AN ABSTRACT OF THE THESIS OF

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Waterfowl and the places they inhabit provide numerous economic benefits to society. The financial and other resources provided by waterfowl hunters to secure and protect waterfowl habitat are a major force for wetland protection, as guided under the North American Waterfowl Management Plan. However, the habitat and population objectives established under NAWMP to produce and protect a continentally viable waterfowl population have failed to be achieved while solutions are becoming increasingly expensive. Both improved biological and economic information is important for meeting NAWMP goals. Since hunters are expected to continue to pay for much of NAWMP, a better understanding of the factors influential to waterfowl hunter participation, and what control waterfowl managers have is needed to maintain and increase conservation revenue for investments in future waterfowl populations and continental wetland health.

Previous attempts to measure hunter demand preferences have been either qualitative, static, or localized to a small geographic region. This thesis addresses some of these limitations by estimating the impacts of regulatory and socio-economic conditions on waterfowl hunter demand over the period 1962 to 2002 at the flyway geographical scale, while still allowing for differences in behavior at the state level. Managers are constrained in their suite of regulations as they must follow recommendations from the Adaptive Harvest Management (AHM) council to maintain waterfowl populations. Biologically-based AHM studies have

recognized, either implicitly or explicitly, the importance of capturing hunter participation trends in harvest estimation, but have had issues with the multicollinearity between annual regulations and hunter numbers. In this thesis, a system of equations with a feedback mechanism between regulations, hunter participation and harvest is developed to satisfy the endogenous nature of the manager's problem. Variables for hunter demand include the price of a Duck Stamp, gasoline prices, income, a time trend, and annual regulations. Duck Stamp sales are estimated in panel form with the Time-Series Cross-Sectional covariance correction method. Estimated Duck Stamp sales, in addition to regulations and hunter effort, are used to estimate a harvest production function at the flyway scale.

The findings of this thesis demonstrate the large effect managers have on hunter participation through their development and implementation of regulations. Season length is the most significant variable in explaining hunter participation in both flyways. A significant and negative time trend reaffirms the importance of understanding waterfowl hunter demand preferences, as a general downward trend in waterfowl hunting participation persists each year. Cross-equation elasticities reveal the potential impact exogenous economic conditions may have on harvest, with expected future gas prices reducing hunting and harvest from 2-10%. The statistical insignificance of the Duck Stamp price variable suggests hunters are inelastic to real price changes in stamp fees, and thus provides managers a potential means to increase conservation revenue without impacting hunter participation or harvest.

An Exploratory Economic Analysis of the Effects of Regulation, Hunter Participation and Harvest on Migratory Bird Management.

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Randal Scott Dell, Author

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Chapter 1: Introduction

Waterfowl are an important cultural and economic resource in the United States. In 2001, there were over 1.8 million migratory bird hunters in the U.S. spending $935 million in total hunting related expenditures. In the same year, bird watchers numbered 7.7 million, generating $84.9 million in total economic activity (USFWS, 2005). However, the greatest importance of waterfowl enthusiasts to society is not measured in their recreation related expenditures. Waterfowl hunters, more than any other group, provide important conservation funds for the protection of wetlands, uplands and related riparian habitat. The economic benefits provided from these increased wetlands are substantial, ranging from improved water quality, flood mitigation, erosion reduction and the storage of greenhouse gasses (Woodward and Wui, 2001).

An important catalyst for much of these conservation activities in the last 20 years has been the North American Waterfowl Management Plan (NAWMP or Plan). The formation of the NAWMP between the United States and Canada in 1986, and later Mexico in 1994, was in response to historic waterfowl population crashes in the1980s. The signatories realized that to produce and protect a viable continental waterfowl population, a comprehensive set of breeding, migratory, and wintering habitat objectives would have to be met. Under NAWMP, $3.3 billion was spent protecting, restoring, and enhancing 13.1 million acres in the U.S., Canada, and Mexico from 1986 to 2002 (USFWS, 2004). An essential component of the NAWMP are the regionally operating Joint Venture partnerships between federal and state agencies, conservation organizations, tribes, and corporations. Joint Ventures allow waterfowl shareholders to pool resources and break down a continent-scale management plan to a manageable regional size.

Waterfowl hunters play an instrumental role in Joint Venture accomplishments. The primary financial source for the Joint Ventures has come from the Migratory Bird Conservation Fund (MBCF) and the North American Wetland Conservation Act (NAWCA) cost-sharing match grant program. The MBCF is responsible for 5.2 million acres of wetland conservation projects since

1934, financed through Duck Stamps and ammunition taxes (USFWS, 2006). Duck Stamps are highly effective conservation funds, as 98% of all sales revenue are used to purchase and lease wetlands through the National Wildlife Refuge System. Waterfowl hunters also provide valuable support in the form of volunteer hours and contributions to conservation organizations that are used to augment Federal dollars from NAWCA grants. From 1991 to 2001, $411 million in Federal grants were matched by $1.14 billion in partner funds. The top two contributors during that time were Ducks Unlimited and Ducks Unlimited Canada, both hunting organizations (Responsive Management, 2002).

1.1 Problem Definition

For all of the attention and resources devoted to NAWMP, its accomplishments have failed to meet population and habitat objectives. By 1999, only 30% of the Plan's initial goals had been achieved, although 90% of the total proposed budget had been spent (Williams, et al 1999). Over the period 1994 to 2003, of the 11 primary dabbling duck species targeted, specie populations of 8 had either decreased or remained constant (USFWS, 2004). These shortcomings do not reflect any particular failure of NAWMP, but rather a changing landscape, changing weather patterns and the development of unforeseen management issues. Habitat objectives have been redefined to address variations of individual specie response, the degradation of existing wetlands, and falling nest success rates in the Prairie Pothole Region (PPR). The Prairie Pothole Region, while only 10% of total waterfowl breeding habitat, under favorable weather conditions can produce up to 50% of the total dabbling duck (*Anatini*) fall flight in North America (Baldassarre and Bolen, 1994). Nest success rates, defined as the probability that a clutch of eggs will produce at least one duckling, are highly variable across time and locations. For successful recruitment, defined as the fledging of a duckling into the breeding population, a 15% nest success rate is needed for mallards (*Anas platyrhynchos*), (Cowardin et al. 1985). However, in some areas of the PPR nest success rates as low as 2% have been observed, attributable to increased predation rates (Svoda et al, 1995). As the prairie has become increasingly fragmented, unnaturally high predator densities have emerged, requiring a greater emphasis on a landscape approach to waterfowl management (Drever et al., 2004).

The challenges facing future waterfowl are numerous, and solutions are growing more expensive as available land becomes more scarce. It is increasingly important to retain current hunters and attract new hunters for the continued provision of conservation resources. To maintain and increase hunter participation, managers need to have an understanding of the influences regulations and socio-economic factors have on hunter demand. Regulation restrictions have had an observed effect on short term participation, potentially driving hunters out of the sport in the long term (Enck, Swift, and Decker, 1993). Federal and state surveys have assisted waterfowl managers by eliciting qualitative hunter preferences, e.g. indices of satisfaction in response to regulation changes with few quantitative studies to capture such impacts (Ringleman, 1997). The few waterfowl hunter demand studies found in the economics literature have been in hypothetical markets, over a short time horizon or small in geographical scale (Hammack and Brown, 1974; Miller and Hay, 1981; Gan and Luzar, 1993). A long term, flyway level, management decision analysis of hunter response to historic regulation changes is needed in waterfowl management.

The role of the manager in the development and implementation of regulations is complicated without consideration for hunter preferences. Although there are numerous data sets and studies on harvest, population dynamics and other aspects of waterfowl, the understanding of regulatory impacts on waterfowl population dynamics from harvest remained uncertain. Stochastic environmental variation, structural uncertainty of biological relationships, imperfect data on wild populations and human harvest, as well as the limited control that management decisions have on waterfowl, all make an informed management decision inherently complex (Nichols et al., 1995). The Adaptive Harvest Management

(AHM) group was developed in 1995 to more accurately observe and predict regulatory impacts on waterfowl population dynamics. Regulatory recommendations from the AHM group are used to minimize regulatory uncertainty, assist the Flyway Councils in making objective management decisions and maximize long term sustainable harvests in accordance with NAWMP population objectives (USFWS, 2005b). A more detailed description of the AHM process and findings can be found in Chapter 3.

An inherent problem in assessing the AHM process is the relatively short time span observed since its initiation and the homogeneity of regulation packages of those years. As the "Adaptive" term implies, future harvest predictions are based on an iterative process. The goal of AHM is to improve the accuracy of harvest predictions as the number of observations increase. Unfortunately, for the time period that AHM has been in place (1995 through the present) the "Liberal" regulation package has been chosen 75% of the time in both the Central and Mississippi flyways. Constant regulation frameworks during this period limit the capability of AHM to predict accurately the harvest rates associated with varying regulation frameworks. Monte Carlo simulations have helped fill this gap, observing potential harvest rates for varying underlying biological conditions and assumptions (Conn and Kendall, 2004; Conroy et al, 2005). The failure to include waterfowl hunters as an endogenous factor in AHM has not gone unnoticed. In 2004, the USFWS commissioned a report on ways to improve AHM. A lack of studies on the impact of regulation changes on hunter participation was identified as a high priority issue (Wildlife Management Institute, 2004).

1.2 Objectives and Tasks

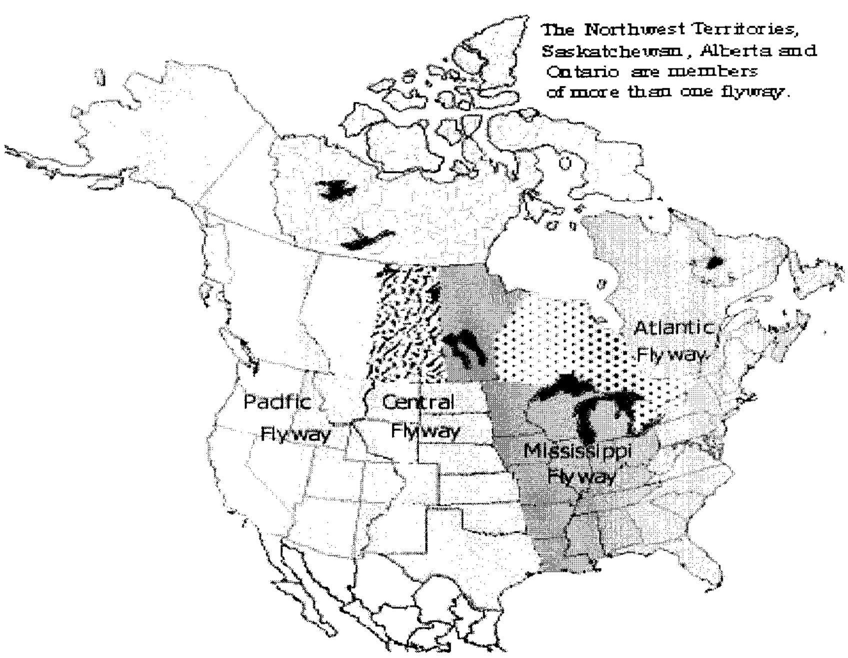
The objective of this thesis is to determine waterfowl hunter response to regulatory and socio-economic conditions and their impact on hunter participation and waterfowl harvest. Hunter and harvest elasticities will be estimated with traditional econometric methods in a two-stage system. The first equation will look at participation, predicting the number of Duck Stamps sold for a given season. Hunter demand elasticities will be derived from this model. Predicted Duck Stamps will then be used in a second equation, estimating harvest prior to the hunting season. Finally, cross-equation elasticities will provide managers with a feed back response mechanism between regulations, participation and harvest and potential revenue losses and gains.

One potential measure of the relationship between hunter participation and regulations are Duck Stamp sales. Duck Stamps provide an excellent proxy for participation as they are required by all hunters age 16 and over wishing to hunt migratory birds in North America. A true demand curve for Duck Stamps can not be derived in the traditional economic sense as the price of a Duck Stamp does not represent a hunter's willingness to pay (WTP) for the opportunity to hunt waterfowl. Hunting permit prices for nearly all species in the United States are historically priced for political and equitable concerns and not the maximization of agency revenue. A waterfowl hunter's decision to purchase a Duck Stamp and hunt in a particular season is more likely dependent upon the regulation package available and/or other socio-demographic variables. This demand component of Duck Stamp sales and waterfowl hunter participation is overlooked in the Adaptive Harvest Management process. A better understanding of hunter elasticity to regulation changes would not only assist the AHM committee in more accurate harvest forecasts, it could do so in a way that increases the sale of Duck Stamps. This is not to suggest that the AHM or Flyway Councils should consider revenue generation when setting regulation frameworks. However, if the same harvest objective can be achieved with a substantial increase in Duck Stamp sales, then such alternatives are worth exploring.

1.3 Study Area

The analysis of hunter response to regulation changes focuses on the Central and Mississippi flyway regions of the United States, for both their cultural and biological significance (Figure 1.1) In terms of waterfowl recreation activity the Mississippi flyway has consistently had the largest share of waterfowl hunters in the United States. In 2001, of the 1.8 million waterfowl hunters in the U.S., 44% recreated in the Mississippi flyway. The Central flyway, the oldest flyway council, was home to the third largest proportion of waterfowl hunters in 2001, with 19% (USFWS 2005c). The Central flyway is also of biological importance as it encompasses the American portion of the Prairie Pothole Region. The Canadian Provinces included within these two flyways and both the Pacific and Atlantic flyways are ignored due to biological and data availability constraints.

