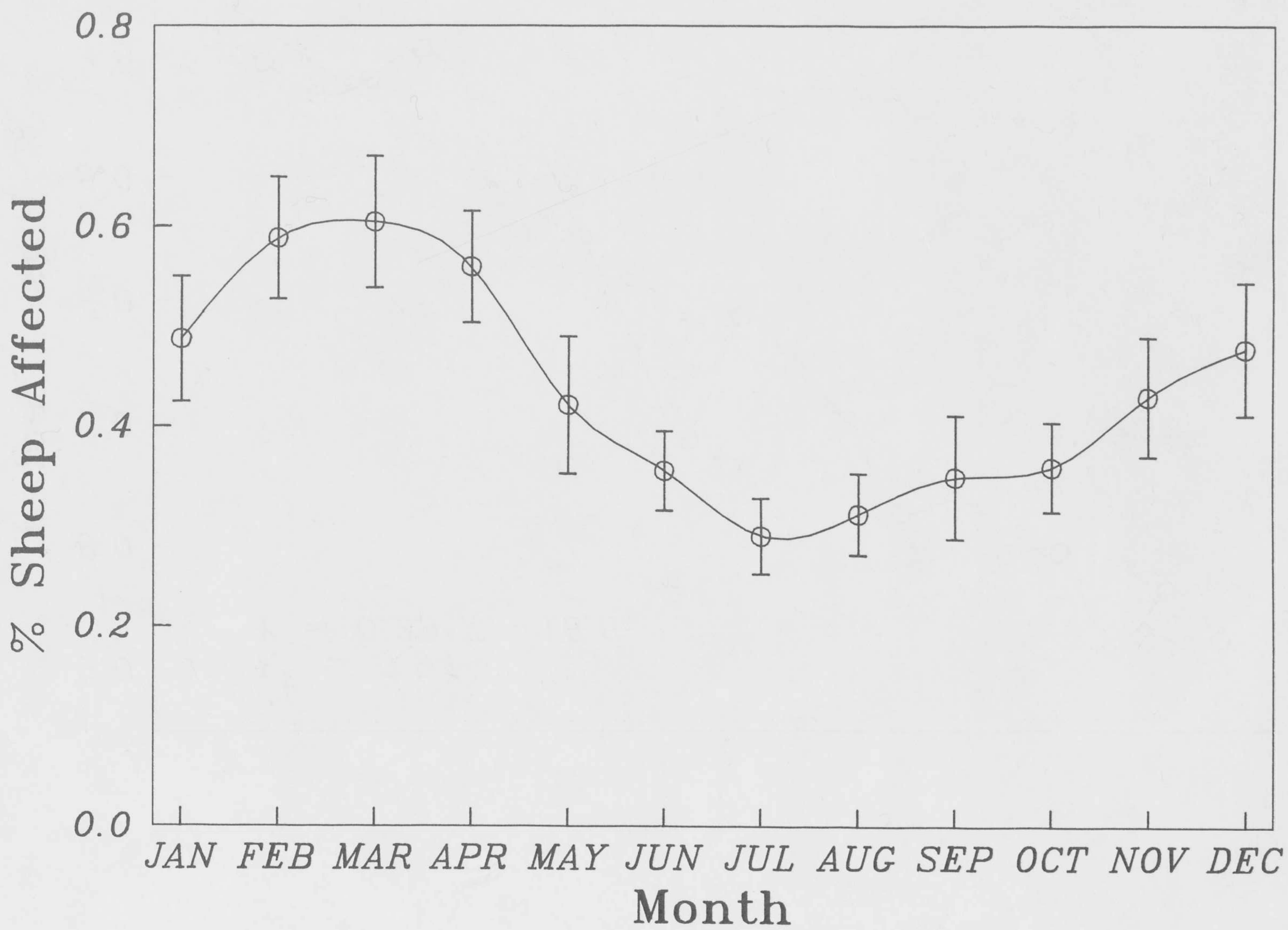
8.0
7.0
6.0
5.0
4.0
3.0
70
75
80
85
Year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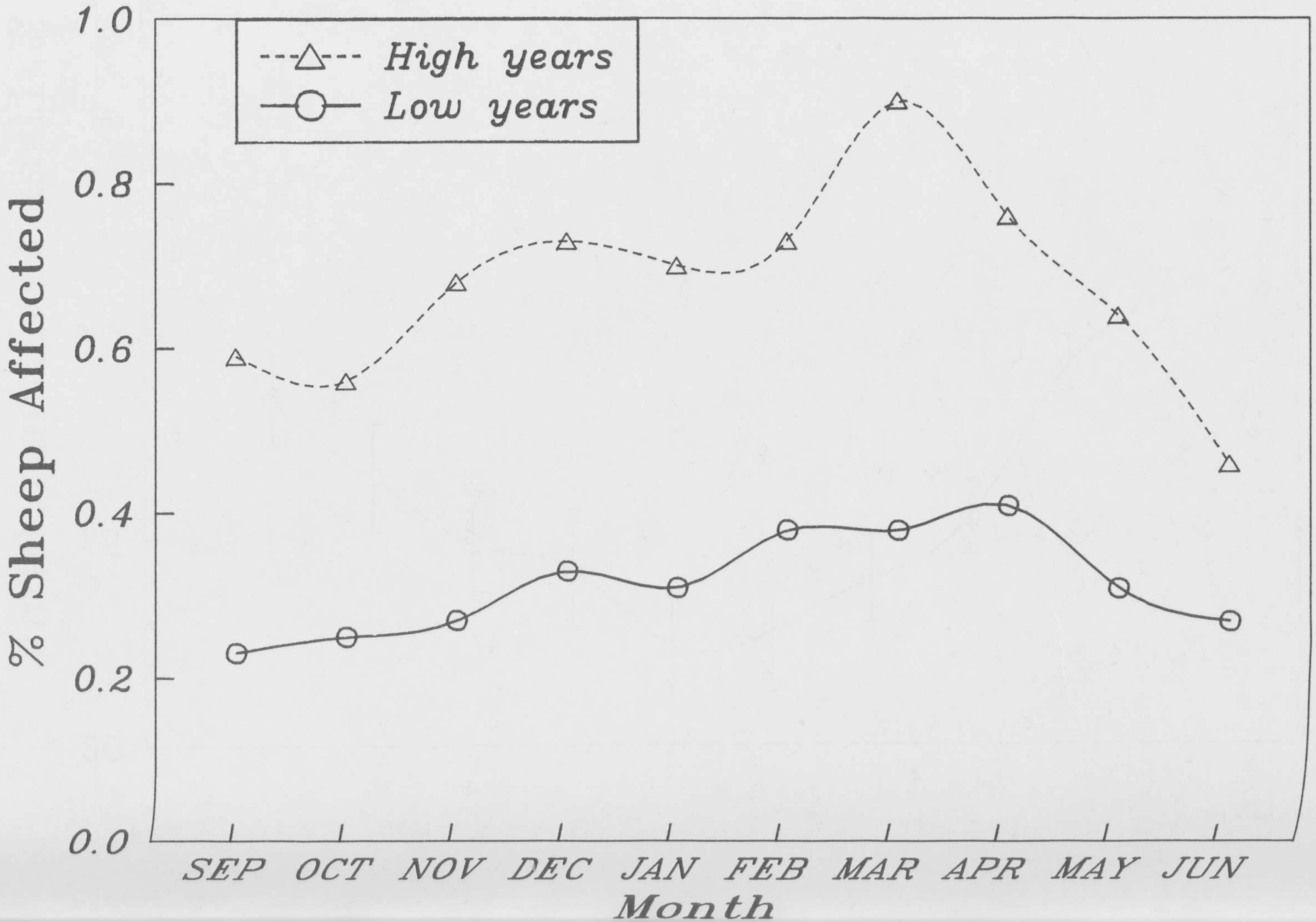
0.6
0.4
0.2
0.0
