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THE INFLUENCE OF REGULATIONS ON DUCK HUNTERS AND HARVEST

by

Matthew T. Haugen

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

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Under the Supervision of Professors Larkin A. Powell and Mark P. Vrtiska

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THE INFLUENCE OF REGULATIONS ON DUCK HUNTERS AND HARVEST

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University of Nebraska, 2013

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Although regulations, duck hunters, and duck harvest are interconnected, the relationships among them have not been fully explored. I used U.S. Fish and Wildlife Service's Parts Collection Survey to examine both duck harvest and duck hunter behaviors with regard to regulations in the Central Flyway. I first examined what factors best explained the daily variation in harvest distribution across the hunting season for mallards (*Anas platyrhynchos*), dabbling ducks (*Anas* spp.), and diving ducks (*Aythya* spp.). Secondly, I examined how hunter behaviors were influenced by harvest regulations. Finally, I documented co-occurrence of duck species in the daily bags of hunters, and developed models to predict the effects of daily bag limit changes on both target and non-target species. I found regulation changes may influence the spatial harvest of both dabbling and diving ducks, whereas the distribution of mallard harvest appeared to be influenced more by hunting pressure, water on the landscape, and mallard density. Regulations also influenced select measures of duck hunter behavior (e.g., average daily bag, gender selectivity of mallards). However, regulations did not differentially affect most duck hunters for the measures of behavior I examined. Co-occurrence results provided insight into the harvest relationships between pairs of ducks species (e.g., redhead [*A. americana*] were likely harvested with canvasback [*A. valisineria*]). Co-occurrence relationships allow managers to consider the effects

regulatory changes have on non-target species, an important consideration given the aggregate nature of duck harvest. Ducks receive considerable attention from managers in North America, and the Parts Collection Survey contains information that should provide managers with tools and inferences for waterfowl management that account for relationships among regulations, duck hunters, and duck harvest.

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PRIMER

Approximately 179,000 active duck hunters spent an estimated 1.15 million days afield and harvested approximately 3 million ducks in the Central Flyway in 2012 (Raftovich and Wilkins 2013). Waterfowl hunters are essential to the conservation and management of waterfowl habitat and populations via funding derived from hunter license sales, Federal Migratory Bird Hunting Conservation Stamps sales (i.e., duck stamps), and the Pittman-Robertson act (Magnum and Shaw 1984, Vrtiska et al. 2013). Recently, the North American Waterfowl Management Plan (NAWMP) recognized this relationship by explicitly stating a goal related to waterfowl hunters: “Growing numbers of waterfowl hunters...” (NAWMP 2012). Additionally, hunters have historically influenced conservation efforts and continue to have political clout with regard to conservation efforts (Thomas 2010). Thus, without continued support from hunters, waterfowl habitat may be lost and waterfowl populations decline.

However, the number of waterfowl hunters is on a decline (Enck et al. 2000, Vrtiska et al. 2013). Although managers may not be able to address all influences on hunter declination, they can address some, such as changes to regulations that may affect hunter participation (Enck et al. 1993, Pierce et al. 1996, Ringelman 1997, Miller and Vaske 2003, National Flyway Council and Wildlife Management Institute 2006). Examination of hunter preferences and satisfaction with hunting regulations is limited by an intuitive disconnect between preferences and actual behaviors (e.g., effort, efficiency, movement, and selectivity). Although satisfaction and preference surveys will always have relevance, research that incorporates hunter behaviors could provide managers with better insight to setting regulations. Data that pertain to actual hunter behaviors may

require significant time and resources to attain. However, the U.S. Fish and Wildlife Service's Parts Collection Survey (PCS) may be a source of data for hunter behaviors that requires relatively less time and fewer resources to collect new data.

The PCS is an annual survey used primarily to examine waterfowl harvest (Baldassarre and Bolen 2006). Each entry in the PCS corresponds to an individual duck that was harvested at a given time and location within the United States of America. The PCS also contains hunter identification which provides a link between individual hunter attributes and harvest metrics validated by wing receipts. Yet, the PCS appears to be rarely exploited for hunter behaviors and other hunter related studies, although it was developed, in part, for such purposes (Martin and Carney 1977). Additionally, beyond annual harvest estimates, studies that use the PCS with regard to duck harvest seem sparse (Oetgen 2002, Green and Krementz 2008, Delta Waterfowl 2012). As such, the PCS may provide some data related to duck hunters and duck harvest yet to be examined.

My research used the PCS to examine both duck harvest and measures of hunter behaviors within the Central Flyway. Specifically, I examined changes in duck harvest spatially across time (1997-2011), which may assist managers to set appropriate duck season dates. It also may help managers explain and educate constituents as to what factors may influence duck harvest. I also examined how harvest regulations affect the behaviors of duck hunters. It provides insight into how regulations may have differentially affected duck hunters. Finally, I examined species co-occurrence within the daily bags of hunters. This information may help managers understand the connectivity among regulations, hunter behaviors, and duck availability on the harvest of duck species. Managers also may be able to assess the potential effects of regulation change

on target and non-target species, an important consideration given the aggregate nature of duck harvest. Overall, my research should aid managers in harvest management as well as hunter recruitment and retention efforts.

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CHAPTER 1 : ASSESSMENT OF SPATIAL CHANGES OF DUCK HARVEST IN THE CENTRAL FLYWAY, 1997-2011.

Abstract

Annual variation exists in spatial and temporal availability of ducks, but managers must set hunting seasons that coincide with duck availability. Thus, knowledge of the factors which influence duck availability would be useful to managers when setting duck season dates. I used changes in mean latitude of harvest to represent changes in duck distribution during the hunting season within the Central Flyway from 1997-2011, derived from harvest data from the U.S. Fish and Wildlife Service Parts Collection Survey. I also developed a candidate set of models to represent competing hypotheses of food availability, weather, water on the landscape, competition via population density, hunting pressure, and regulatory change to explain the variation in harvest distribution of mallard (*Anas platyrhynchos*), dabbling ducks (*Anas* spp.), and diving ducks (*Aythya* spp.). The model selection process revealed that hunting, water on the landscape, and mallard density best explained the distribution of mallard harvest. Regulations had the largest influence on both dabbling (non-mallards) and diving duck harvest distribution. Trends in the distribution of harvest should be instructive for future harvest management decisions.

Introduction

Waterfowl managers try to coincide hunting seasons with duck availability to maximize hunting opportunities (Bellrose 1980, Vrtiska 2012). However, annual variation makes predictions of spatial and temporal duck availability difficult for waterfowl managers. Although precise knowledge of duck migration chronology prior to setting season dates is improbable, managers still need to set reasonable hunting seasons. Setting hunting seasons too early or too late may result in dis-satisfied constituents, which may influence hunter recruitment and retention (Stankey et al. 1973, Case 2004). Subsequently, funding for conservation or management activities may be affected (Vrtiska et al. 2013). As such, setting appropriate hunting seasons may be important to duck conservation. Thus, information about duck distribution, and factors that affect duck harvest distribution, spatially and temporally, is important.