Figure 1.1. Map of Flyway Council Administrative Units



Source: Central Flyway, http://www.centralflyway.org/

Flyways are important as both an administrative and biological unit, and demonstrate the need for management at the continental scale. The Flyway Councils were established after early banding studies recognized four distinct longitudinal flyways across North America (Baldassarre and Bolen, 1994). Flyway Councils allow a cooperative approach between State game agencies and the

USFWS for the establishment of annual hunting regulations and other management activities. All states have an important role in the management of the flyway, as the habitats from each state contribute to the overall health of the flyway's waterfowl population. The majority of ducks within the Central and Mississippi flyways are produced in the PPR. Most dabbling duck species from the PPR make several discontinuous flights along narrow habitat corridors within the much larger flyways. The connectivity of habitat along a migration corridor provides ducks with needed food and cover from predators while resting in unfamiliar areas (Baldassarre and Bolen, 1994). The migration corridors used by PPR produced ducks stretch from the breeding grounds down to the wintering habitat of the Gulf of Mexico. Quality winter habitat, in terms of food availability and adequate precipitation, has been found to be directly correlated to increased breeding populations of key dabbling duck species (Heitmeyer, 88). The protection of all three types of habitat (breeding, migrating, winter) and the need to limit regionalized over harvesting, make the flyways ideal and effective management units.

1.4 Thesis Organization

The importance of waterfowl and the challenges facing managers in designing future conservation activities require a greater understanding of hunter demand. The first chapter of this thesis has established the role hunters play in conservation and their relationship with managers and waterfowl populations. To address these issues, this thesis will review relevant literature, develop, estimate and discuss models for hunter demand and harvest impacts and provide policy implications and future research recommendations.

The organization of the remainder of the thesis will be as follows. Chapter 2 provides a review of the literature pertaining to the "economics of duck hunting", other hunting demand studies, and AHM harvest studies. From this literature, a theoretical and empirical model to estimate hunter response to regulations and other socio-economic conditions will be developed in Chapter 3. A discussion of model estimates from Chapter 3, comparing the cross-equation elasticities of significant factors on hunter participation and harvest are provided in Chapter 4. Chapter 5 discusses the findings of the thesis in the context of their implications for future policy and research.

Chapter 2: Review of Literature

"Every head of wildlife still alive in this country is already artificialized, in that its existence is conditioned by economic forces." Aldo Leopold penned this observation in *Game Management* recognizing not only the role of economic incentives guiding land use, but also a societal demand for wild animals and related recreation. Modern wildlife management has heeded Leopold's observation, embracing economic incentives to promote waterfowl production on private lands. The economic forces behind consumptive waterfowl uses have received comparatively little attention since market hunting was outlawed in 1918. Not surprising then is the limited number of studies on waterfowl and hunter demand in the environmental and resource economics literature. Studies on hunter demand have generally been devoted to big game hunting. Primary attention to waterfowl harvest has come from the biological world, with an interest of harvest rates, distribution, and impacts upon species and population dynamics. A review of relevant literature is provided below and organized as follows; a review of the "economics of duck hunting" literature, a review of historic hunting license demand studies and a review of harvest studies since the 2002 AHM update.

2.1 The Economics of Duck Hunting

Through the past half-century a string of economic literature has explored various aspects of waterfowl management. For a comprehensive political economy perspective of waterfowl management see van Kooten and Porter's treatment of agricultural policy on Canadian prairie pothole wetlands (1993). Bioeconomic analyses on waterfowl recreation and the production of wetlands in California and Canada have been done by Cooper and Loomis (1993) and van Kooten (1993). A unique societal cost-benefit analysis of waterfowl hunting was conducted in Australia, estimating that the net costs of hunting measured in psychological costs and loss of development opportunities to non-hunters, outweighed net benefits to hunters (Bennet and Whitten 2003). More relevant to this thesis are three waterfowl hunter demand studies: Hammack and Brown, 1974; Miller and Hay, 1981; Gan and Luzar, 1993. A more complete review of these studies is found below.

The seminal waterfowl economic study is Hammack and Brown's extensive bioeconomic analysis (1974). This study is also notable as it is credited with being the second contingent valuation study performed, the first attempt at an empirical waterfowl population model and one of the first bioeconomic studies. The theoretical hunter demand model was the first time the management of migratory waterfowl had been formulated as an externality problem. Specifically, farmers in prairie Canada were incurring the entire costs of production by retiring land from agricultural use for the creation and/or allowance of wetlands. American hunters were then receiving the benefits in terms of harvested waterfowl as they migrated south. To estimate a Pareto optimal redistribution of benefits the authors analyzed waterfowl production and hunter demand from a continental perspective. The authors did not wish to assume hunters' harvest preferences between annual maximum sustained yield or over harvesting in the present by discounting future lower harvest. Optimal harvest would be based upon waterfowl managers renting wetlands from farmers, with payments equal to hunters' net willingness to pay for the ability to hunt waterfowl through time. With the optimal number of wetlands secured, waterfowl would be harvested to the point where the contribution of an additional bird to the population's growth rate equals the future discount rate.

To determine waterfowl hunters' willingness to pay, a demand model for daily bag limit, the number of birds legally allowed to harvest, and days hunted was developed. Hunters acting as economic agents maximize constrained consumer surplus by hunting up to the regulatory constraints. The hunter's consumer surplus could then be observed as: $V=V(Y, U, D/Z, Z)$, with V a measure of consumer surplus; Y an income measure; U a measure of hunter's taste; D total waterfowl bagged; and Z the total number of days hunted during the season. The partial derivative $V_{(D/Z)}$ is then the marginal value of an additional waterfowl taken for each day hunting, or relaxing the bag constraint by one bird.

To approximate the values in the model, the authors employed a mail questionnaire survey to conduct a contingent valuation study. Surveys were sent to 4,900 randomly sampled Pacific flyway hunters who had hunted waterfowl during the 1967-68 season. Respondents were asked their willingness to accept value as the amount of money needed in order to give up their hunting rights for a single season. Willingness to pay values were elicited from each respondent by asking the amount by which season costs would have to rise before deciding not to hunt. Factors found to have the greatest impact on a waterfowl hunter's CS were days hunted per season (0.48), household income (0.47), and harvest per day (0.31). Other significant factors that positively influenced CS included the number of seasons hunted, annual season cost, and harvest in the previous year. Estimates of marginal values per waterfowl harvested ranged from \$3.08 to \$5.21, depending on included explanatory variables and/or sub sample observed (populations of hunters who bought a duck stamp; hunted; and harvested). Mallard population dynamics were estimated in a steady state system with three exploratory production models providing pond-to-mallard relationships. Results suggest that wetlands and waterfowl were grossly under supplied to meet waterfowl hunter demand.

Final results of this study have little relevance on present waterfowl management. By the authors' own admission, the simplicity of many of their assumptions, as dictated by the limitations of their data, casts doubt on the empirical estimates. The biological understanding of waterfowl and habitat needs has progressed substantially since 1968. The model assumes the underlying constraint on waterfowl production is ponds, which was the case in the late 1960s. Current management now emphasizes the need to protect surrounding upland habitat and predator management in conjunction with wetland preservation. The waterfowl management community has now also made the assumption that maximized long term sustainable yield is the preferred harvest strategy. By explicitly stating a population objective and targeting a specified quantity of habitat (input), economic efficiency has not been introduced directly into waterfowl management.

The next important economic analysis of waterfowl sought to quantify non-agricultural wetland use values to hunters in the Mississippi flyway (Miller and Hay, 1981). Miller and Hay estimated hunters' demand for wetland availability by classifying waterfowl hunting as a potential outdoor recreation activity in an individual's household production function. Personal, geographical, and regulatory attributes, including wetland availability in hunter's home state, would contribute to the participation decision. Based on data from the 1975 National Survey of Hunting, Fishing and Wildlife Associated Recreation, first stage logit analysis determined the probability of participation in any form of hunting activity. The second stage of the logit analysis determined participation in waterfowl hunting. Age and hunter success, as measured by average season bag per hunter in the preceding year, were the most statistically significant variables for participation in waterfowl hunting. Wetland habitat acres were second to gender in terms of the largest impact on waterfowl hunting participation. Variables estimated to decrease the likelihood of participation in waterfowl hunting were age (-0.03) and inhabiting a metro area (-0.18). A third stage logit analysis on the intensity of waterfowl hunting found income, wetland habitat acres, and a preference for waterfowl hunting as favorite outdoor activity to positively impact days spent waterfowl hunting. Distance traveled to hunting site was the only negative variable (-0.11). Overall findings show a 10% reduction in wetland habitat in the Mississippi flyway would reduce waterfowl hunting participation by 0.87%, with 56,550 fewer waterfowl hunters under 1975 conditions. Associated consumer surplus losses would equal $17 million at a rate of -$82 for every acre of wetland habitat lost.

The static conditions under which the data were collected place some limitations on the applicability of the studies findings. The neglect of relative waterfowl populations and regulations during the hunting season observed limit waterfowl hunting participation coefficients. Static wetland conditions are also poor indicators of hunter wetland preferences as environmental factors have a great effect on wetland availability and quality. Further, the estimated $17 million loss in consumer surplus would likely be less as waterfowl hunters would substitute other goods or leisure activities for waterfowl hunting into their household production function.

The final study in the economics of waterfowl hunting demand reported here addresses issues specifically relevant to state-level management. Gan and Luzar used conjoint analysis, an extension of the referendum closed end contingent valuation method, to determine relevant hunt attributes for waterfowl hunters in Louisiana (1993). A mail survey of hunters active during the 1990-1991 season were asked to rank 20 hypothetical hunt vignettes. Vignettes varied in social, economic and institutional hunt attributes and attribute levels. Hunters ranked the vignettes on a 1 to 10 scale. Rating scale results were converted into WTP values using the ratio of parameter coefficients divided by the coefficient of season trip costs. Values represent WTP per hunter for an entire season of a given attribute level. Attributes found to have a negative WTP were travel time (-$687.47), hunting with strangers (-$504.09), high degree of congestion at hunt site (-$990.06) and hunting on public land (-$318.07). Season length was the least economically important hunt attribute, with surveyed hunters willing to pay $30.67 for an increase to the next highest season length (20,30, and 40 days). Hunter WTP for an increase in the daily bag limit from 2, 3, and 7 days was valued at $395 and less important than travel time, composition of hunting party, site congestion or hunting on private-public land.

Policy inferences based on this study are of limited value as results are likely biased by localized conditions. The authors state a motivation for the paper was to explore a 35% drop in Louisiana waterfowl hunters from 1986 to 1990. The hunter decline was largely attributed to a drastic decline in waterfowl populations and restrictive hunting regulations. Waterfowl hunters participating in the 1990-1991 season, and the sample of this study, are likely less responsive to regulations and hold a more inelastic demand for waterfowl hunting. The preferences of these hunters are likely to be different from the general waterfowl hunting population. Further, regulation preferences are likely understated as the authors made no attempt to distinguish the hypothetical vignettes from the diminished waterfowl populations of the survey period. Hunters viewing liberal regulations as detrimental to future waterfowl populations likely selected restrictive regulations, even if they held a general preference for liberal regulations. The limitations of static, localized studies demonstrate the need for a cross-sectional time series analysis of waterfowl hunter participation and attribute preferences.

2.2 Hunting Regulation Studies

As emphasized by Miller and Hay, modern hunting is a form of outdoor recreation. To better understand the factors influencing utility derived from outdoor recreation, the economic subfield of recreation economics emerged. Recreation economics developed from a need by policy makers to assess the comparative benefits of large scale natural resource projects. The evolution of the subfield has gravitated towards the estimation of recreationalists' non-market consumer surplus values. However, to the natural resource manager such values are of little assistance as they can only influence consumer surplus indirectly and in an unclear manner. The limitation of such demand side analysis has not gone unnoticed by resource economists. After an early Travel Cost study, Gum and Martin called for greater emphasis on the allocation of natural resources in the supply of outdoor recreation (1975). Batie and Shabman reiterated these sentiments, calling for economists to devote greater attention to the inputs controlled by policy and management so as to assist resource managers (1979). An initial attempt to address these concerns was Matulich, Workman and Jubenville's speculations on how to model resource economic issues in a management context (1987). The authors recommended that such a model should "account for feedback and/or simultaneity between or among producers, consumers, the underlying biophysical system and even policymakers" (p 313). Notable efforts to integrate these concerns into hunting management include Nickerson (1990); Loomis, Pierce and Manfredo, (2000); and Sun, van Kooten, Voss (2005). A review of these studies is provided below.

Nickerson saw an opportunity to assist Washington game managers in their task of designing regulated lottery hunts. It is asserted that the optimal portfolio of regulations should reduce site congestion and distribute recreation opportunities across hunter preferences and species. Historically, game managers relied on trial and error for congestion reduction effectiveness and public hearings to gauge hunter support for regulation choices. To directly measure hunter demand for regulation alternatives, Nickerson compared lottery applications to regular season permits from 1973 to 1982. Lottery regulation alternatives included antlerless animal, primitive weapon season, a trophy only restriction and a late season regulation for both deer and elk. Data limitations prevented actual representation of game units and population characteristics and were instead observed with dummy variables. Regional dummy variables were used to capture geographic characteristics, species of elk and deer present, and proximity to population centers. Dummy variables for time captured human population growth, changing prices, hunter tastes and income.

Results contradict several notions held by the Washington hunting and game management communities. First, deer managers and hunt groups disagreed over the desirability of antlerless only permits. Managers find these permits undesirable since the initial purpose of permit hunts was to reduce excess females from the herd. The percentage of hunters holding the either-antler tag and harvesting males was uncertain but remained in use from pressure by hunting clubs. Management units with antlerless-only tags saw a 25-30% drop in hunter applications, the lowest of all regulation options and were the most desirable lottery permit offered. The least preferred regulation was the primitive hunt permit, responsible for a 70% decrease in hunter demand for a management unit. The second misconception disproved was that hunters prefer the management of herds for trophy animals. The restriction of male harvest to animals with a certain antler size increases the probability that more animals will grow to a larger size while reducing overall harvest opportunities. The trophy hunting contingency in Washington appears to be a vocal minority with a small demand for such hunts. Management units with trophy animals restrictions had a 55% decrease in hunter demand compared to units without the restriction. This study provides important regulatory information for big game managers, but neglects the other variable that managers have direct control over, price.