% Sheep Affected
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


High years
Low years
% Sheep Affected
1.0
0.8
0.6
0.4
0.2
0.0
SEP
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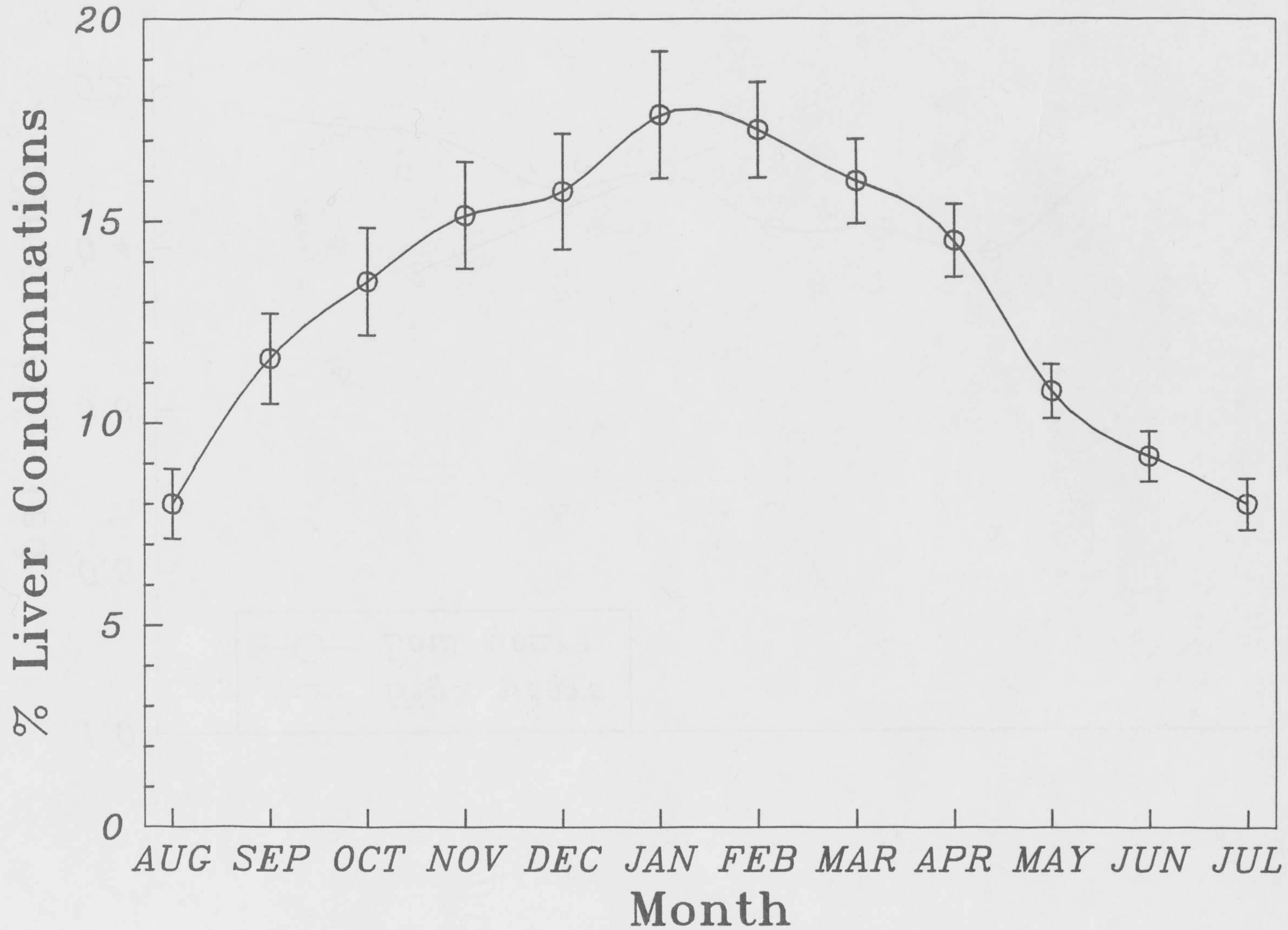
DEC
JAN
FEB
MAR
APR
MAY
JUN
Month


% Liver Condemnations
20
15
10
5
0
AUG
SEP
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NOV