Many factors may influence the annual variation in duck distribution, movement, and migration. For example, weather has been documented to influence duck migration and movement (Richardson 1978, Nichols et al. 1983, Pearse 2007, Schummer et al. 2010). Additionally, water on the landscape (i.e., wetlands) in terms of availability and diversity may also affect duck distribution on the landscape (Kaminski and Prince 1981, Kaminski and Prince 1984, Webb et al. 2010, Pearse et al. 2012). Still yet, studies suggest hunter activity and regulation change can affect wildlife movement and habitat selection (Root et al. 1988, Conner et al. 2001, Cox and Afton 1997, Casazza et al. 2012). Finally, food availability and competition may affect duck behaviors (Jorde et al. 1983, Baldassarre and Bolen 1984), which in turn may affect duck distribution. All these aforementioned factors that affect duck distribution, movement, and migration may

consequently influence duck harvest. However, few studies have attempted to offer explanations as to if or why harvest patterns have changed (Delta Waterfowl 2012).

Understanding changes in harvest may allow managers to more accurately predict duck availability during hunting seasons and inform constituents. Thus, I used the U.S. Fish and Wildlife Service's (USFWS) Parts Collection Survey (PCS) database to examine what factors influence duck harvest patterns. My objectives were to: (1) use a candidate set of competitive models to best explain the variation in duck harvest distribution, and (2) determine the magnitude of potential harvest change.

Methods

I obtained PCS data from the USFWS Branch of Harvest Surveys and selected only Central Flyway records from the 1997-2011 regular duck seasons. I created three groups of ducks, mallard (*Anas platyrhynchos*), dabbling ducks (excluding mallards), and diving ducks to account for differences in management concern and life history strategies. The dabbling duck group included green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), gadwall (*A. strepera*), northern pintail (*A. acuta*), American wigeon (*A. americana*), and northern shoveler (*A. clypeata*). The diving duck group included redhead (*Aythya americana*), canvasback (*A. valisineria*), and scaup (*A. marila* and *A. affinis*).

Multi-model Inference

I used mean latitude of harvest to represent duck distribution across time during the fall migration. I used SAS® software (SAS Institute 2009) to calculate mean

latitudes of harvest for each group of ducks for each day (i.e., an ordinal day that starts on 21 September and ends on 31 January) during each hunting season from 1997-2011.

Mean latitudes of harvest were weighted averages of county centroids where a duck was reported to be harvested. I removed data that did not contain county information, as there was no way to reliably determine where the duck was harvested.

I ran initial sets of models to determine how the principle hypotheses were best represented (i.e., as an additive or interaction model) for each duck group. I used a corrected Akaike Information Criterion (AIC_c) to select among the alternatives. Mean latitude of harvest was used as the response variable. I used an ordinal day (DAY) in all models, and AIC_c was used to determine if a quadratic or linear ordinal day best explained the variation in harvest distribution. From the initial model fitting, I developed a candidate model set for each group of ducks separately. I included a null model (i.e., DAY only model) in all candidate models sets, and AIC_c was again used to select among the alternative hypotheses. I looked for correlations between the principle hypotheses before proceeding with the analyses by running a Pearson's correlation test. I was prepared to modify or eliminate variables as needed. Plots of best models were created.

Principle Hypotheses

I tested six principle hypotheses to determine what factors may best explain the variation in harvest distribution for mallard, dabbling, and diving ducks: food availability, weather, water on the landscape, competition via population density, hunting pressure, and regulatory influences. Each hypothesis was treated as a factor, and I calculated an

average estimate across years for each hypothesis and categorized annual estimates either as above or below average, unless otherwise noted.

I used corn acres planted annually in North and South Dakota ($\text{FOOD}_{\text{DAKOTAS}}$), as well as Nebraska (FOOD_{NE}) total corn acres planted annually from 1997-2011 to examine if food availability influenced duck harvest distribution at different latitudes (U.S. Dept. of Agriculture 2013). I used total corn acres planted because it is a food source readily used by waterfowl (Moore 1980), and if residual corn is sufficiently abundant, ducks may delay migration, which could influence harvest. Estimates of total corn acres planted were categorized into high and low corn years (Figure 1.1).

I used a daily cumulative weather severity index (hereafter WSI; Schummer et al. 2010) to examine weather's influence on the distribution of duck harvest. The WSI index includes factors of snow fall, snow depth, temperature, and consecutive days with unfavorable temperatures (Schummer et al. 2010). I only used weather data from North and South Dakota in October and November months (WEATHER), because weather in these two months would better indicate when ducks migrate to southern latitudes. I used U.S. Historical Climatology Network data from 8 weather stations (Menne et al. 2013), 4 each in North and South Dakota, to calculate a daily WSI. I used weather stations Crosby, Grand Forks (Univ Nws), Jamestown (State Hosp), and New England in North Dakota and Alexandria, Clark, Cottonwood, and Dupree in South Dakota (Menne et al. 2013). To calculate an annual WSI across all stations, I calculated the average of the maximum daily WSI estimates for each station sampled. Annual estimates above average were classified as severe and below average estimates were classified as mild (Figure 1.1). I also created a model that incorporated both weather and food factors,

because abundant food on the landscape may delay migration even in the face of inclement weather.

I obtained mean Palmer drought severity index (PDSI) from June-September for 1997-2011 to examine water on the landscape's effect on the distribution of duck harvest (National Climate Data Center 1994). I calculated an average PDSI for northern (North Dakota and South Dakota; $PDSI_{NORTH}$), mid (Nebraska and Kansas; $PDSI_{MID}$), and southern (Oklahoma and Texas; $PDSI_{SOUTH}$) latitudes for each year in the sampling frame. Interactions between the annual PDSI estimates at north, mid, and south latitudes were used to examine where water on the landscape was most influential to harvest. Annual PDSI estimates were categorized into wet or dry years dependent on if they were greater than 0.0, or less than or equal to 0.0 for a given year, respectively (Figure 1.2). I tested additional models that included water on the landscape and either WEATHER or $FOOD_{DAKOTAS}$ factors. While inclement weather may cause birds to migrate, if enough water or open food is on the landscape, birds may be able to find useable resources, and thus delay migratory movements.

I expected high densities of ducks to cause competition for limited resources, which may influence duck movements. To test competition via population density (DENSITY) effects on harvest, I first created a fall population size index for a given species. I calculated corrected age ratios of harvest based on the proportion of a species harvested in the Central and Mississippi Flyways. I then obtained breeding population estimates (USFWS 2013) and assumed females represented half the breeding population. I multiplied the estimated female population size by the age ratio to obtain an estimate of young produced. Finally, I added the estimated number of young to the breeding

population, which resulted in my fall population size index for a given species. I summed species estimates into their respective duck groups (e.g., redhead, canvasback, and scaup estimates were summed for total fall diving duck population index). I then divided the population estimates by the number of U.S. May ponds (USFWS 2013), which resulted in my estimate of density (i.e., ducks per pond). DENSITY was categorized into high or low categories for each group of ducks (Figure 1.2). I included a model that incorporated DENSITY and FOOD_{DAKOTAS}, because high competition for food or habitat (i.e., water on the landscape) with other ducks may cause some ducks to move to areas with less competition, and thereby influencing harvest.

I used active hunter estimates as an indicator of hunting pressure (PRESSURE). I summed active hunter estimates annually for all Central Flyway states from both the Mail Questionnaire Survey (1997-1998, Kruse et al. 2002) and the Harvest Information Program (1999-2011, Kruse 2013). Annual estimates were categorized into high or low hunting pressure years (Figure 1.2). I also included a model that incorporated hunting pressure and water on the landscape, because hunting pressure may differentially affect duck distribution based on water availability (Webb et al. 2010).