Big game hunting, unlike waterfowl hunting, has relatively homogenous regulations across time and regions. Big game hunters, especially non-resident hunters, are likely to be more responsive to license costs. Loomis, Pierce and Manfredo (2000) derived historic (1965-1995) demand for Colorado non-resident deer and elk licenses. Although the intent of the study was a comparison between observed and WTP estimates obtained via CVM, some useful hunter demand characteristics are revealed. A license demand model, including real license prices of Colorado elk and deer licenses, real prices of substitutes (non-resident hunting license prices for deer and elk in Montana and Wyoming), real price of complements (gasoline prices), disposable per capita income, U.S. hunter population, and a time trend was estimated in a log-linear specification. Disposable per capita income, hunter population and the time trend had a high degree of multicollinearity and could not be included concurrently in any regressions. For elk license demand, real license price (-0.004), time trend (0.06), a constant (9.94) and an autoregressive correction variable were all statistically significant at the 99% level. Deer hunters were equally unresponsive to price (-0.007) with real disposable income and hunter populations having negligible impacts as well. The authors offer no speculations on results, as they were an intermediary step for comparison to CV WTP estimates. The high R-square values for both elk and deer models (0.97 and 0.83), although excellent for WTP estimates, provide little guidance to wildlife managers. A potential policy implication would be the potential to generate additional agency revenue through increasing license prices. The authors' inability to identify a structural demand model of little policy significance would leave a door open for future research.

Sun, van Kooten and Voss would also analyze big game hunter demand, addressing the issues of management concern remaining from the Loomis et al. study (2005). Resident and non-resident hunter demand for British Columbia big game hunting permits were analyzed over the time period of 1971-2000. The potential to increase permit revenue, particularly from foreign hunters, to help cover the increasing cost of wildlife management provided further motivation. Analysis was complicated by the numerous regulation costs of big game hunting in British Columbia. Hunters are required to obtain a basic hunting license, a conservation surcharge, an additional species-specific license for big game, the employment of a guide outfitter for non-residents, and an additional royalty fee for each harvested animal. The conservation fee, similar to a Duck Stamp, is an additional charge on the basic hunting license with revenues used to preserve habitat within the province. Independent variables for the basic demand model included basic license price, a vector of complementary license fees, income, and a time trend to capture secular trends impacting hunting. Unlike the Loomis et al. study, detrended real personal disposable income (U.S.) was chosen to capture shorter business cycle fluctuations. Linear and log estimates of the model were made with OLS.

For Canadian residents, factors found to be statistically significant on the quantity of basic licenses sold in the log model included the lagged dependent variable (0.77), basic license fee (-0.23) and the time trend (-0.01). Model estimates support the theory that resident hunters view the conservation tag as an additional expense and not a separate good with a unique WTP value. Although the model captured nearly 97% of the variation in license sales, the lagged dependent variable and time trend were responsible for most of the model's explanatory power, limiting the applicability of the model. Estimation of non-resident demand was complicated by high collinearity between basic license fee prices and species license fees, prompting the authors to construct a weighted composite license fee variable. As was the case with resident hunters, the lagged dependent variable was positive and statistically significant (0.43) and the license fee coefficient negative and significant (-0.18). The major difference between residents and non-residents is the strongly positive cyclical income coefficient of 3.45 for non-resident hunters. Overall findings suggest that short and long term demand for the basic license fee and species license fees are inelastic. Opportunities exist for wildlife managers to increase revenue through increased hunting license fees, but such gains are limited by exogenous economic conditions.

2.3 Biological Harvest Studies

The management of waterfowl harvest has received considerably more attention from the wildlife management field than by resource economists. The synthesis of this knowledge can be found in the Adaptive Harvest Management process, implemented in 1996. The AHM group formulated an iterative process that is initiated with the recommendation of an optimal regulatory package based on current population and environmental conditions in year t. Choice of regulation package is based upon Bayesian harvest rate estimates associated with each regulatory package as determined by the AHM Regulation Matrix. The AHM Regulation Matrix simplifies the regulation decision to estimated breeding population and May pond counts (See Table 2.1). Each regulatory package is composed of season lengths, bag limits, and framework dates for season opening and closing days (See Table 2.2). Population estimates for year t +1 are also made at this time for future comparison and model validation.

Table 2.1. AHM Decision Matrix

Bpop[b]	Ponds[c]									
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
≤5.25	C	C	C	C	C	C	C	C	C	C
5.50-6.25	R	R	R	R	R	R	R	R	R	R
6.50	R	R	R	R	R	R	R	R	R	M
6.75	R	R	R	R	R	R	M	M	M	L
7.00	R	R	R	R	R	M	M	L	L	L
7.25	R	R	R	M	M	M	L	L	L	L
7.50	R	M	M	M	L	L	L	L	L	L
7.75	M	M	M	L	L	L	L	L	L	L
8.00	M	M	L	L	L	L	L	L	L	L
8.25	L	L	L	L	L	L	L	L	L	L
≥8.5	L	L	L	L	L	L	L	L	L	L

[a] C = closed season, R = restrictive, M = moderate, L = liberal.
[b] Mallard breeding population size (in millions) in the traditional survey area (survey strata 1-18, 20-50, 75-77) and Michigan, Minnesota, and Wisconsin.
[c] Ponds (in millions) in Prairie Canada in May.

Mid-Continent mallard population dynamics are estimated from May Canadian prairie pond counts, gender and age composition of population, and summer survival rates. Mallards are an ideal species for the basis of analysis since Mallard population dynamics are a strong indicator of other species dynamics, and Mallards compose a large portion of total U.S. hunter harvest. Mid-continent mallards are observed since this region supplies waterfowl to the three Western flyways, with the Eastern Mallard stock considered separately and the basis for Atlantic flyway recommendations. Model estimates made in year t for year t+1 are compared to actual harvest data at the end of the hunting season. The process is iterative in the sense that new weights are assigned to each of the four models based upon their predictive accuracy. Population dynamics are estimated with four weighted models, varying in underlying assumptions towards harvest impact (additive vs. compensatory) and breeding density dependence (weak vs. strong).

Density dependence is the biological equivalent of the economic concept diminishing marginal returns: the rate at which breeding success (output) declines with an increasing population (input). Based on 10 years of data, harvest impacts are some what ambiguous with a slight indication towards an additive impact (59% weight) while density dependence is clearly weak (91%) for Mid-Continent Mallards.

Table 2.2. AHM Regulation Alternatives

Regulation	Mississippi Flyway	Central Flyway
Framework dates		
Restrictive	Saturday nearest Oct 1 to the Sunday nearest January 20	
Moderate and Liberal	Saturday nearest Sept 24 to the last Sunday in January	
Season length (days)		
Restrictive	30	39
Moderate	45	60
Liberal	60	74
Bag limit (total/mallard/female mallard)		
Restrictive	3/2/1	3/3/1
Moderate	6/4/1	6/5/1
Liberal	6/4/2	6/5/2

As stated previously in this thesis, a limitation of the AHM process has been the lack of variability of regulations in the years observed. The 2002 AHM report attempted to address this concern, updating current harvest rates by analyzing historical harvest rates over 1981-1995. Harvest impacts were observed by capturing successful duck hunter trends and daily harvest with a linear model. The successful hunter per state model was estimated using daily mallard bag limit (MALBAG), season length (SEASLEN), and state dummy variables. Coefficients between the three management units of interest, the High and Low Plains Central flyway (CF) units and the Mississippi flyway (MF), varied drastically in sign, magnitude and statistical significance. For example, in the Low Plains management unit of the CF, the intercept for North Dakota is -3,930.6 (3,021) but the High Plains management unit has an intercept of 4,559.1 (541.7). A comparison between regulation parameters in the Central flyway management units is also inconsistent. In the High Plains, MALBAG is the dominant regulation attribute with a coefficient of 734.0 (181.6) compared to SEASLEN -1.33 (16.3). Low Plains results are somewhat ambiguous, with a statistically insignificant MALBAG 577.8 (715.6) in comparison to SEASLEN 317.9 (100. 9). Multicollinearity between regulations or regulation and hunter participation is the cause for most of these inconsistent results. A further limitation of these estimates is for the time period observed, 1981-1995, duck stamp sales steadily declined in the Central flyway. In terms of harvest this is acceptable, as a small percentage of highly active hunters are responsible for a large percentage of total harvest. It is likely that these hunters would remain in the activity as general participation declined.

Further analysis of AHM has focused on the determination of biological structural relationships, unspecified in the original model but possibly having a stochastic influence on model weights. Conn and Kendall examined the effects of increasing uncertainty regarding natural mortality, crippling loss, season sex-ratios, and model-specific recruitment functions (2004). Original AHM models assume all of the preceding relationships are deterministic. Monte Carlo simulations that allowed for variance in recruitment predictions and non-hunting survival were compared on their convergence to observed data from an *a priori* population model. Simulation results indicate that AHM models from 1995-2001 did not incorporate enough uncertainty, and could likely have assigned false model weights due to stochastic factors. Although this study focused on the population models of AHM, the need for more stochastic properties in AHM opens the door for re-examination of the harvest estimation process.

Conroy et al addressed potential shortcomings of harvest models by examining the impact of regulations, hunter numbers, regional variation and random effects on harvest rates (2005). Banded black duck data from 1971-1994 in the Atlantic and Mississippi flyways served as the basis of analysis. Regional distribution affects were captured in a spatial structural model. Harvest variations were modeled as a function of management variables (season length, bag limit) and hunter numbers. Parameters were estimated with the SUR IV method. To expand the number of observations and introduce regulation parameters outside the historical data set, Bayesian Monte Carlo analysis was employed. Three primary models with random errors sources 1.) common to year and regions, 2.) independent of year and region, and 3.) independent of year and region with random noise, were employed. Many variations of the three random error models were tested, controlling for regulations, hunters, or interaction variables. Posterior predictions of non-occurring season lengths included random effects independent of time and region and white noise, with season length and bag limit as explanatory variables for harvest.

Harvest rates of 0.15, 0.20 and 0.30 of fall flight were found for season lengths of 30, 60, and 110 days. Actual season length alternatives for the Atlantic flyway in 2005 were 30, 45 and 60 for the restrictive, moderate and liberal seasons respectively. Results suggest that harvest rates should be carefully considered as a large degree of overlap in predicted harvest distributions exists, particularly between the 30 and 60 day season lengths. Management implications from this study indicate regulations impact harvest rates. A relationship between harvest regulations and harvest rates was supported by the finding that models accounting for regulations performed better than those with only random effects. Interpretations of marginal impacts are limited due to the high degree of multicollinearity between regulations and hunters and imprecise harvest data. Limitations of the study include the possibility that the unobservable random effects or latent variables may be economic in nature and therefore not captured in a biological model. Further, black ducks may be viewed as an incidental bonus in terms of hunter participation. In 2004 the black duck bag limit was one bird and regulation variations would likely have little impact on total duck hunter participation.

Although not extensive, the literature pertaining to waterfowl regulation demand reviewed here provides useful insights and suggests areas for future research. Hammack and Brown's ambitious initial attempt provided the groundwork and interest for future analysis. Subsequent economic studies included hunter characteristic and hunting site attributes and disaggregating analyses to the flyway and state level. Economic analysis of the supply side of wildlife management for hunter recreation has been more extensively covered for big game hunting. Early requests by Gum and Martin and Batie and Shabman to provide useful economic analysis to resource managers motivated the big game hunting studies of Nickerson; Loomis, Pierce and Manfredo; and Sun, van Kooten, and Voss. To date, the analysis of waterfowl management supply has not been attempted. The wildlife management literature has recognized, either implicitly or explicitly, the need to capture regulation and hunter participation impacts on waterfowl harvest. Initial attempts focusing on short time periods, less common duck species, or ignoring multicollinearity effects, have limited the policy implications of these studies. Clearly, there is a need for a cross-sectional, multi-flyway, time series analysis of the simultaneity of regulation supply, hunter demand, and harvest.

Chapter 3: Theoretical and Analytical Model

Waterfowl management is a unique wildlife resource in that excess populations are managed almost entirely for hunting recreation. The waterfowl manager setting annual hunting regulations has to take into consideration both hunter satisfaction and harvest impacts upon the population. The decision process is complicated by the inter-connectedness of season regulations, hunter participation, and harvest rates. To capture these influences effectively, a system of equations allowing for feedback between decisions is needed (Matulich et al., 1987). A recursive system for hunter participation and annual harvest is one way to satisfy the endogenous nature of the manager's problem. This thesis performs an exploratory analysis of statistically influential factors of participation in waterfowl hunting at the flyway level and ensuing harvest impacts. The organization of this chapter is as follows: a discussion of the hunter participation decision and the demand for a waterfowl stamp and regulations, followed by a presentation of an empirical recursive system, including definitions of variables and sources of data.

3.1 A Recursive System

In the market for Duck Stamps, demand comes from two primary groups, hunters (users) and collectors or conservationist (non-users). The demand from non-users is considered to be inelastic through time, with hunters responsible for the year-to-year variation. Hunters can also be further classified as active, inactive or potential. Active hunters may also be classified as avid, intermediate and casual hunter. No classification effort is made due to the constraints of the data; thus all forms of hunters are considered to be a "duck hunter" in this thesis. Regardless, the three stage decision process is the same for all waterfowl hunters. The first decision of the waterfowl hunter is the choice of leisure activities over working and consumption. Once leisure is chosen, hunting is selected from the list of possible leisure activities. Finally, of potential hunting activities, waterfowl hunting is chosen. The decision of interest to this thesis is the participation in a waterfowl hunting activity. This can be specified as

$$DS_{ti} = DS_{ti} (r_{tj}, p_t, m_{ti}, z_{ti}, t) \qquad (1)$$

where DS_{ti} is the quantity of Duck Stamps sold in year t, state i; r_{tj} is the regulation package in year t, flyway j; p_t is the real price of a Duck Stamp in year t; m_{ti} is a measure of income in year t, state i; z_{ti} is a vector of complementary and substitute goods and prices; and t is a time trend to capture secular hunting trends.