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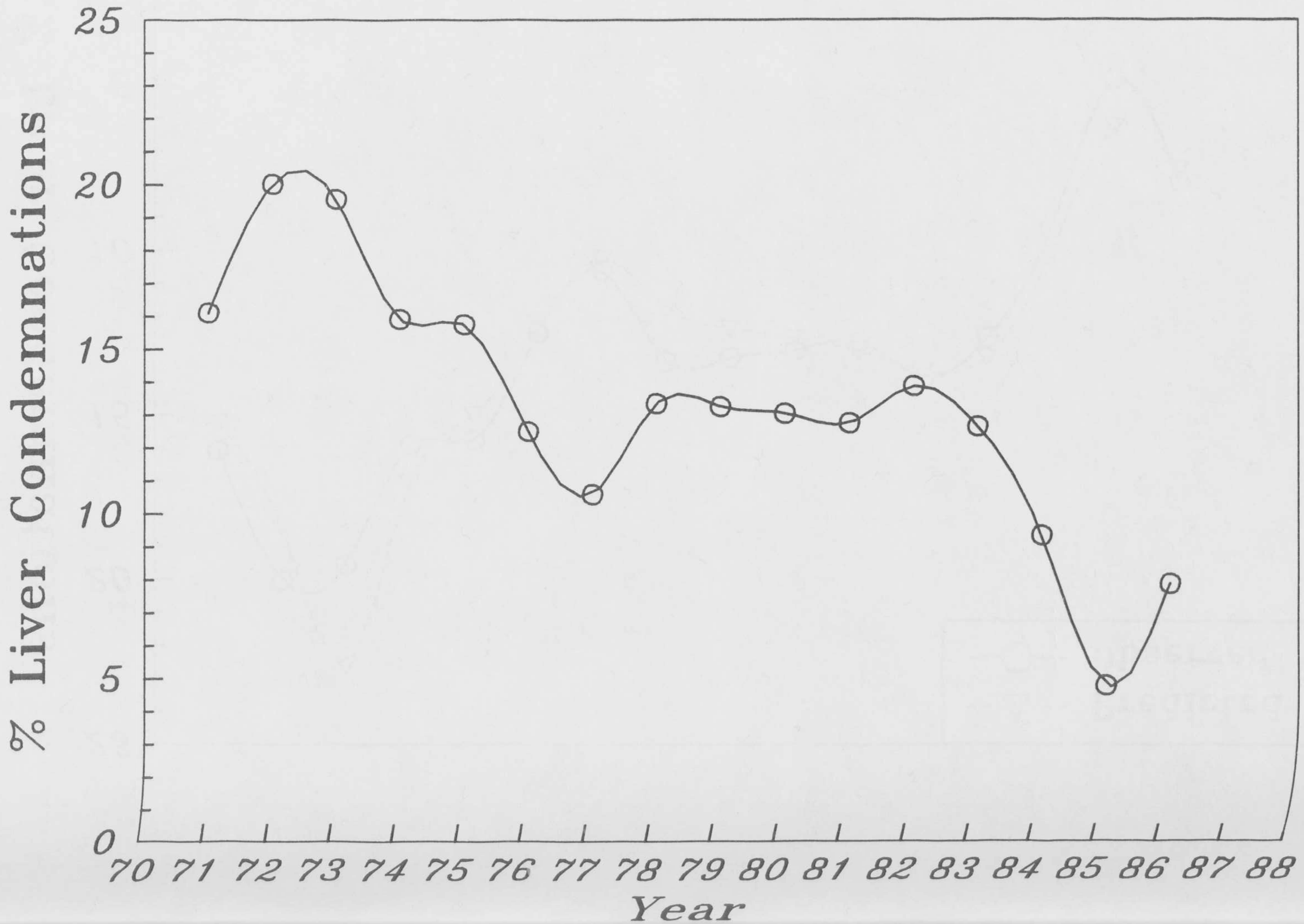
JUL
Month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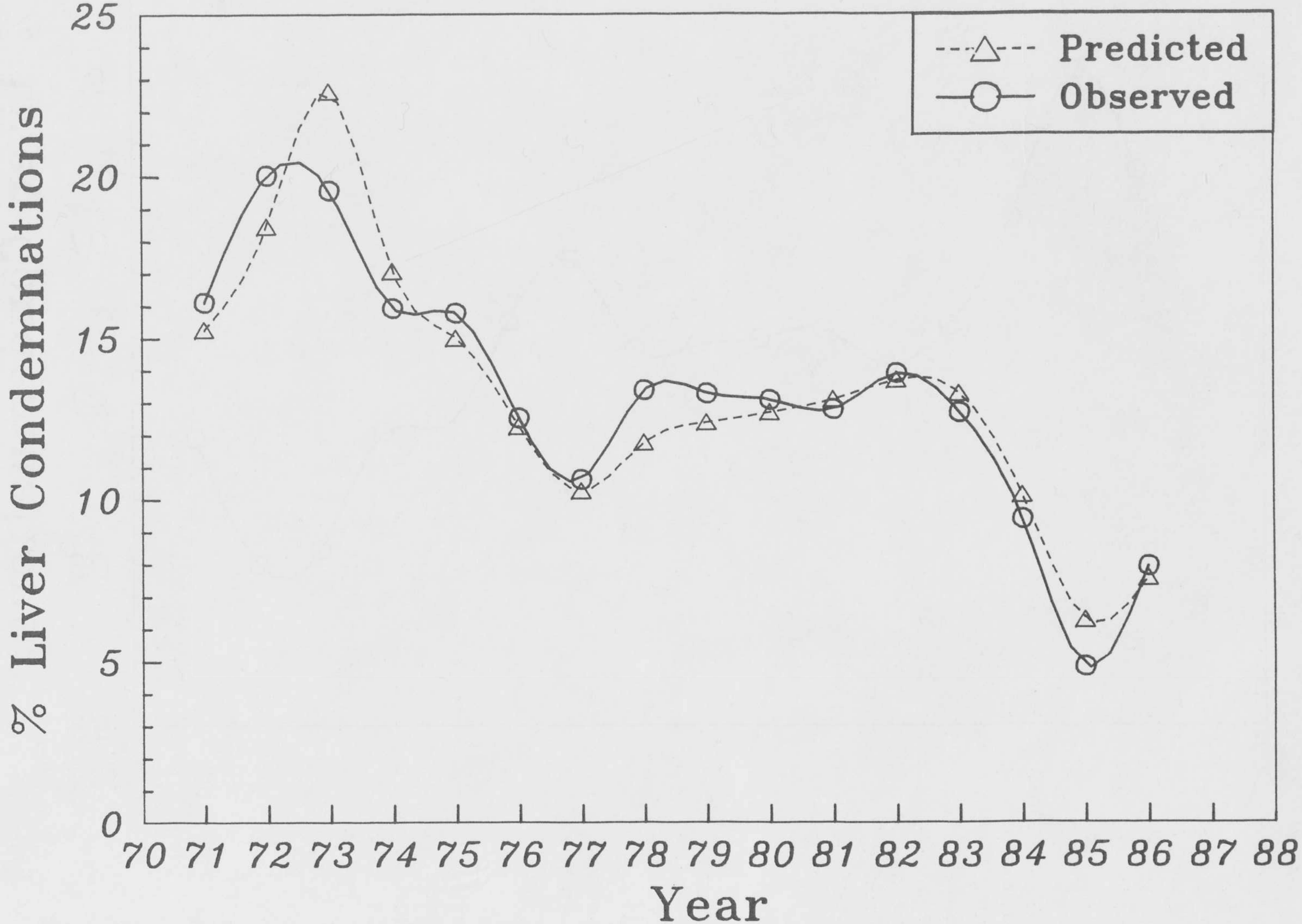
5
10
15
20
25
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
Year


Predicted
Observed
% Liver Condemnations
25
20
15
10
5
0
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
Year