Finally, I divided the sampling frame into two periods, 1997-2001 and 2002-2011, to test regulatory influences on duck harvest distribution (FRAMEWORKS). From 2002-2011, hunting seasons were allowed to start earlier and end later compared to 1997-2001, but still retained the same season lengths and daily limits (Kruse et al. 2002, Kruse 2013). Thus, more ducks may be harvested or exposed to hunting pressure prior to or after migration. As such, more harvest may occur in the north and vulnerability may

decrease (Eadie et al. 2002, Szymanski and Afton 2005) in the south, which may influence harvest patterns.

Results

A quadratic description of harvest distribution by ordinal day provided a better fit than a linear model (linear model: Mallard $\Delta AIC_c = 149.1$; Dabbling duck $\Delta AIC_c = 981.8$; and Diving Duck $\Delta AIC_c = 355.9$), so a quadratic function of day (i.e., DAY + DAY²) was used in all models (Table 1.1; Figure 1.3; Figure 1.4).

Water on the landscape in North and South Dakota (PDSI_{NORTH}) and Nebraska and Kansas (PDSI_{MID}) were negatively correlated with mallard, dabbling, and diving duck DENSITY ($P < 0.05$, Appendix 1.A). As such, mallard, dabbling, and diving duck DENSITY replaced PDSI_{NORTH} and PDSI_{MID} parameters. Total corn acres planted in North and South Dakota (FOOD_{DAKOTAS}) and Nebraska (FOOD_{NE}) were positively correlated ($P < 0.05$, Appendix 1.A). FOOD_{NE} was removed from analyses because FOOD_{DAKOTAS} may have a stronger influence on duck harvest as it is on the breeding grounds (i.e., corn in North and South Dakota may affect more ducks and ducks prior to migration). Hunting pressure (PRESSURE) and FOOD_{DAKOTAS}, mallard DENSITY and FOOD_{NE}, and FOOD_{NE} and PDSI_{NORTH} and PDSI_{MID} were correlated ($P < 0.05$, Appendix 1.A). Because FOOD_{NE} was removed from the analyses, the correlations with mallard DENSITY, PDSI_{NORTH}, and PDSI_{MID} should not have affected the results. PRESSURE and FOOD_{DAKOTAS} were negatively correlated, but both parameters were included in the candidate model sets as food and hunting pressure may not be mechanistically correlated. For example, corn may have increased due to increases in

corn prices (U.S. Dept. of Agriculture 2013) and hunting pressure may have decreased because of increased urbanization and other societal factors (Heberlein 1987). Thus, I included both parameters, and I was prepared to make a posteriori decisions to eliminate a model if it appeared the correlation was affecting model results.

Mallard

The variation in harvest distribution (Figure 1.3) for mallards was best explained with a model that incorporated DAY, PRESSURE, and an interaction between $PDSI_{SOUTH}$ and mallard DENSITY (Table 1.2, weight $[w_i] = 0.996$, parameters $[k] = 13$). High hunting pressure shifted mallard harvest 0.57 degrees latitude (63 km) southward relative to low hunting pressure, if water on the landscape at southern latitudes and mallard density was held constant at either wet and low, or dry and high, respectively (Figure 1.4). If hunting pressure was held constant at either high or low pressure, dry landscapes (i.e., water at southern latitudes) and high mallard density shifted mallard harvest 0.34 degrees latitude (38 km) southward relative to wet landscapes and low mallard densities (Figure 1.4). Wet years with low mallard densities and low hunting pressure shifted the mean latitude of mallard harvest 0.91 degrees north (101 km) relative to dry years with high mallard densities and high hunting pressure (Figure 1.4). Alternatively, dry years with high mallard densities and low hunting pressure shifted the mean latitude of harvest 0.23 degrees north (26 km) relative to wet years with low mallard densities and high hunting pressure (Figure 1.4).

Dabbling Duck

The annual variation in the harvest distribution of dabbling ducks was best explained by DAY and FRAMEWORKS (Table 1.3, $w_i = 1.000$, $k = 5$). Dabbling ducks were harvested at higher latitudes, 0.69 degrees latitude (77 km), under 2002-2011 frameworks that allowed seasons to be set one week earlier and end one week later relative to 1997-2001 frameworks (Figure 1.4). Actual PCS harvest indicated the temporal trends of average daily harvest for dabbling ducks between framework sets were similar (Figure 1.5).

Diving Duck

The variation in the harvest distribution of diving ducks (Figure 1.3) was best explained by an interaction between DAY and FRAMEWORKS (Table 1.4, $w_i = 1.000$, $k = 9$). Under current frameworks (i.e., 2002-2011) diving ducks were harvested further south at the beginning of the hunting season, then around mid- to late October harvest shifted northward relative to 1997-2001 (Figure 1.4). Harvest distribution converged upon similar latitudes towards then end of the hunting seasons (e.g., 31 January, Figure 1.4). The maximum degrees harvest shifted southward was 3.36 degrees (373 km) on 21 September. The maximum degrees harvest shifted northward was 1.92 degrees (213 km) on 2 December. Actual PCS harvest indicates differences existed in the temporal trends of average daily harvest between regulation sets (Figure 1.5). Current framework resulted in more diving duck harvest during the first half of the hunting season relative to 1997-2001 frameworks, however harvest was equitable later in the hunting season (Figure 1.5).

Discussion

Hunting pressure, water in Oklahoma and Texas, and mallard density best explained the variation in mallard harvest. Hunting pressure may influence duck movements (Cox and Afton 1997, Casazza et al. 2012), as well as water availability (Kaminski and Prince 1984, Webb et al. 2010, Pearse et al. 2012), and competition (Jorde et al. 1983, Baldassarre and Bolen 1984). Thus, it seems plausible that all three factors may affect mallard harvest.

Although high mallard densities may appeal to hunters, it may also influence the distribution of mallards. High mallard densities can indicate either higher production or lower water availability. Low water availability may concentrate waterfowl, but also may concentrate hunters. As such, there may be increased localized hunting exposure on ducks as well as increased intraspecific competition for habitat resources. Either of these mechanisms may prompt ducks to migrate to potentially better conditions, which consequently may influence harvest. Thus, a trade-off may exist between high mallard densities and the persistence of mallards in an area. Given hunters may prefer longer hunting seasons (Ringelman 1997), ducks moving out of an area prematurely may not be desirable. Managers should focus on food resources, water conditions, and local hunting regimes when they consider mallard harvest and regulation setting.

Framework changes provided the greatest explanation for the variation in harvest distribution for both dabbling and diving ducks. Northward shifts in dabbling duck harvest may have occurred because earlier seasons allowed more dabbling ducks to be exposed to hunting pressure closer to the breeding grounds prior to migration. Specifically, there may be fewer ducks available at southern latitudes in addition to a

higher proportion of ducks at southern latitudes that have been exposed to hunting pressures, which may reduce their vulnerability (Eadie et al. 2002, Szymanski and Afton 2005, Ackerman et al. 2006).