To accurately capture Duck Stamp demand dynamics it is important that the determination of independent variables in Eq. 1 be exogenous to the sale of Duck Stamps. The supply of Duck Stamps to waterfowl hunters is unlimited and therefore exogenous. Demand is instead constrained by annual regulations and hunter income. The decision by the marginal hunter to purchase a duck stamp is likely to occur after season regulations have been determined, and therefore regulations may also be treated as exogenous. A hunter that has already chosen to hunt waterfowl has already explicitly chosen leisure over work. Days spent waterfowling are assumed to substitute for other leisure activities and are therefore exogenous to personal income. Duck stamp prices are set by Congress and do not reflect any sort of market value. They are assumed to have no impact on the price of either complementary or substitute goods, rendering all three exogenous to the Duck Stamp purchase decision.

Although managers are interested in providing optimal recreation opportunities to hunters, the health of waterfowl populations weighs heavily in the regulatory decision. Regulations are a control mechanism to limit hunter consumption of the waterfowl population. The hunter is therefore an attribute taker. To better understand regulation impacts on hunter participation and on harvest directly, a separate harvest production model is needed. For the purposes of this thesis, harvest is produced by

$$H_{tj} = H\,(r_{tj}, ds_{tj}, e_{tj}) \qquad (2)$$

where H_{tj} is the harvest in year t, flyway j; r_{tj} is the regulation in year t, flyway j; ds_{tj} is the estimated number of duck stamps sold in year t, flyway j; and e_{tj} is hunter effort in year t, flyway j.

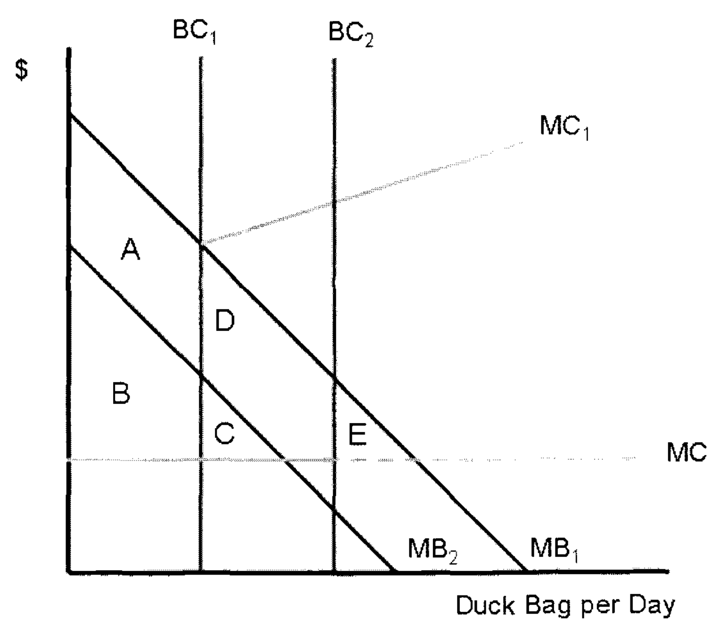
3.2 Hunter Demand for Waterfowl Regulations

The only input in Eq. 1 over which waterfowl managers have direct control is the setting of regulations. To better understand hunter demand for regulation alternatives, an expansion of Hammack and Brown's (1974) graphical representation is presented in Figure 3.1 and Figure 3.2. The following regulation demand models require several basic assumptions. First, hunters value a harvested bird equally regardless of age, sex or species. Hence, each additional bird harvested has diminishing marginal benefits to the hunter. Hunters also recreate at the same site for the entire season receiving diminishing marginal benefits from each additional day of hunting and are assumed to have constant opportunities to see and harvest birds. Hunters are assumed to be rational agents, preferring regulation alternatives that maximize personal net benefits. Net benefits are defined as Consumer Surplus, CS, measured in dollars. However, CS values can not be measured in this thesis as license prices are not reflective of hunter's willingness to pay values for the right to hunt. Further, the data used are secondary, and there is no way to directly elicit WTP values from hunters.

Figure 3.1 represents a hunter's demand for birds harvested in a day of hunting. Marginal benefits are assumed to be diminishing with each harvested bird, accounting for the downward sloping Marginal Benefit curves. The first day of hunting is represented by MB_1. In the absence of a bag constraint, a hunter maximizes CS by harvesting birds until the Marginal Cost curve intersects MB_1, area A + B + C + D + E. A binding bag limit constrains hunter CS to the area A + B. Increased marginal costs at the Bag Constraint would be in the form of poaching fines or social stigma for each bird over the legal bag limit. The second day of hunting, represented by MB_2, has decreasing marginal benefits while increasing total net benefits. At some point the marginal cost for a day of hunting will exceed the benefit of harvesting the daily bag limit allowed. The hunter will harvest less than the legal bag limit for each additional day beyond this point.

To increase total net benefits with out increasing the number of hunting days, the bag limit will have to be relaxed one unit, represented by BC_2. Hunters' CS increases by the area (C + D) for the first day of hunting with the additional bird. As under the initial bag constraint, the hunter will continue to hunt until the marginal benefit of a bird harvested equals the constant marginal cost curve. With the relaxed bag constraint, the hunter will not harvest the legal limit sooner, but will harvest more birds through out the season. Under these assumptions, waterfowl hunters are assumed to prefer more liberal bag limits compared to conservative alternatives. An exception would be a bag limit set beyond the hunters MB curve. The legal bag limit would have no effect on the hunter as they would choose to under harvest each day.

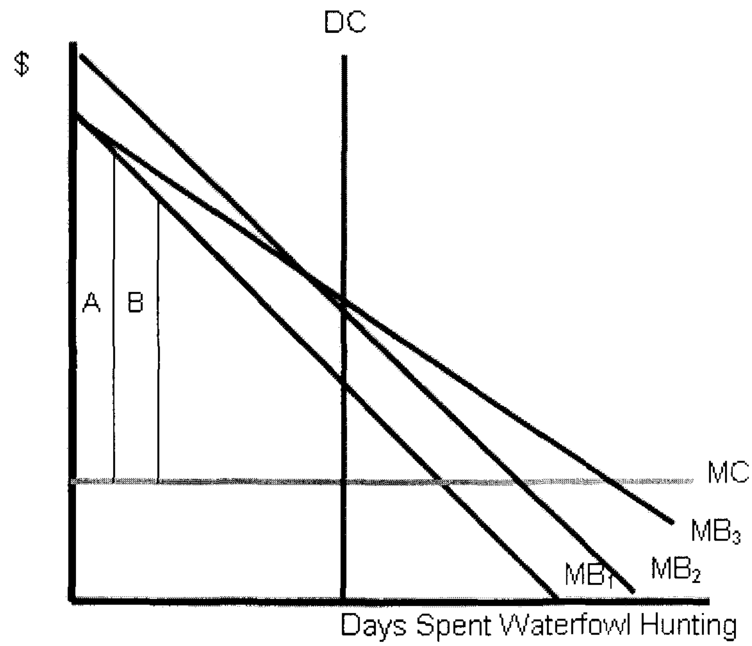
Figure 3.1. Waterfowl Hunter Demand for Bag Limits



The demand for days hunted also faces a regulatory constraint, represented by the Day Constraint, DC in Figure 3.2. On the first day of hunting, the hunter has a consumer surplus value of A. Due to diminishing marginal returns, an additional day will have a consumer surplus value of B. Without any day constraints, the hunter will continue to add days of hunting until marginal costs equal marginal benefits. However the hunter may not hunt up to the regulatory constraint, as a separate cost constraint may be binding, e.g. loss of job for an additional day of hunting. The hunter would not be impacted by any extensions of the season length if such a constraint is in effect. The only way to increase marginal benefits in the day length model would be the relaxation of the daily bag limit. An increase in the bag limit would shift the marginal benefit curve up to MB_2 for a day of waterfowl hunting as well as increase total net benefits for the season. As CS can not be measured in this analysis, a direct comparison of total net benefits for the relaxation of a constraint in either model is unattainable.

There has been a long standing belief that waterfowl hunters prefer longer seasons relative to high daily bag limits. Several explanations exist. Waterfowl migrations are not entirely predictable, and longer seasons increase the likelihood of hunting seasons coinciding with peak migrations. Hunters may not have the opportunity to harvest their full bag in non-peak periods, or may choose not to for other reasons. Bag constraints are therefore rarely binding and of lesser concern to hunters. Additionally, the manner in which marginal benefits are discounted may lead to a preference for relaxing season lengths. For example, a cost constraint may limit a hunter to 10 hunting days during any given season. In a 20 day season, future hunting opportunities would be highly discounted as fewer opportunities exist to substitute a lost day of hunting. A 90 day long season would allow the hunter greater flexibility and opportunities to select days with favorable weather conditions, waterfowl migration patterns, or other preferred hunt attributes. The 10 days of hunting can then be further spread out, with a more elastic (flatter) benefit curve, MB_3 in Figure 3.2, increasing both marginal and net benefits for a day of waterfowling. Historically, increases in either regulation have generally been accompanied by an equally proportioned increase in the other.

Figure 3.2. Waterfowl Hunter Demand for Season Length



3.3 Empirical Considerations

Estimation of equations (1) and (2) require some further considerations. First, waterfowl hunting expenses are influenced by other consumer goods and prices. To address possible inflation issues, the consumer price index (CPI) was used to deflate dollar values into dollars in a base year (2002). Second, waterfowl hunting is but one of many recreation activities with no known perfect substitute. The vastness of the geographic region prohibits substituting waterfowl hunting in other states or regions. Species have been observed to be poor substitutes to hunters (Loomis et al, 2000 and Boyle, et al., 1990). Other outdoor activities that could serve as substitutes are too numerous to include in a model and are thus excluded. Complementary goods to waterfowl hunting are also numerous and difficult to measure. Retail gasoline prices were therefore chosen as a complementary good. Although retail prices may vary across states due to taxes or distributional costs, CPI adjusted annual U.S. average pump prices will identify general price directions. Changes in other price or socio-demographic variables are assumed to be detected with a linear time trend. Other regional disparities in the Duck Stamp demand equation will be observed through state dummy variables.

Regulation and harvest variable estimation also require some additional attention. Estimation has focused on the inclusion of the two primary regulations, bag limit and season length (see table 3.1 for definitions of variables). A high degree of collinearity between bag limit and season length prevents the inclusion of both variables in any model. Season length provided the most variability for the time period observed and has historically been the regulation component of greatest concern to managers, so serves as the regulation of primary analysis. Identical increases in both bag limit and season length for the majority of the sample likely mask any demand preferences for increased bag limits. Elasticity to bag limit variations are instead captured by a relative change variable:

$$BAG = \frac{Bag_t - Bag_{t-1}}{Bag_{t-1}} - \frac{Seas_t - Seas_{t-1}}{Seas_{t-1}}$$

Other regulation components considered, but ignored, include the point system and season framework dates. The largely unpopular point system for harvested birds is ignored here, as the inclusion of a dummy variable for years in which a point system was/is in place would be expected to capture primarily white noise as it would cover such a large portion of the sample. Instead, shifts in parameter coefficients during point system years will be tested. Framework dates, the time period from which states can select to have their waterfowl hunting seasons, have remained relatively stable for the time period and flyways observed. Compared to season length and bag limit, framework dates are a minor concern for the majority of hunters.

The full model will be estimated as a recursive system, with estimated Duck Stamp sales from the Eq. 1 serving as independent variables in Eq. 2.

$$\ln DS^f_t = \Phi \ln DS^f_{t-1} + STATEdum_i + \beta_1 \ln SEAS^f_t + \beta_2 \ln BAG^f_t + \beta_3 \ln DSpr_t + \beta_4 \ln GAS_t + \beta_5 \ln PDI_{ti} + \beta_6 YEAR + u_1$$

$$\ln HARV^f_t = \alpha_1 + \gamma_1 \ln SEAS^f_t + \gamma_2 \ln DShat_t + \gamma_3 AVGDay + u_2$$

To provide a better understanding of the above variables, Table 3.1 provides a brief description of each variable. A more detailed description of the data and their sources are provided below.

3.4 Description of Variables

Table 3.1. Description of Variables

	Duck Stamp Demand Model
DS	Number of Duck Stamps sold per flyway, in 1,000s
SEAS	Total number of legal hunting days in each flyway
PDI	Personal Disposable Income, at the state level and adjusted into 2002 dollars
BAG	Comparitive change in Bag limit relative to Season Length variation
DSpr	Real Duck Stamp price adjusted into 2002 dollars
GAS	National average annual reatil gas price, CPI adjusted into 2002 dollars
YEAR	A linear time trend
DS_{t-1}	The number of Duck stamps sold in the preceding year.
State	A state specific dummy variable.

	Harvest Estimation
HARV	Annual harvest of ducks in each flyway, in 1,000s
SEAS	Total number of legal hunting days in each flyway
DShat	Estimated number of Duck Stamps sold per flyway from previous model.
AVGD	The average number of days spent waterfowling per hunter.

DS- The number of Migratory Bird stamps sold by state within the Mississippi and Central flyways per year, as recorded by the Federal Duck Stamp Office of the

USFWS (USFWS, 2005d). The purchase of a Duck Stamp is used as a proxy for the decision to participate in waterfowl hunting.

Note: Since the 1961-1962 hunting season in Montana and the 1962-1963 season in Wyoming, Duck Stamp sales have been divided between the Central and Pacific Flyways. Duck Stamps sold only in the Central Flyway are counted in this thesis.

SEAS- The total number of legal hunting days during a duck hunting season. Historically, seasons in these flyways take place between October 1 and January 20th, with states allowed to choose the allocation of days within this time period.

PDI- Personal disposable income data came from the Bureau of Economic Analysis (USDC, 2006). Personal disposable income is defined as the State level personal income (wages, rent and transfer payments, interest, etc) minus personal taxes in the current year. A per capita value is derived by taking personal disposable income divided by state population. The population employed by the BEA is the U.S. Census Bureau's Mid-year population estimate conducted in July. All estimates were taken in current year values and adjusted into 2002 dollars.

BAG- The daily bag limit is the legal number of ducks that may be harvested in a day of hunting. Daily bag generally allows any combination of species or gender for most years observed. In the AHM era, 1995-2001, a mallard bag limit and hen mallard bag limit are included within the general bag limit. The previously mentioned point system places further restrictions on gender and species composition of total bag. Hunter preferences for bag limit are measured by the variable described on page 28.

DSprice- The real price of a Duck Stamp, adjusted into 2002 dollars. Prices increased 6 times during the time period observed.

GAS- The U.S. annual average retail price for gasoline is included as complementary good. Gasoline prices directly influence travel cost to hunting sites and are expected to be negatively correlated with hunting participation. Data came from the American Petroleum Institute and is the annual U.S. average retail pump price, cents per gallon, of motor gasoline (API, 2006). Current prices are adjusted into 2002 dollars.

YEAR- A linear time trend to capture unobservable changes in hunter population and/or preferences. The inclusion of a time trend was motivated by historical trends of potentially influential populations. Over the last few decades, an increasing general population in the U.S. a declining total hunting population, and an increasing waterfowl hunter population complicate the identification of a correct population for possible waterfowl hunters. Further, as the population becomes more urban, hunting opportunities may diminish or become less desirable. Without the ability to survey hunters, the time trend is the best approximation of these secular influences on preferences and hunter populations.

STATE- A state specific dummy variable intended to capture heterogeneous preferences, social demographics, hunting land availability, and/or other white noise between states.

HARV- The total number of ducks harvested during the fall hunting season in each flyway. Harvest estimates are derived from the Waterfowl Hunter Survey (WFS) and the Mail Questionnaire Survey (MQS) which were employed by the USFWS from 1952 to 2001. The Mail Questionnaire Survey was administered to a randomly sampled 25% of U.S. post offices and 20% of National Wildlife Refuges, the primary retail locations of Duck Stamps. Customers purchasing a duck stamp at the sampled site would be given a post card inquiring the customer's intention to hunt waterfowl in the upcoming season. A random sample of MQS respondents that intended to hunt were then sent the Waterfowl Hunter Survey at the end of the waterfowl season. Annually about 50,000 hunters were asked about their level and location of hunting activity, harvest composition as well as estimated crippling rate.

AVGD- The average number of days spent waterfowling are derived from Mail Questionnaire Survey estimates for total days spent waterfowling per flyway. Total days were divided by estimated Duck Stamp sales to obtain average days waterfowling per hunter.

3.5 Econometric Methods

The Duck Stamp demand model, with observations at the state level, is treated and estimated as panel data. Panel data estimation techniques are common in many economic and non-economic fields. The use and popularity of panel data can be attributed to its advantages over an exclusively cross-sectional, i, or time-series, t, analysis represented in the equation below.

$$Y_{it}=\beta X_{it}+\varepsilon_{it}$$

The increase in estimation power does not come without a cost. Panel data must address heteroscedasticity issues arising from cross-sectional data and autocorrelation from time-series data. Estimation techniques focus on removing these omitted variable effects from the error term to improve parameter consistency. Heteroscedasticity and autocorrelation of the error term can be attributed to three forms of omitted variables: 1) Panel-unique time invariant variables, 2) panel-common but time-variant, and 3) variables that vary both through time and panels (Hsiao, 1986). Researchers must carefully consider their assumptions about the expected forms of omitted variables before selecting a treatment.

The inclusion of region-specific and time-specific dummy variable intercepts, otherwise known as the Least Squares Dummy Variable (LSDV) model, may capture some of the omitted variable bias. The LSDV requires the assumption that the panel specific time-varying omitted variables are individually insignificant but collectively significant and uncorrelated with the other variables, included and excluded. This is a strong assumption and a modified Lagrange statistic can indicate if a Fixed or Random effects model is preferred to LSDV. The Fixed effects method would be the option most suitable to this thesis, but is infeasible for several reasons. First, in order to accurately capture Fixed effects, it requires the assumption that changes in the error term are uncorrelated with changes in x and that changes in x_i have some variation across i. Flyway-general variables such as GAS, SEAS and BAG all have no variation across i, and would be unestimatable. Fixed Effect estimation is also undesirable if non-time specific correlation across units is present, such as a neighbor effect. A neighbor effect appears evident in the data, as hunters living near other states are likely to travel if better recreation sites are available or season's overlap between states to provide longer seasons. Another motivation for the neighbor effect on Duck Stamps is the "stopping-short" phenomenon where migrating waterfowl find suitable winter habitat in the north and do not continue their migration south. Such an occurrence would have a positive effect on northern states hunting effort while negatively impacting southern states.

The undesirability of the Fixed Effects model and the expected neighbor effect make a Time Series Cross Sectional (TSCS) analysis appropriate. The primary difference between panel and TSCS estimation are their assumptions towards asymptotic convergence. Consistent and unbiased panel data estimates rely upon asymptotic convergence of N and T. Typical data sets for a panel data analysis are characterized by a large number of regions or units, N, and relatively few T. The cross-sections by which panel data are stratified are considered observations from a larger sample, with no correlation among panels. TSCS differs in that unbiased and consistent estimators rely on the asymptotic convergence of T, with N assumed to be fixed (Greene, 2002). TSCS methods are popular in the Political Science literature, where N is typically a large geographic unit such as a nation or state. The large size and contact between units make assuming cross-sectional non-correlation unrealistic. TSCS recognizes that such cross sectional correlation may exist and allows for the covariance correction of such a possibility. The framework of TSCS is similar to panel data, with data pooled by observation or region in the form

$$Y_{it}= \beta X_{it} +\varepsilon_{it};$$
$$i= 1,\ldots..,n \text{ and}$$
$$E[\varepsilon_i\varepsilon_{j'}|X]= \sigma_{ij}\Omega_{ij.}$$

An additional component is introduced with the cross-sectional covariance across groups' component; j. Error covariance can now take form in either t-correlation through time, i-panel specific correlation, or j-cross-section correlation (Greene, 2002). Heteroscedasticity and autocorrelation will render OLS an inconsistent estimator. Heteroscedasticity can be corrected with either a White or a Panel Corrected Standard Error (PCSE) correction (Beck and Katz, 1995). A Feasible Generalized Least Squares or a Maximum Likelihood Estimator will be preferred if significant autocorrelation is present.

In this chapter a recursive waterfowl hunter-manager model was developed. The intention of such a model is to assist in the estimation of Duck Stamp demand elasticities and their impact on annual duck harvest. The estimation of duck stamp demand and harvest production as a system provides the manager with a useful tool to receive feedback on hunter response to regulations. An exploratory analysis, as first developed by Hammack and Brown (1974), provided an understanding of expected hunter preferences for regulations. Empirical estimation of Duck Stamp demand thus focuses on season length, gas prices, real stamp price, income, and bag limit variation. The panel nature of the duck stamp data motivates the employment of the Time Series Cross Sectional covariance correction technique (Green, 2002). The results of both Duck stamp demand, and harvest production are presented and discussed in the next chapter.

Chapter 4: Results

In the previous chapter, models were developed to estimate waterfowl hunter demand for Duck Stamps and the waterfowl manager's demand for harvest. This chapter presents and discusses the empirical results from the estimates of these models. An overview of the descriptive statistics of the data, Table 4.1, and graphs of relevant relationships are provided to assist in understanding these findings. The identification of the most efficient Duck Stamp model and the robustness of parameter estimates are also addressed. Duck stamp sales estimates are then used in the estimation of flyway harvest production. Harvest responses associated with regulation and economic factors are also presented and discussed.

4.1 Descriptive Statistics

The descriptive statistics presented in Table 4.1 assist in understanding the underlying data used in the model estimates. All variables display variation for the time period observed. Variables with flyway-unique values include season length, bag, total and average days waterfowling, and Duck Stamp sales aggregated to the flyway level. Gas and duck stamp prices are the only variables measured nationally and personal disposable income is measured at the state level. Distinctions between flyway observations include a larger number of Duck Stamp purchasers in the Mississippi Flyway and a more substantial annual harvest. The disparity in Duck Stamp sales and Harvest can be attributed to a larger population in the Mississippi flyway. And surprising is the distinctive lower average days spent waterfowling in the Central flyway (almost one whole day at the mean) despite having mean season lengths 10 days longer than the Mississippi flyway.

Table 4.1. Descriptive Statistics, by Flyway

	Minimum	Mean	Maximum	Std.Dev.
Central Flyway				
Duck Stamps	185,633	335,492	454,635	70,786
Duck Stamps Predicted	214,953	333,002	459,459	69,514
Annual Harvest	403,564	1,978,530	3,401,820	804,186
Average number of days hunting	4.14	6.90	8.38	0.95
Total days waterfowl hunting	978,827	2,311,840	3,354,230	617,690
Season Length (days)	25.00	53.51	74.00	12.41
Bag Limit	2.00	4.48	6.00	1.09
BAG	-0.50	0.00	0.60	0.17
Annual Petrol Price	$1.23	$1.75	$2.69	$0.33
Real Stamp Price	$12.30	$16.35	$21.50	$2.15
Personal Disposable Income	$9,312	$18,607	$30,153	$3,900
Mississippi Flyway				
Duck Stamps	411,981	721,840	1,005,270	134,062
Duck Stamps Predicted	485,693	718,123	1,003,170	132,591
Annual Harvest	1,078,970	4,823,400	8,358,320	1,782,310
Average number of days hunting	4.44	7.79	10.54	1.36
Total days waterfowl hunting	2,156,490	5,613,030	7,764,630	1,425,820
Season Length (days)	25.00	43.75	60.00	10.127
Bag Limit	2.00	4.38	6.00	1.01
BAG	-0.20	0.00	0.60	0.12
Annual Petrol Price	1.23	1.75	2.69	0.33
Real Stamp Price	12.30	16.35	21.50	2.15
Personal Disposable Income	$7,381	$18,250	$28,734	$4,309

To check the initial assumption of a hunter preference for longer seasons, Duck Stamp sales were plotted against corresponding season lengths. An upward sloping waterfowl hunter demand curve for season length is revealed (Figure 4.1). Although generally trending upward for both flyways, high end outliers appear to have a diminishing effect on Duck Stamp demand. Of interest to this thesis is the significant variation in Duck Stamp sales for a given season length, as signified by the vertical clustering in both flyways. For example, a 50 day season length in the Mississippi flyway was responsible for 10 unique Duck Stamp sale figures, ranging from 685,000 to 1,000,000.

The satisfaction of hunters and their demand for liberal season lengths represents half of the waterfowl manager's dilemma. Hunters and regulations are both inputs for the achievement of duck harvest objectives. An initial plotting of waterfowl harvest for corresponding season lengths and Duck Stamp sales in the Mississippi flyway (Figure 4.2) highlights the manager's predicament. Harvest generally trends upwards, as expected, with more inputs (hunters and season length) producing more outputs (harvest). However, harvest per input varied substantially. For example, the harvest from a 50 day season length varied from 4.8 million to 6.8 million birds within the flyway. Duck Stamp sales appear to be no better an indicator as sales of approximately 700,000 supplied a harvest ranging from 2.2 million to 8.0 million birds. Duck Stamp sales display a diminishing marginal impact on harvest, as suggested by the declining number of Duck Stamp sales associated with the higher annual harvests. A more accurate preseason harvest forecast will be attainable by taking exogenous economic factors and waterfowl regulations to predict corresponding hunter participation. A panel model exploring the factors influencing a waterfowl hunter's decision to purchase a Duck Stamp is presented next.