Diving ducks also were influenced by framework changes, however contrary to dabbling ducks, an interaction between FRAMEWORKS and DAY provided the best fit. Scaup daily bag limits were reduced in 1999 from six to three (Kruse et al. 2002), which may account for the interaction between FRAMEWORKS and DAY. Although daily limits on other diving duck species remained comparable among framework sets (Kruse 2013), it appears actual diving duck harvest may have increased earlier in the hunting season (Figure 1.5). The increase in diving duck harvest earlier in the hunting season may also have influenced the results. Dabbling ducks did not exhibit the same noticeable changes in actual harvest between the framework sets.

Some waterfowl management actions may have the potential to affect the harvest distribution of duck species because changes in framework dates appeared to influence harvest distribution in both dabbling and diving ducks. Future management actions should consider how regulatory changes may affect harvest, because changes in harvest patterns may have implications for harvest management as well as hunter recruitment and retention. For example, if managers do not account for changes in harvest patterns and cannot provide hunters with adequate harvest opportunities, then hunter satisfaction may decrease (Stankey et al. 1973), resulting in reductions in hunter retention (Case 2004). Thus, managers should carefully consider possible ramifications of regulatory changes on hunters as well as duck populations.

Lastly, although my results offer reasonable explanations as to why certain distributions of duck harvest has changed, there may be alternatives which better explain duck harvest distribution, as the candidate models may omit the best explanation. Additionally, year was not treated as a random effect because parameter estimates were already calculated on an annual basis. Thus, variation due to year should be have been accounted for in the initial principle hypotheses estimates.

Management Implications

Managers may be able to use these results to predict mallard availability when setting hunting season dates under different anthropogenic and environmental stimuli (Appendix 1.C). For example, water on the landscape from June to September is largely uncontrollable at continental scales. However, estimates of PDSI are easily obtainable online. Thus, managers should be able to access PDSI data and project what the water conditions for southern latitudes may be like from June-September, and then modify duck season dates accordingly. My results also may help managers explain and educate their constituents on why changes in harvest may occur.

Additionally, managers can account for regulatory (i.e., framework change) effects on dabbling and diving duck harvest, both of which could help in setting appropriate hunting seasons. Because it is important to provide hunters with opportunities to harvest waterfowl (Brunke and Hunt 2007), appropriate hunting season are critical to hunter satisfaction. Increased hunter satisfaction may lead to increased hunter recruitment and retention (Case 2004), which is important as hunters provide support to wildlife and habitat conservation efforts (Vrtiska et al. 2013).

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Table 1.1: Parameter estimates from the best model explaining the variation in harvest distribution across the hunting season for each duck group (mallard [*Anas platyrhynchos*], dabbling duck [*Anas* spp.], and diving duck [*Aythya* spp.]), as determined by Akaike's Information Criterion correct for small sample sizes (SE=standard error) from U.S. Fish and Wildlife Service Parts Collection Survey data, 1997-2011.

Duck Group	Effect	Parameter				Estimate	SE	p > t
		PRESSURE	PDSI SOUTH	DENSITY	FRAME-WORKS			
Mallard ^a	Intercept					48.75	0.14	<.0001
	DAY					-0.15	0.00	<.0001
	DAY ²					0.00	0.00	<.0001
	DENSITY			High		0.39	0.10	<.0001
	DENSITY			Low		0.00	-	-
	PDSI _{SOUTH} ^f		Dry			-0.12	0.09	0.2109
	PDSI _{SOUTH}		Wet			0.00	-	-
	DENSITY x PDSI _{SOUTH}		Dry	High		-0.61	0.13	<.0001
	DENSITY x PDSI _{SOUTH}		Wet	High		0.00	-	-
	DENSITY x PDSI _{SOUTH}		Dry	Low		0.00	-	-
	DENSITY x PDSI _{SOUTH}		Wet	Low		0.00	-	-
	PRESSURE ^g	High				-0.57	0.07	<.0001
	PRESSURE	Low				0.00	-	-
Dabbling Duck ^{b,d}	Intercept					49.77	0.18	<.0001
	DAY					-0.32	0.01	<.0001
	DAY ²					0.00	0.00	<.0001
	FRAMEWORKS ^h				Post	0.69	0.10	<.0001
	FRAMEWORKS				Pre-	0.00	-	-
Diving Duck ^{c,e}	Intercept					55.86	0.53	<.0001
	DAY					-0.48	0.02	<.0001
	DAY ²					0.00	0.00	<.0001
	FRAMEWORKS ^h				Post	-3.51	0.60	<.0001
	FRAMEWORKS				Pre-	0.00	-	-
	DAY x FRAMEWORKS				Post	0.15	0.02	<.0001
	DAY x FRAMEWORKS				Pre-	0.00	-	-
	DAY ² x FRAMEWORKS				Post	0.00	0.00	<.0001
	DAY ² x FRAMEWORKS				Pre-	0.00	-	-

^a Model: Mean latitude of harvest = Intercept + Day² + Density x PDSI_South + Hunting Pressure

^b Model: Mean latitude of harvest = Intercept + Day² + Frameworks

^c Model: Mean latitude of harvest = Intercept + Day² x Frameworks

^d Dabbling ducks: American green-winged teal [*Anas crecca*], blue-winged teal [*A. discors*], gadwall [*A. strepera*], northern pintail [*A. acuta*], American wigeon [*A. americana*], and northern shoveler [*A. clypeata*].

^e Diving ducks: canvasback [*Aythya valisineria*], redhead [*A. americana*], scaup [*A. affinis* and *A. marila*]

^f Factor of Palmer Drought Severity Indices for Oklahoma and Texas (South)

^g Factor of Central Flyway active hunter estimates.

^h Factor of year, 1997-2001 and 2002-2011. Represents federal framework change for allowable season dates.

Table 1.2: Competing mallard (*Anas platyrhynchos*) harvest models (w_i = weight, k = parameters) to explain variation in Central Flyway mallard harvest distribution. Mean latitude of harvest was used as the response variable (weighted county centroid of duck harvest). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 1997-2011.

Candidate Models				
Mallard	AIC _c	Δ AIC _c	w_i	k
DAY + PRESSURE + DENSITY x PDSI _{SOUTH}	6472.3	0.0	0.996	13
DAY + FOOD _{DAKOTAS} + DENSITY x PDSI _{SOUTH}	6483.4	11.1	0.004	13
DAY + WEATHER + FOOD _{DAKOTAS}	6506.1	33.8	0.000	7
DAY + FOOD _{DAKOTAS} ^b	6513.5	41.2	0.000	5
DAY + DENSITY + FOOD _{DAKOTAS}	6513.9	41.6	0.000	7
DAY + PRESSURE ^f	6519.3	47.0	0.000	5
DAY x FRAMEWORKS ^e	6524.0	51.7	0.000	5
DAY + DENSITY x PDSI _{SOUTH} ^d	6538.0	65.7	0.000	11
DAY + WEATHER + DENSITY x PDSI _{SOUTH}	6541.0	68.7	0.000	13
DAY + WEATHER ^c	6587.0	114.7	0.000	5
DAY ^a	6597.0	124.7	0.000	3
DAY + DENSITY ^g	6600.0	127.7	0.000	5

^a Quadratic function for ordinal day from 21 Sept to 31 Jan.

^b Factor of total corn acres planted in North and South Dakota.

^c Factor of a weather severity index for North and South Dakota in Oct and Nov.

^d Factor of Palmer Drought Severity Indices for Oklahoma and Texas (South)

^e Factor of year, 1997-2001 and 2002-2011. Represents federal framework change for allowable season dates.