Figure 4.1. Duck Stamp Sales per Season Length

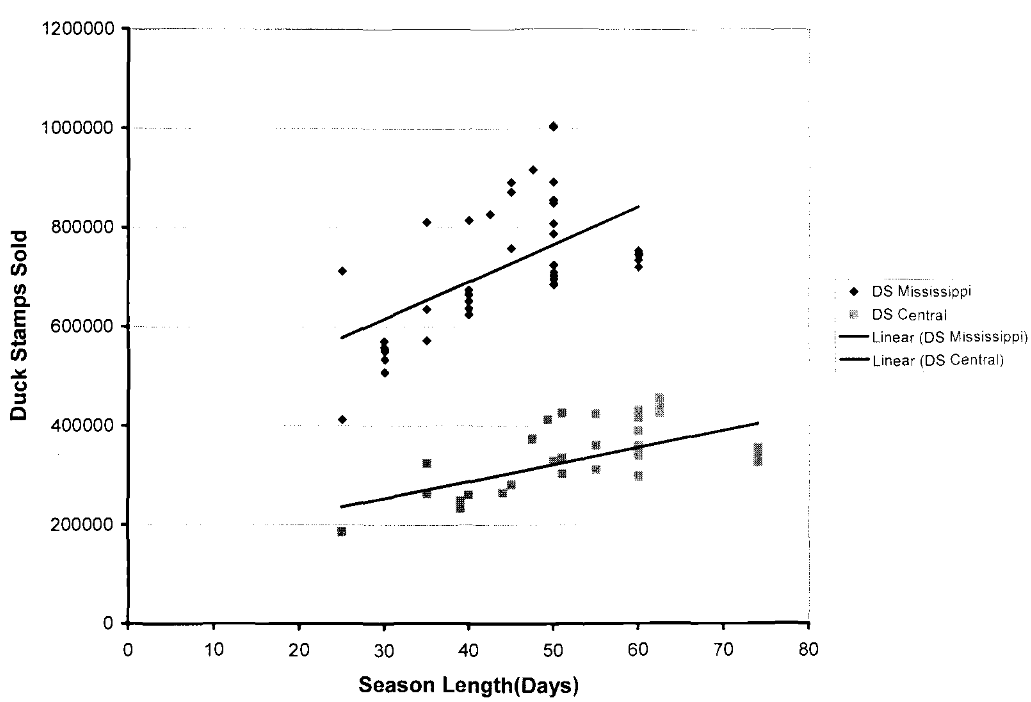
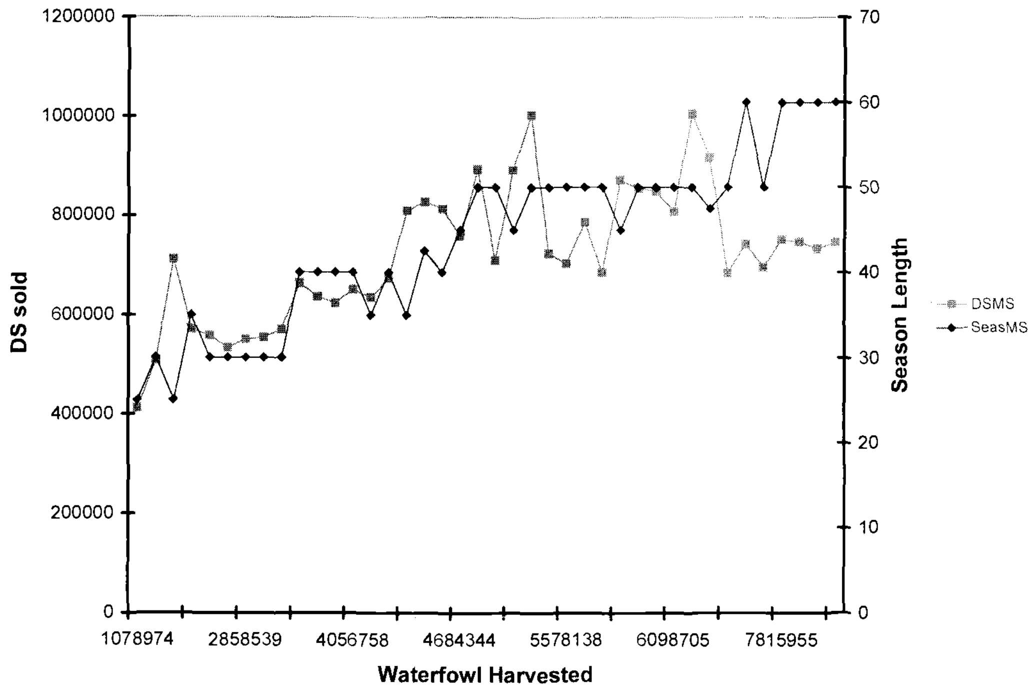


Figure 4.2. Harvest per Season Length and Duck Stamps Sales in the Mississippi Flyway



4.2 Duck Stamp Panel Selection

Predicted Duck Stamp sales were estimated in a Time Series Cross Sectional (TSCS) model. Model estimates were obtained from Limdep Version 8.0. Nine separate models were estimated, based upon heteroscedasticity and autocorrelation specifications outlined below (Greene, 2002b).

Heteroscedasticity specifications with a period-specific covariance matrix, Σ:

S0: $\Sigma = \sigma^2 I$ (homoscedastic errors),

S1: $\Sigma = \text{Diag}\ [\sigma^{11},\ldots, \sigma^{ii}]$, groupwise heteroscedasticity,

S2: Σ = an i x i positive definite matrix with groupwise heteroscedasticity and cross-group correlation.

Autocorrelation specifications:

R0: $\rho_j = 0$, no autocorrelation,

R1: $\rho_j = \rho$, common autocorrelation coefficient for all panels,

R2: $\rho_j = (\rho_1, \rho_2, ..., \rho_i)$, panel-specific autocorrelation coefficients.

The uncorrected pooled OLS model would therefore correspond to S0, R0 and the most general and robust model would be S2, R2. Autocorrelation coefficient estimates, ρ, were obtained from pooled OLS residuals. The common autocorrelation coefficient in R1 was obtained from the sum of the group specific residual autocorrelation, ρ_i. Residual autocorrelation was then corrected with the Prais-Winsten transformation. Heteroscedasticity restrictions were tested by imposing the above restrictions on Σ and parameters estimated with FGLS. Although each model specification is unbiased, the fewer restrictions imposed, the greater the efficiency of parameter estimates and standard errors. The selection of the most appropriate model specification was based on a Log-likelihood test using the log-likelihood ratio. Log-likelihood statistics for the nine model specifications for the Central flyway, Table 4.2, and Mississippi flyway, Table 4.3, and explanations are presented below.

Table 4.2. Central Flyway TSCS Specification[1]

	R0		R1		R2	
	Log-L	Parameters	Log-L	Parameters	Log-L	Parameters
S0	174.197	18	173.095	19	193.638	28
S1	230.501	27	231.558	28	249.207	37
S2	362.994	72	363.117	73	360.232	82

The restriction of homoscedasticity on groupwise heteroscedasticity, S0 on S1, is strongly rejected, as the log-likelihood ratio for all autocorrelation

[1] Critical Values at 95% and 99% confidence intervals: 1 d.f. (3.84, 6.63); 9 d.f. (16.92, 21.67); 45 d.f. (61.66, 69.96)

specifications greatly exceed the 99% significance level of 21.67. Homoscedastitcy is rejected, since the gain in fit from the log-likelihood function of groupwise heteroscedasticty exceeds the loss of observations from the added nine parameters (a heteroscedasticity parameter for each panel). The assumption of groupwise heteroscedasticity on cross-panel correlation can be tested by taking the Log-Ratio of S2 and S1 for the same level of autocorrelation. For all levels of autocorrelation, groupwise heteroscedasticity is strongly rejected in favor of groupwise heteroscedasticity with cross-panel correlation, S2. Autocorrelation specifications can be identified in a similar manner. For all levels of heteroscedasticity, the restriction of no autocorrelation on common autocorrelation can not be rejected. Autocorrelation is not expected in this model, since a lagged dependent variable is expected to eliminate most autocorrelation of the error term. To test panel specific autocorrelation, the restriction of R1 on R2, can be strongly rejected in the cases of homoscedasticity and groupwise heteroscedasticity. However, for S2, zero autocorrelation on common autocorrelation can not be rejected. Based on log-likelihood ratio tests, the S2, RO specification provides the most consistent parameter and standard error estimates. The Panel Corrected Standard Error OLS version of S0, R0 is also considered as a potentially more efficient estimator than the FGLS estimate of S2, R0 (Beck and Katz 1995).

Table 4.3. Mississippi Flyway TSCS Specification[2]

	R0		**R1**		**R2**	
	Log-L	Parameters	Log-L	Parameters	Log-L	Parameters
S0	400.2	22	409.494	23	438.347	36
S1	429.118	35	440.708	36	470.339	49
S2	653.893	126	652.281	127	670.858	140

[2] Critical Values for 1, 9 and 45 degrees of freedom:

1 d.f. (3.84, 6.63); 13 d.f. (22.36, 27.69); 91 d.f. (114.27, 125.29)

Again, the restriction of S0 on S1 and S1 on S2 are strongly rejected, indicating the presence of groupwise heteroscedasticity and cross-panel correlation. The restriction of R0 on R1 is also strongly rejected, as is the restriction of R1 on R2 for all heteroscedasticity specifications. The ideal model for the Mississippi flyway is therefore the S2, R2 specification of groupwise heteroscedasticity with cross-panel correlation and panel specific autocorrelation.

4.3 Interpretation of Results

All parameter coefficients are constant elasticities, $\log(y) = \beta_0 + \beta_1 \log(x)$, except for YEAR and BAG, which are semi-elasticities, $\log(y) = \beta_0 + \beta_1(x)$. Constant elasticity coefficients are interpreted as a percentage-to-percentage change. For example, the coefficient of PDI in the Central Flyway is 0.399, indicating a 1% change in personal income will result in a 0.399% increase in Duck Stamp sales. Year coefficients are interpreted as $(100^* \beta_{year})\, \Delta x$, so a coefficient of -0.012 would equal a 1.2% decrease in Duck Stamp sales for each additional year. The large adjusted R-squared values for both models should not be taken to indicate the strength of either model. High R-squared values are common for panel data with regional dummy variables that capture most of the regional disparity and a lagged dependent variable capturing the majority of time effects. For these reasons, the coefficients and significance of state and DSlag are of little interest. The inclusion of DSlag is to capture expected autocorrelation between waterfowl populations, hunter numbers and harvest as waterfowl populations fluctuate. Attention should instead focus upon the coefficients and significance of the variables of interest.

4.3.1 Central Flyway Duck Stamp Results

The S2, R0 specification is the most consistent model estimator for the Central flyway, but as mentioned previously, the PCSE OLS (S0,R0) model is also considered, as it is potentially more efficient. The S2,R2 specification is presented for comparison and robustness of parameter estimates. Coefficients retain expected signs across specifications with GAS, DSpr and YEAR having negative signs. The negative and significant YEAR coefficient reaffirms a secular trend away from waterfowl hunting in the general population. The positive sign and significance of PDI reaffirms that Duck stamps are a normal good and that hunters are constrained by income. Season length has the largest coefficient and statistical significance across all covariance specifications (ignoring DSlag), indicating that Central flyway hunters are most responsive to season length. It is also the only variable to retain significance in the PCSE specification. The insignificance of BAG would also suggest that Central flyway hunters have a greater preference for Season length over increased bag limits.

Table 4.4. Central Flyway Duck Stamp Estimation Results

	PCSE OLS		S2,R0		S2,R2		AR coef
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	
DSpr	-0.022	-0.168	-0.088	-1.467	-0.089	-1.392	
PDI	0.209	1.094	0.234	2.830	0.399	4.255	
SEAS	0.418	5.126	0.365	9.197	0.412	10.087	
GAS	-0.083	-0.791	-0.151	-3.058	-0.153	-2.780	
BAG	0.084	0.859	0.060	1.319	0.129	3.301	
YEAR	-0.008	-2.208	-0.010	-5.088	-0.012	-5.707	
DSLAG	0.624	12.578	0.641	21.155	0.556	17.158	
MONT	-0.102	-0.059	-0.030	-0.041	-1.024	-1.195	-0.214
ND	0.562	0.322	0.604	0.832	-0.248	-0.291	0.209
SD	0.517	0.297	0.562	0.775	-0.298	-0.349	0.371
WYM	-0.102	-0.058	-0.033	-0.045	-1.046	-1.203	0.016
NEB	0.497	0.283	0.540	0.738	-0.335	-0.389	-0.064
COL	0.468	0.264	0.510	0.692	-0.378	-0.436	-0.077
KAN	0.461	0.262	0.505	0.689	-0.383	-0.444	0.481
NM	-0.195	-0.113	-0.116	-0.161	-1.123	-1.317	-0.501
OK	0.320	0.184	0.374	0.516	-0.530	-0.621	0.333
TEX	0.936	0.534	0.961	1.318	0.184	0.215	-0.011

R-sq 0.974, Adj. R-sq 0.972, n= 400

4.3.2 Mississippi Flyway Duck Stamp Results

The S2, R2 specification in Table 4.5, is identified as the most consistent and efficient estimator and is used as the basis of further analysis for the

Mississippi flyway. The PCSE and S2, R0 specifications are presented to demonstrate parameter robustness. The autocorrelation coefficients, ρ, listed on the right hand side of Table 4.5, demonstrate the need to correct for autocorrelation even with the inclusion of a lagged dependent variable. The large coefficients and significance of PDI and SEAS are not surprising. The two primary constraints on a waterfowl hunter, or any other outdoor recreationalist, are the supply of the activity, SEAS, and their personal income, PDI. The small coefficient of 0.33 for SEAS is deceptive, as most changes in season length are quite large. For example, the AHM regulation alternatives in the Mississippi Flyway have 50% and 33% changes in season length for a change from the Restrictive to Moderate and Moderate to Liberal alternatives. These increases in regulation have a *ceteris paribus* Duck Stamp Elasticity of 16.5% and 10.9%. Personal income variation, however, is much lower. A large 5% annual growth rate in personal income would result in a 2.09% increase in Duck Stamp sales. Since data are aggregated to a state level, income effects are suspected to be larger at the household level. The significant and negative sign of GAS justifies its inclusion as a complementary good. A substantial increase in gas prices from the mean of $1.75 to $2.50 (a 43% annual increase) would be responsible for a 5.1% decrease in Duck Stamp sales. The positive sign and significance of BAG indicates waterfowl hunter's have a predilection for increased bag limits. Holding season length constant, an increase in the bag limit from 3 to 4 birds would increase Duck Stamp sales by 5.6%. However, BAG should be interpreted with some caution as the variable had no variation between 1979 and 2001 in the Mississippi flyway.