^f Factor of Central Flyway active hunter estimates.

^g Factor of a fall population index/ May ponds in the U.S.

Table 1.3: Competing dabbling duck (*Anas* spp.; excluding mallard [*Anas platyrhynchos*]) harvest models (w_i = weight, k = parameters) to explain variation in Central Flyway dabbling duck harvest distribution. Mean latitude of harvest was used as the response variable (weighted county centroid of duck harvest). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 1997-2011.

Candidate Models				
Dabbling Duck ^a	AIC _c	Δ AIC _c	w_i	k
DAY + FRAMEWORKS ^e	7616.8	0.0	1.000	5
DAY + PRESSURE + DENSITY	7649.2	32.4	0.000	7
DAY + PRESSURE ^f	7649.7	32.9	0.000	5
DAY + WEATHER + FOOD _{DAKOTAS}	7650.6	33.8	0.000	7
DAY + FOOD _{DAKOTAS} ^c	7652.7	35.9	0.000	5
DAY + DENSITY + FOOD _{DAKOTAS}	7655.2	38.4	0.000	7
DAY + WEATHER ^d	7657.8	41.0	0.000	5
DAY + WEATHER + DENSITY	7659.3	42.5	0.000	7
DAY ^b	7660.6	43.8	0.000	3
DAY + DENSITY ^g	7660.8	44.0	0.000	5

^a Dabbling duck: American green-winged teal [*Anas crecca*], blue-winged teal [*A. discors*], gadwall [*A. strepera*], northern pintail [*A. acuta*], American wigeon [*A. americana*], and northern shoveler [*A. clypeata*].

^b Quadratic function for ordinal day from 21 Sept to 31 Jan.

^c Factor of total corn acres planted in North and South Dakota.

^d Factor of a weather severity index for North and South Dakota in Oct and Nov.

^e Factor of year, 1997-2001 and 2002-2011. Represents federal framework change for allowable season dates.

^f Factor of Central Flyway active hunter estimates.

^g Factor of a fall population index/ May ponds in the U.S.

Table 1.4: Competing diving duck (*Aythya* spp.) harvest models (w_i = weight, k = parameters) to explain variation in Central Flyway diving duck harvest distribution. Mean latitude of harvest was used as the response variable (weighted county centroid of duck harvest). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 1997-2011.

Candidate Models				
Diving Duck ^a	AIC _c	Δ AIC _c	w_i	k
DAY x FRAMEWORKS ^f	8334.5	0.0	1.000	9
DAY + FOOD _{DAKOTAS} + DENSITY x PDSI _{SOUTH}	8359.1	24.6	0.000	13
DAY + DENSITY + FOOD _{DAKOTAS}	8359.8	25.3	0.000	7
DAY + FOOD _{DAKOTAS} ^c	8360.3	25.8	0.000	5
DAY + WEATHER + FOOD _{DAKOTAS}	8360.5	26.0	0.000	7
DAY + PRESSURE + DENSITY x PDSI _{SOUTH}	8361.5	27.0	0.000	13
DAY + DENSITY x PDSI _{SOUTH} ^e	8362.9	28.4	0.000	11
DAY + WEATHER + DENSITY x PDSI _{SOUTH}	8364.1	29.6	0.000	13
DAY + PRESSURE ^g	8364.5	30.0	0.000	5
DAY + DENSITY ^h	8367.9	33.4	0.000	5
DAY + WEATHER ^d	8368.8	34.3	0.000	5
DAY ^b	8368.9	34.4	0.000	3

^a Diving duck: canvasback [*Aythya valisineria*], redhead [*A. americana*], scaup [*A. affinis* and *A. marila*]

^b Quadratic function for ordinal day from 21 Sept to 31 Jan.

^c Factor of total corn acres planted in North and South Dakota.

^d Factor of a weather severity index for North and South Dakota in Oct and Nov.

^e Factor of Palmer Drought Severity Indices for Oklahoma and Texas (South)

^f Factor of year, 1997-2001 and 2002-2011. Represents federal framework change for allowable season dates.

^g Factor of Central Flyway active hunter estimates.

^h Factor of a fall population index/ May ponds in the U.S.

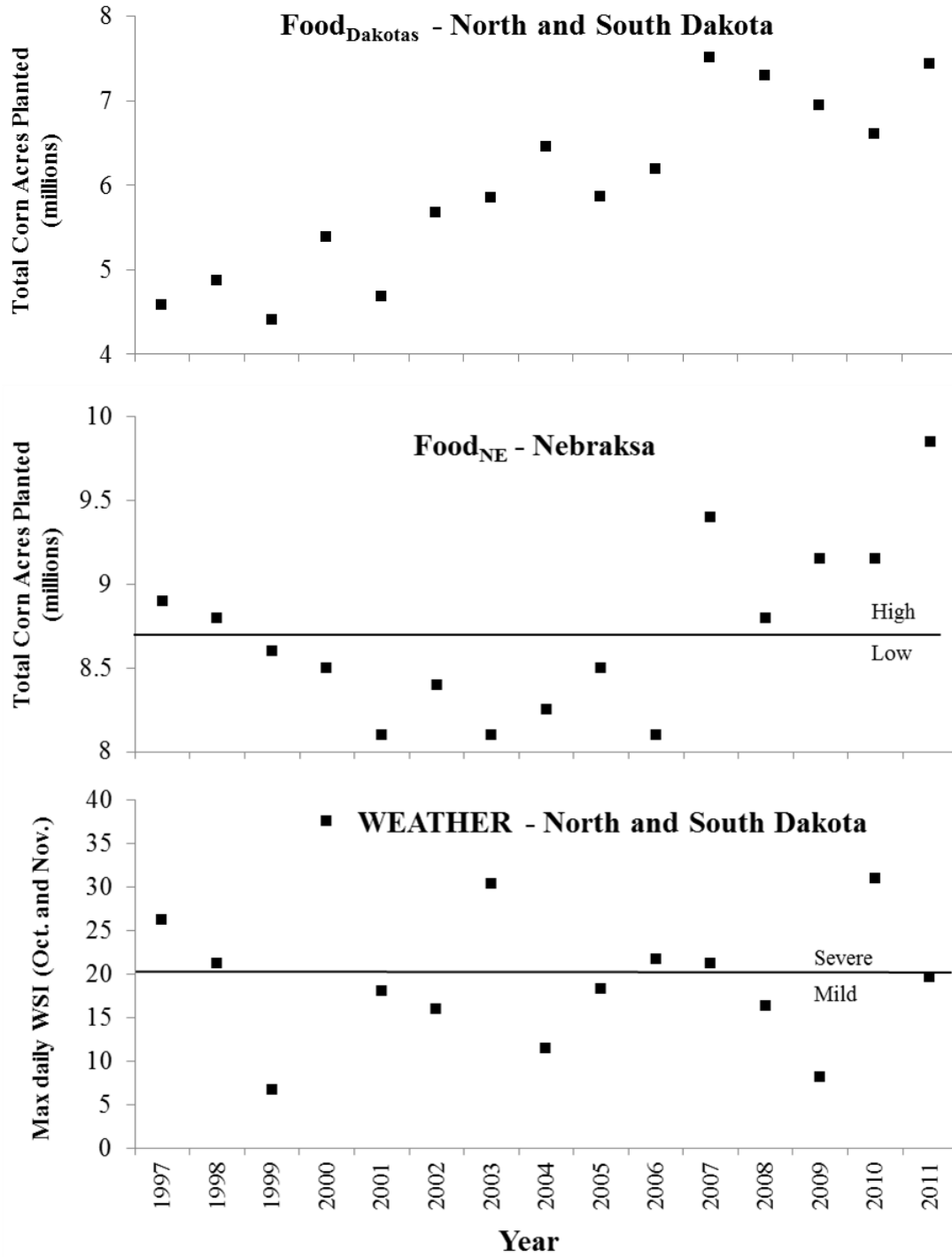


Figure 1.1: Annual estimates (1997-2011) for potential food availability (corn) in North and South Dakota and Nebraska (U.S. Dept. of Agriculture 2013), and weather severity indices (WSI) in North and South Dakota from October and November (U.S. Historical Climatology Network, Menne et al. 2013). Annual estimates were treated as factors (i.e., high or low, severe or mild).

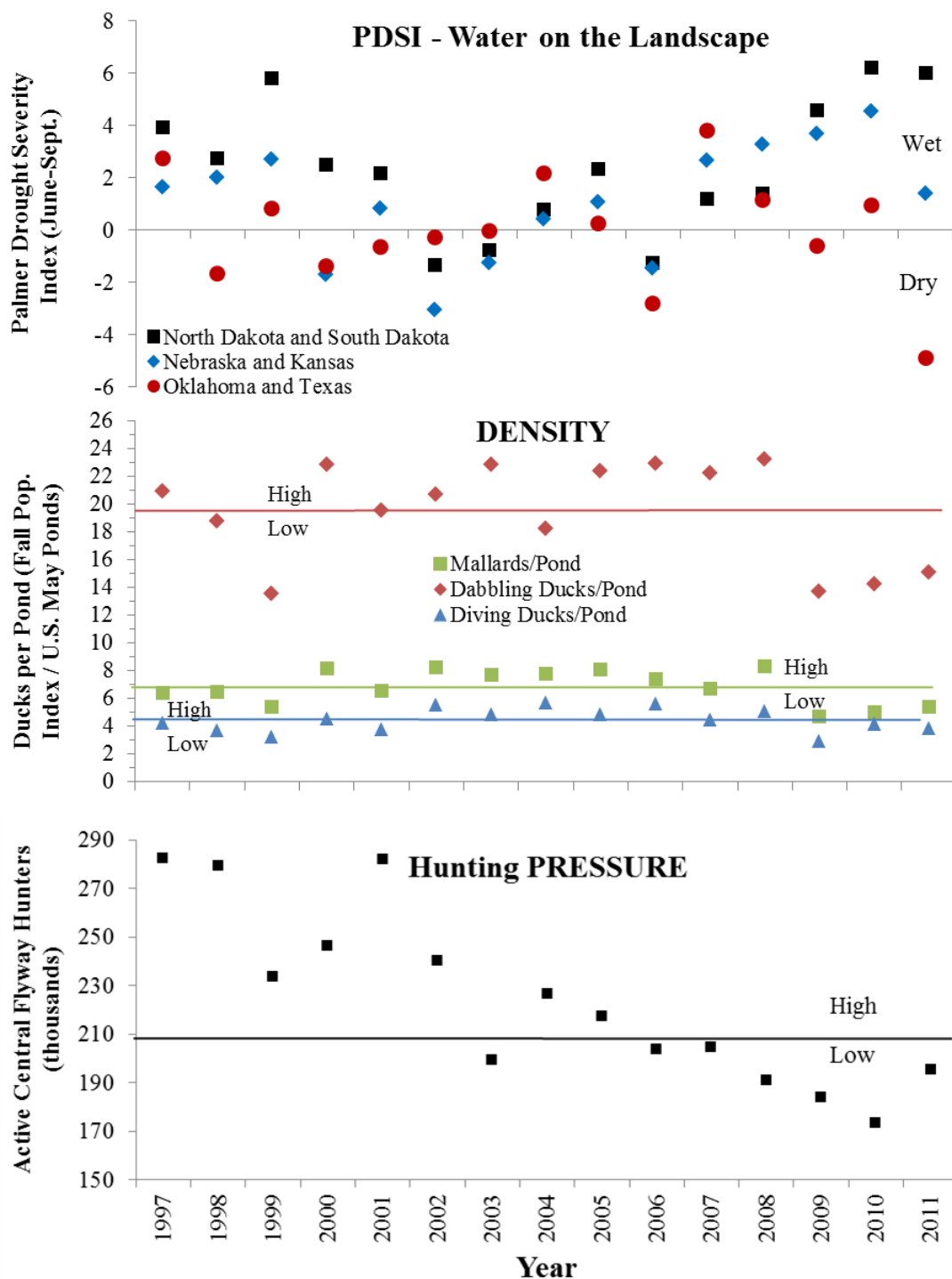


Figure 1.2: Annual estimates (1997-2011) for water on the landscape (mean Palmer Drought Severity Index; National Climate Data Center 1994), density (Fall Population Index/U.S. May Ponds), and hunting pressure (Central Flyway Harvest and Population Survey Data; Kruse et al. 2002, Kruse 2013). Annual estimates were treated as factors (i.e., high or low, wet or dry).