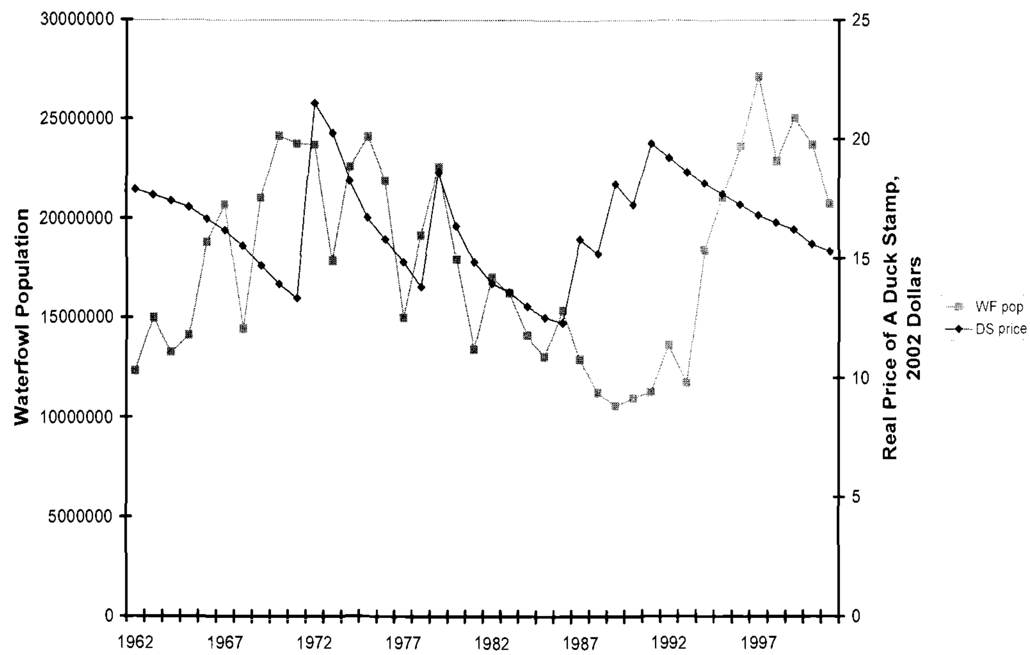
The negative coefficient on YEAR reaffirms the secular trend away from waterfowl hunting in the Mississippi flyway as well. The negative coefficients of DSpr and GAS support the hypothesis that hunters are responsive to the economic costs of hunting. The sign, statistical significance and magnitude of real duck stamp price conform to economic theory, but unexpected for this model. As stated earlier, the cost of a Duck Stamp is a relatively small portion of total hunting costs and would not be expected to have a measurable impact on the waterfowl hunting decision. For the time period observed in this analysis Duck Stamp prices were adjusted on 6 occasions by the U.S. Congress. Adjustments induced spikes in real price that gradually declined with inflation. The increased attention of Congress to waterfowl management during periods of population crashes appears to explain Duck Stamp price adjustments. The coincidence of price adjustments with low periods in continental waterfowl population cycles and low real prices with waterfowl population peaks explain the significance of real Duck Stamp prices (See graph 4.3). It should also be noted that the significance and magnitude of Duck stamp price only occurs in the S2, R2 specification, limiting the robustness of the parameter.

Table 4.5. Mississippi Flyway Duck Stamp Estimation Results

	PCSE OLS		**S2,R0**		**S2,R2**		**AR coef**
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	
DSpr	-0.030	-0.285	-0.064	-1.048	-0.132	-2.336	
PDI	0.370	1.875	0.274	3.112	0.418	5.382	
SEAS	0.292	4.861	0.208	6.100	0.330	9.779	
GAS	-0.184	-2.163	-0.126	-2.515	-0.132	-2.691	
BAG	0.162	1.556	0.176	2.879	0.171	3.635	
YEAR	-0.010	-2.735	-0.007	-4.294	-0.012	-6.565	
DSLAG	0.683	14.014	0.737	28.881	0.595	21.009	
MINN	-0.613	-0.355	0.022	0.027	0.092	0.135	0.049
WISC	-0.705	-0.410	-0.059	-0.073	-0.025	-0.037	0.437
MICH	-0.838	-0.483	-0.167	-0.204	-0.193	-0.280	0.515
IOWA	-0.996	-0.576	-0.301	-0.370	-0.394	-0.575	0.367
ILL	-0.908	-0.519	-0.223	-0.271	-0.277	-0.401	0.133
IND	-1.222	-0.703	-0.487	-0.597	-0.680	-0.989	0.442
OH	-1.060	-0.609	-0.351	-0.429	-0.479	-0.696	0.354
MO	-0.970	-0.562	-0.279	-0.343	-0.365	-0.534	0.022
KEN	-1.289	-0.751	-0.544	-0.677	-0.784	-1.154	0.579
ARK	-0.871	-0.516	-0.198	-0.249	-0.259	-0.388	-0.238
TENN	-1.090	-0.635	-0.379	-0.469	-0.528	-0.778	-0.451
LOUS	-0.635	-0.376	-0.002	-0.003	0.048	0.072	0.091
MISS	-1.072	-0.637	-0.368	-0.465	-0.520	-0.780	-0.072
AL	-1.265	-0.739	-0.525	-0.654	-0.759	-1.121	0.156

R-sq: 0.978, Adj R-sq 0.977, n=560

Figure 4.3. Duck Stamp Price vs. Waterfowl Population



4.4 Robustness of Duck Stamp Parameters

Robustness of parameter estimates and statistical significance were verified across panels, time, and variable specifications for both flyways. To justify general system model parameter coefficients compared to individual state equation estimations, a cross panel parameter comparison model was conducted. First, the model was estimated in pooled OLS with a constant term in place of the panel-specific state dummy variables. The inclusion of state dummy variables greatly improved model fit as well as the statistical significance of the variables of interest. The correctly identified heteroscedasticity and autocorrelation specification of the Duck Stamp panel model was regressed iteratively, dropping each state to test if model-common parameters are justified. All variables of interest retained their sign, level of statistical significance across specifications, and only slight variation in magnitude in either flyway, justifying model-common parameter coefficients.

Coefficient robustness was also validated by iteratively omitting each variable of interest (DSpr, PDI, SEAS, GAS, YEAR, BAG, DS_{t-1}) in the TSCS model and comparing signs, magnitude and significance across specifications. In both flyways, parameters were consistent for the exclusion of DSpr, PDI, GAS, and BAG. The exclusion of DS_{t-1} created problems, increasing the significance of PDI and SEAS while rendering GAS insignificant. This is not of concern, as DSlag was introduced to capture autocorrelation, which is expected for gas prices, income, and season length. Multicollinearity between PDI and YEAR appears to have an affect on parameter estimates. The correlation between the two variables is 0.821 and 0.886 in the Mississippi and Central flyway, respectively. When YEAR is omitted, PDI has a negative sign, while retaining statistical significance as other parameters remain unchanged. The omission of PDI causes YEAR to decrease in magnitude, while retaining statistical significance as other parameters remain unchanged. Multicollinearity also arises when SEAS is omitted; PDI decreases and becomes strongly insignificant, while YEAR retains significance but decreases in magnitude. Although personal disposable income is deflated into 2002 dollars, general post-war growth in the U.S. has been positive and hence correlated with the linear YEAR variable. For the fully specified model in the Mississippi flyway, all parameters are significant at the 99% confidence level, with the exception of DS price, which is significant at a 97.5% confidence level. In the fully specified Central flyway model, YEAR, SEAS and PDI are all significant at the 99% level. The individual significance of these variables justifies leaving PDI, YEAR, and SEAS in the model in the presence of multicollinearity.

The robustness of coefficients to time was tested over time periods expected to have a significant impact on waterfowl hunting. The introduction of the point system on harvest and the Federal ban of lead shot are the two primary time frames tested. The point system is considered due to its unpopularity among hunters as it requires greater skill in the identification of birds in the sky. Daily harvest opportunities may be greatly reduced if a high valued bird is harvested.

The point system has been in practice in the Central flyway since 1970, and remains a part of the flyway's harvest management strategy. For the Mississippi flyway the point system was introduced flyway wide in 1973 and was last chosen as a management tool in 1987. Although initial efforts to ban lead shot began in the 1970's, its use in waterfowl hunting was not entirely banned by the Federal government until 1991.

Shifts in coefficient estimates for the above time periods were tested with interaction variables. For the point system in the Central Flyway, the interaction on Season length and Gas are significant at the 99% level. The significance of the DPoint*GAS interaction variable is unexpected, and likely a coincidence with rising gas prices from the OPEC embargo of the mid 1970's. The point system interaction variables were not deemed significant, as the improvement in fit did not pass the Log-likelihood ratio test and parameter estimates are not significantly different from original estimates. The point system encompasses over 75% of the observed time period for the Central flyway, and the affected coefficients are from 1962-1969, a period of littler interest to this analysis. It is therefore assumed acceptable to omit point system interaction variables for the Central flyway. The point system interaction variables in the Mississippi flyway were statistically insignificant and therefore ignored as well.

The introduction of steel shot, although understood to be necessary, was unpopular amongst hunters due to the poor shooting qualities of early non-lead alternative shot shells. Through time, quality of substitutes has increased and is now considered to be a non-factor by most hunters. The ban of lead shot coincided with the beginning of a large boom in North American waterfowl populations and the most liberal season lengths of the entire sample. Interaction variables are not likely to capture a direct impact of the lead shot ban. This may explain the positive sign and significance of a dummy variable for the time period of steel shot in the Central flyway but the insignificance of all Dsteel interaction variables. Estimation of Dsteel interaction variables in the Mississippi flyway was not possible, due to the near perfect collinearity of regressors. The time period of NAWMP in the sample, from 1985-2001, was used as an alternative with the benefit of 6 additional years of variation. Unfortunately, the collinearity of regressors again limited estimation across this time period in the Mississippi flyway. The dynamic feedback of the lagged Duck Stamp variable and the autocorrelation correction are relied upon to remove the majority of time effects on parameter estimates.

4.5 Harvest Production

Flyway harvest models were estimated in both linear and log-linear Ordinary Least Squares. The log-linear specifications, specifications A through D in Table 4.6, appear to better accommodate the variable scale differences of the data. A diminishing effect for increases in hunter numbers on harvest is expected due to increased competition for birds and congestion at hunting sites. The linear specification, E, was included to see if a quadratic relationship between Duck Stamp sales and harvest exists. The insignificance of the quadratic term for both flyways suggests that such a relation does not exist. The non-linear diminishing effects of large hunter populations on waterfowl harvest are adequately captured with the log-linear specification. Harvest model specifications in Table 4.6 demonstrate the significance of season length and hunter numbers on annual waterfowl harvest. Season length has the most explanatory power of annual harvest variation, accounting for approximately 88% of the total variation in annual harvest for both flyways. Hunter numbers, as measured in Duck Stamp sales, explain 20% more of the variation in harvest in the Central flyway than in the Mississippi flyway, but can account for over 50% of the annual harvest variation in either flyway. Both flyways lose approximately 5% of their explanatory power when predicted Duck Stamp sales are substituted for actual sales (DShat compared to DSflyway) in the Duck Stamp simple regression model. The inclusion of DShat with SEAS, and a variable to capture hunter effort, AVGD, greatly improve model fit to (0.96 adjusted R-square for both flyways). The negative intercepts in certain model specifications have little meaning since there are no samples with zero duck stamp sales, season length or average days hunted. Parameter robustness to time was also tested by running interaction variables of suspected important time breaks, i.e. NAWMP or AHM. These interaction variables are not presented as they were found to be insignificant, supporting time robust parameter estimates.

Table 4.6. Harvest Production Results

Central Flyway Harvest Model Specifications					
	A-log	**B-log**	**C-log**	**D-log**	**E**
ONE	6.992***	-10.266***	-8.904***	-2.055	-3,305,550.0***
SEASCEN	1.873***			0.935***	32,343.9***
DSCHAT			1.835***	0.920***	8.386
AVGDCN				0.155***	213,779.0***
DSCEN		1.942***			
DSC2					-0.000006
R-sq(adj)	0.879 (0.876)	0.745 (0.738)	0.649 (0.640)	0.960 (0.957)	0.942 (0.935)
D-W	0.871	0.565	1.011	1.946	2.217
Mississippi Flyway Harvest Model Specifications					
	A-log	**B-log**	**C-log**	**D-log**	**E**
ONE	9.175***	-7.422**	-6.471*	1.787	-7,677,770.0***
SEASMIS	1.635***			0.889***	105,654.0***
DSMHAT			1.617***	0.677***	11.8937*
AVGDMS				0.139***	364,987.0***
DSMISS		1.687***			
DSM2					-0.000007
R-sq(adj)	0.861 (0.857)	0.556 (0.545)	0.506 (0.493)	0.959 (0.955)	0.950 (0.945)
D-W	0.589	0.316	0.647	2.090	1.881
***99%	**95%	*90%	significance levels		

The high adjusted R-squared values for both flyways indicate a highly accurate account of variation in historical harvest variation. The strength of the harvest model presented relies on its ability to forecast accurately an upcoming season's harvest. Actual harvests are all within the model's 95% forecast interval except for 2001 in the Mississippi flyway and 1963 for the Central flyway. The 2001 hunting season was likely influenced by the terrorist attack of September 11, 2001 and therefore excluded as an outlier. The omission of 2001 data points from the Mississippi sample increased model fit, lifting the adjusted R- squared from 94.8% to 95.5% and serves as the basis of D-log in Table 5.6. There is no explanation for the Central flyway's largest outlier, 1963, and it therefore is kept in the sample

4.6 Duck Stamp and Harvest Elasticities

As demonstrated in Table 4.6, the number of Duck Stamps sold in a flyway has a substantial impact on flyway harvest, accounting for up to 70% of annual variation. The Duck Stamp model demonstrated the significant effect regulatory and economic factors have on a hunter's decision to purchase a duck stamp. The recursive system of the model allows for the cross-equation elasticity between exogenous demand factors on flyway harvest. Since both models are estimated in a constant elasticity format, demand elasticities can be interpreted from equation coefficients. Cross-equation elasticities can be determined from

$$(\delta DS/\delta X) \times (\delta HARV/ \delta DS) = (\Delta x^{*}\beta_x) * \gamma_{DS.}$$

Harvest responses to changes in statistically significant variables for Duck Stamp demand and resulting changes in revenue from duck stamp sales are presented in Table 4.7. Personal disposable income values were taken from the 75 percentile of each flyway, so that percent changes would still be within the sample but close to present, and larger, PDI values. The 75 percentile PDI is approximately $21,400 for each flyway. Duck Stamp price comparisons are based on the current $15 price. Gas prices are based on a $2.00 base price and increases assigned to replicate current gas prices. Season length responses are based on changes from the nearest regulation alternative. For example, a 60 day season from a 45 day season, and a 30 day season from a 45 day season. Revenue calculations are based on an approximate flyway mean of 720,000 duck stamps for the Mississippi and

335,000 for the Central flyway. Revenue values for changes in Duck Stamp price are based upon the new price multiplied by the number of hunters still purchasing a stamp at the new price level. Harvest responses to season length variations include the Duck Stamp response to season length, as well as the percentage change in season multiplied by the season coefficient of the harvest model. Season lengths vary by flyway to represent AHM Restrictive, Moderate and Liberal regulation alternatives.