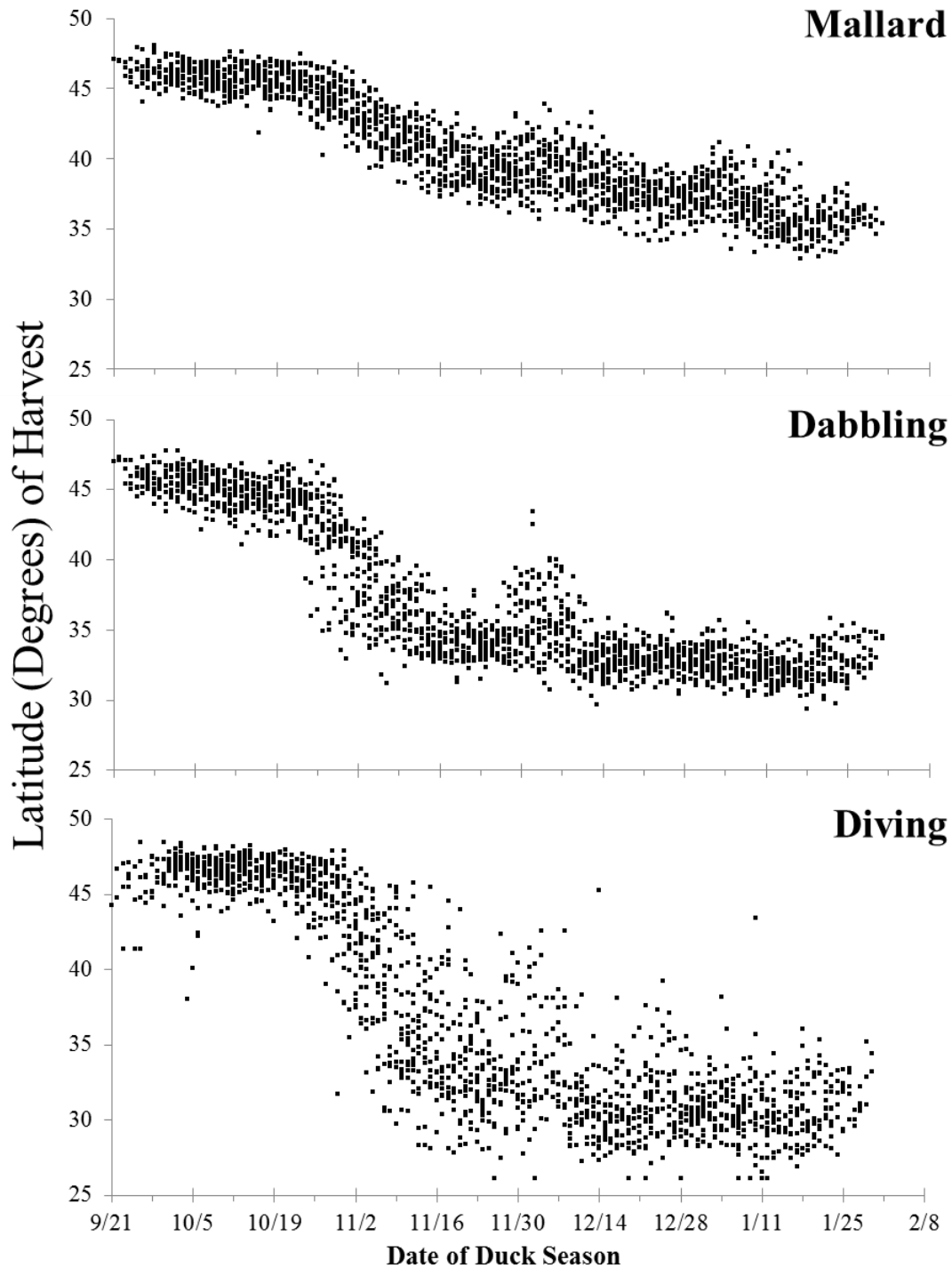


Figure 1.3: Variation in harvest distribution for mallard (*Anas platyrhynchos*), dabbling (*Anas* spp.), and diving ducks (*Aythya* spp.). Figures represent annual (1997-2011) mean latitudes of duck harvest (weighted county centroids) on a given day during the fall hunting season. Derived from U.S. Fish and Wildlife Service Parts Collection Survey data from the Central Flyway, 1997-2011.

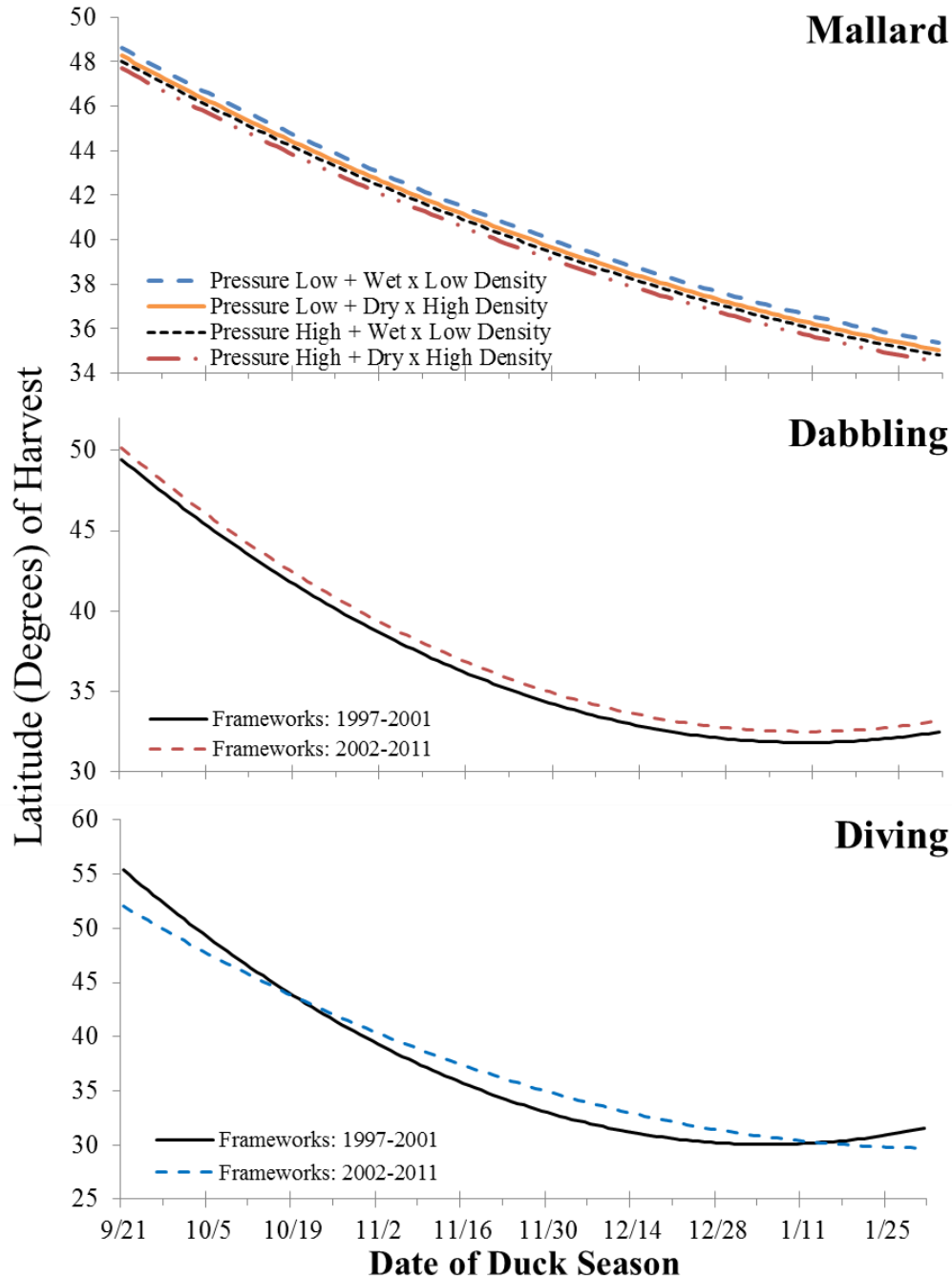


Figure 1.4: Plots of best models to explain variation in duck harvest distribution in the Central Flyway from 1997-2011 for mallard (*Anas platyrhynchos*), dabbling (*Anas* spp.), and diving ducks (*Aythya* spp.). Mallard harvest variation was best explained by hunting pressure (factor of active Central Flyway duck hunters [low < 224,000 < high]), water on the landscape (mean annual Palmer Drought Severity Indices from June-September for Oklahoma and Texas [dry ≤ 0.0 < wet]), and density (mallard fall flight index/U.S. May ponds [low < 6,800 < high]). Dabbling and diving duck harvest variation were best explained by framework changes in 2002 which allowed duck seasons to be set earlier and end later. Derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