As can be seen from Table 4.7, personal disposable income has a negligible effect on harvest. An assigned 10% growth in income induces only a 2-3 % increase in harvest, despite its strong statistical significance for Duck stamp demand in both flyways. Season length, as expected, has the largest impact on harvest. For a direct comparison between flyways, an increase of a 30 day to a 45 day season would increase harvest by 64% and 56% in the Central and Mississippi flyways, respectively. Harvest responses demonstrate diminishing marginal returns for both flyways, with an increase to the liberal regulation increasing harvest at a lower rate than an increase to the moderate regulation. The diminishing rate of harvest associated with extended season lengths support a binding income constraint, as presented in Chapter 3. Gas prices have a small impact on duck stamp sales and harvest. Central flyway hunters are the most responsive to gas price increases, with a 50% annual increase in prices reducing harvest by 7%. Harvest responses to gas prices are likely conservative, as the impact on hunter effort is unmeasured. The impact of rising gas prices would likely lead to a decline in days spent in the field, and subsequently lower harvests. Duck Stamp prices in the Mississippi flyway have a noticeable impact on harvest, as well as the potential to generate lost revenue from rising gas prices or decreasing season lengths. In general, the results presented above demonstrate an effect, on both waterfowl hunter participation and annual hunter harvest, from economic conditions.

Table 4.7. Cross-Equation Responses

Central Flyway Elasticities				
	Change	DS Response	Potential Revenue	Harvest Response
PDI growth	3.0%	0.70%	$35,175.00	0.64%
	5.0%	1.17%	$58,793.00	1.08%
	10.0%	2.34%	$117,585.00	2.15%
Gas	$2.50 (25%)	-3.78%	-$189,945.00	-3.48%
	$3.00 (50%)	-7.55%	-$379,388.00	-6.95%
	$3.50 (75%)	-11.33%	-$569,333.00	-10.42%
Season Length	39	-12.78%	-$642,195.00	-44.48%
	60	19.65%	$987,413.00	68.42%
	74	8.52%	$428,130.00	29.66%

Mississippi Flyway Elasticities				
	Change	DS Response	Potential Revenue	Harvest Response
PDI growth	3.0%	1.44%	$155,844.00	0.98%
	5.0%	2.41%	$259,740.00	1.63%
	10.0%	4.81%	$519,480.00	3.26%
DS price	$18.00	-2.64%	$1,817,856.00	-1.79%
	$20.00	-4.40%	$2,966,400.00	-2.98%
	$25.00	-8.80%	$5,616,000.00	-5.96%
Gas	$2.50 (25%)	-3.30%	-$356,400.00	-2.23%
	$3.00 (50%)	-6.60%	-$712,800.00	-4.47%
	$3.50 (75%)	-9.90%	-$1,069,200.00	-6.70%
Season Length	30	-11%	-$1,188,000.00	-37.08%
	45	16.50%	$1,782,000.00	56.15%
	60	11%	$1,188,000.00	37.08%

4.7 Discussion

Problems that plagued previous hunting demand studies also occurred in this thesis. Multicollinearity, lack of variation in observations, and obscured structural demand relationships were addressed here by a large sample size and appropriate estimation techniques. The multicollinearity between regulations that influenced AHM hunter predictions were overcome with the inclusion of a variable accounting for the relative change in the limit regulation. The relative changes in bag limit variable was able to capture hunter response to bag limit changes, while focusing on the more important season length regulation. The demand for bag limit appears minimal as it is insignificant in the Central flyway and not likely influential in the Mississippi flyway, as there was no variation over the last half of the time period observed. Multicollinearity was an issue between time and income and the possibility of omitting either is unattractive. The strong statistical significance of the variables of interest in the Mississippi and most in the Central flyway suggest that any multicollinearity problems are not likely to be important. Despite a model fit dominated by region and time effects, valuable demand relationships for Duck Stamps have been revealed.

The harvest production model used here provides a highly accurate depiction of harvest under historical conditions, as the model fit suggests. The harvest production model does not attempt to explain harvest impacts upon specific species, or the structure of population, age or gender harvest rates. The strength of the harvest model lies in its ability to observe responses to varying season lengths and factors influential to hunter numbers. The economic conditions observed indicate that although income appears to have a minimal effect on either duck stamp sales or harvest, hunters are sensitive to gas prices and season lengths. The large harvest response between regulation alternatives highlights the importance of the flyway manager's decision. An attempt to over supply harvest could have a substantial impact on waterfowl population health.

The accuracy of harvest impacts could be improved upon with the use of Harvest Information Program (HIP) data, rather than harvest estimates derived from the Mail Questionnaire Survey (MQS). The USFWS replaced the MQS with HIP in 2002, as it became apparent that harvest was not equally distributed amongst hunters. HIP estimates more accurately reflect the concentration of harvest from a small percentage of avid hunters by giving them a greater weight in total flyway harvest estimates. However, the limited number of HIP estimates at this point in time prohibited their use for this thesis. More accurate harvest elasticity should be attainable as HIP estimations accumulate. The results in this chapter raise many policy implications and raise questions for future research which will be addressed in the concluding chapter.

Chapter 5: Implications and Conclusions

5.1 Summary

The primary objective of this thesis is to determine waterfowl hunter participation and harvest responses to economic and regulatory factors. The biological and cultural significance of the Central and Mississippi flyways provided excellent regions to observe these effects. The need to attract and retain waterfowl hunters for the sake of the sports continuance and to generate management funds to assist in the accomplishment of NAWMP objectives heighten the importance of understanding factors impacting waterfowl hunting participation. The models developed and results presented are exploratory in nature, yet provide assistance to the direction of future policy and research concerning economically efficient waterfowl harvest management.

A recursive two-equation system was developed to portray accurately the manager-hunter relationship. In the first equation, the waterfowl manager acts as the supplier in a monopolistic market. The provision of annual regulations, based on waterfowl population health, is supplied to the attribute-taking waterfowl hunter. Hunters then decide whether or not to purchase a waterfowl stamp based on regulations and/or economic factors. By measuring hunter response in a demand equation, the determination of hunter elasticity to regulation and economic conditions was possible. Previous attempts to measure hunter preferences and responses were limited by their restricted regional specifications and the time scope of analysis. This motivated the measurement of hunter response over a longer time period (1962 to 2001) at the flyway scale, while still allowing for regional disparities at the state level.

The Time-Series Cross-Sectional (TSCS) covariance structure estimation method is employed to estimate waterfowl hunter demand preferences. The TSCS model was chosen for its ability to treat cross-correlation between panels, an expected relationship between units as large as states. Results for both flyways contain expected signs and are robust to the omission of parameters, time, heteroscedasticity and autocorrelation. Common to both flyways is a general trend away from waterfowl hunting through the time period observed. Factors found to be significant on the Duck Stamp purchase decision include season length, personal disposable income, and gas prices. Central flyway hunters are more responsive to changes in season length and gas prices. Mississippi flyway hunter demand was more responsive to income and real Duck Stamp prices, although both of these are smaller in comparison to those of gas and season length.

Predicted duck stamp sales for each flyway provided instrumental variables for the second equation of the system; a harvest production function. Harvest was modeled as a function of the number of hunters in a flyway and the amount of effort expended, while constrained by seasonal regulations. To make harvest estimations useful to waterfowl managers, estimations are based on regulations and economic conditions determined prior to the waterfowl season. Under historic waterfowl populations and conditions, season length, predicted duck stamp sales and average number of days spent waterfowling per hunter provide a reasonably accurate harvest forecast.

The ultimate purpose of the two-equation system is to estimate both hunter participation elasticities and resulting harvest elasticities. The objective of waterfowl management in North America, as specified by the NAWMP, strives to maximize inter-temporal harvest by the establishment of a continentally stable waterfowl population. A Duck Stamp and revenue optimization solution would be undesirable in this context. Waterfowl managers are concerned with the impacts of regulation decisions on harvest due to the need to ensure sustainable annual harvests. Still, potential revenue gains and losses from Duck Stamp elasticities are important for budget forecasting and habitat protection purposes. Based on historical waterfowl populations and hunting conditions, the Duck Stamp sale responses presented in Chapter 4 demonstrate the potential impact that economic conditions have on Duck Stamp sales and harvest.

5.2 Policy Implications

The results of this thesis contain several policy implications for future waterfowl management. The results dealing with hunter and harvest response have potential to improve AHM estimation. Previous attempts in AHM to predict hunter trends at the state level based in response to regulations are limited by the large degree of multicollinearity between included variables. As recommended by the AHM committee, hunter participation response is an important aspect of waterfowl management (Wildlife Management Institute, 2004). The hunter participation model designed in this thesis would improve AHM's ability to forecast hunter participation in response to regulation changes. At present, hunter response variation is likely captured under the stochastic component of AHM models. This thesis highlights the importance of socio-economic factors outside of the waterfowl manager's control on hunting participation. The accuracy of harvest forecasts could therefore be improved by treating hunting participation, regulations and harvest as an endogenous relationship. Until sufficient resources are devoted for a large scale state-level survey of hunters, the findings of this thesis help fill an information gap on historic hunter response to regulation change.

The estimates of hunter and harvest response should also be of interest to state wildlife agencies and Flyway councils, as they have the ultimate power to select a regulation package. For a State or Flyway council to opt for a regulation package more restrictive than the AHM council recommendation, it is important to understand the impacts upon hunter participation and harvest. Model findings suggest that an assumed preference by hunters for increased bag limits appear to be over stated based on the statistical insignificance of bag limit variations over 40 years on hunter participation. Admittedly, this finding is based on the limited bag limit changes within the sample and the indirect way in which bag limit preferences were measured. A lack of hunter preference for bag limits needs to be recognized by waterfowl management as some groups of hunters feel managers over supply harvest to keep hunters happy at the expense of waterfowl population health. Based on the estimates of this thesis, managers should only consider increased bag limits as a means to increase harvest and not as a means to increase hunter participation or gain political support. Single species analysis of bag limits may have been more informative for capturing hunter preferences. Again, results are based on historical conditions. As gas prices and travel distances to hunting sites increase, larger bag limits may serve as an important substitute for fewer hunting trips per hunting season.

The elasticity of hunter demand to Duck Stamp prices should be of interest to the Migratory Bird Conservation Commission, State game agencies and Joint Venture coordinators. The ability to forecast future Duck Stamp revenue and have accurate revenue predictions could then better guide management planning activities. The need for sustaining conservation funds also suggests a more frequent schedule of price adjustments for Duck Stamps. The retail price of a Duck Stamp has remained at $15 since 1991, equivalent in buying power to $10.14 in 2006. A negative hunter response to a price increase is unexpected, as results demonstrate that hunter demand is strongly inelastic to real price changes. The insignificance of Duck Stamp prices in the Central flyway and questionable significance in the Mississippi flyway, suggest that waterfowl hunters hold a value for Duck Stamps greater than the retail price. It is hypothesized that waterfowl hunters view stamps as more than a right to hunt, but also representative of option values to enjoy waterfowl in the future.

5.3 Research Agenda

The findings of this thesis assist many aspects of waterfowl management, as discussed above, but they also raise further policy questions that can only be answered through additional research. Among them, it is hypothesized that bag limit and season length combinations outside of AHM regulation alternatives can achieve comparable harvest objectives, while increasing hunter satisfaction and Duck Stamp revenue. The lack of variability of bag limits in the modern waterfowl management era and corresponding harvest impacts, constrain waterfowl managers from utilizing a potentially important regulation criterion. To estimate such demands, survey work in an experimental environment is required. Ideally, such a study should be conducted on a flyway basis but at the state level, as regional disparities are strong. The elicitation of regulation preferences at the individual level would also allow the inclusion of greater complimentary goods, such as state hunting license prices, state-specific hunting regulations and the availability of hunting land in the hunter's home state. Further, waterfowl hunting markets for avid, intermediate and casual hunters should be considered. The participation decision of avid hunters is likely insular to exogenous economic conditions or regulation changes. The intermediate and casual hunter would be expected to be more responsive to regulatory and economic changes. As these hunters are likely the majority of hunters, understanding their demand relationships will better serve the general well being of the hunting community.

It is paramount that the continent's waterfowl populations remain healthy to ensure that adequate hunting opportunities exist to meet hunter demand. As the land resources employed in the production of waterfowl become more scarce and the availability of management funds are reduced, it will become increasingly important for waterfowl biologists, managers, land owners, hunters and economists to work together. In this context, an analysis of the efficiency of management dollars on waterfowl production is a high priority. Although it has now been almost 20 years since the North American Waterfowl Management Plan was created, an analysis of the returns in terms of duck recruits is lacking. Economic analysis in conjunction with biological modeling, as attempted by Hammack and Brown (1974), can assist to identify the most efficient land to be acquired or leased with management dollars. As can be seen, the role for future interdisciplinary work in waterfowl management is quite large.

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