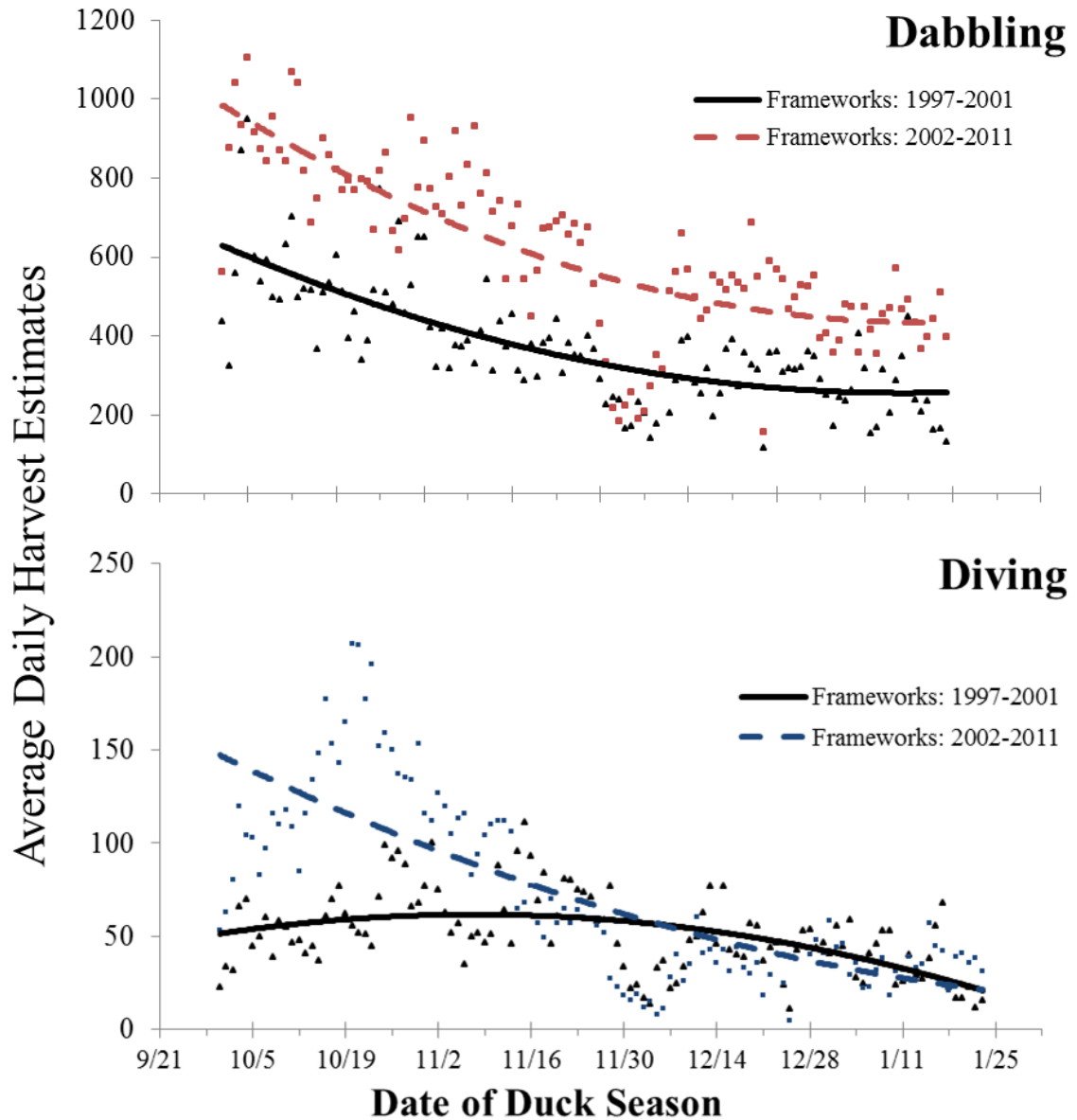


Figure 1.5: Average daily harvest estimates for both dabbling (*Anas* spp.) and diving (*Aythya* spp.) ducks for each regulatory period, 1997-2001 and 2002-2011 (when changes in frameworks allowed states to set seasons earlier and end seasons later relative to 1997-2001; season length and daily bag limits were comparable). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

CHAPTER 2 : THE EFFECTS OF HARVEST REGULATIONS ON BEHAVIORS OF DUCK HUNTERS.

Abstract

Uncertainty exists as to how duck harvest regulations may influence waterfowl hunter participation and behavior. To meet constituency demands and address hunter recruitment and retention, managers need to better understand how regulations influence hunter participation and behavior. I used the U.S. Fish and Wildlife Service's Parts Collection Survey (PCS) data to examine how harvest regulations may affect behaviors of Central Flyway duck hunters. I stratified hunters into ranked harvest groups based on seasonal harvest and identified three time periods that represented different harvest regulations. I examined seven measures of duck hunter behaviors across the time periods: days harvesting ducks, daily harvest, hunter mobility (# of counties where duck harvest occurred), mallard selectivity (% mallard [*Anas platyrhynchos*] harvest), gender selectivity (% female mallard harvest), daily female mallard harvest, and timing of harvest. Harvest regulations seemed to influence (i.e., increase or decrease) select measures of duck hunter behaviors (e.g., daily harvest, gender selectivity). Regulations also appeared to influence most duck hunters equally for the measures of behavior I examined. I provide evidence to suggest that future regulation change will impact hunter behaviors and harvest. Additionally, my data on hunter behaviors should aid managers in harvest management and hunter recruitment and retention efforts.

Introduction

Hunters exhibit numerous behaviors, and although behaviors cannot be measured, harvest metrics may be indicative of hunter behaviors. For example, biologists can readily gather harvest metric data on days harvesting ducks, daily harvest, counties visited to harvest, and timing of harvest which may then relate to hunter effort (Figure 2.1). Thus, measures of hunter behaviors (i.e., harvest metrics) can be linked back to hunter behaviors such as effort, efficiency, and movement (Figure 2.1). Differences in hunter effort, efficiency, movement, and selectivity may lend insight into differences among hunter characteristics such as skill and experience, persistence and dedication, and conservation concern (Figure 2.1), which should aid in hunter recruitment and retention strategies. For example, hunters who exhibit weak dedication should be targeted more by hunter retention messages relative to more dedicated hunters.

Responses of hunter behaviors to regulation change are of management concern. Duck harvest regulations can only indirectly affect duck harvest (Johnson and Case 2000, U.S. Fish and Wildlife Service 2001, Nichols et al. 2007), yet hunter participation and behaviors (e.g., effort) can directly affect duck harvest. Previous studies have addressed the effect of regulations on duck hunter participation (Enck et al. 1993, Pierce et al. 1996, Ringelman 1997, Miller and Vaske 2003, National Flyway Council and Wildlife Management Institute 2006). However, these studies are limited by an intuitive disconnect between preferences or satisfactions and actual behaviors (e.g., effort, efficiency, movement, selectivity; Figure 2.1). Thus, to meet constituency demands, address hunter recruitment and retention, and improve harvest management, managers need to better understand how regulations influence hunter participation and behavior.

Waterfowl managers traditionally have conducted surveys, hosted public meetings, or relied on word of mouth to obtain hunter behavior data (Johnson et al. 1993). However, these methods may contain biases which may include prestige (Atwood 1956), non-response (Pendleton 1992), and over-representation biases (Johnson et al. 1993). Additionally, traditional methods often rely on hunters to report future intentions or recollect previous events, both of which could be influenced by prestige and memory biases (Atwood 1956).

In contrast, the U.S. Fish and Wildlife Service's (USFWS) Parts Collection Survey (PCS) is a readily accessible form of data which has been under-examined with regards to measures of hunter behaviors. The PCS is an annual survey used primarily to examine waterfowl harvest (Baldassarre and Bolen 2006), but also contains data keyed to individual hunters that can be interpreted for measures of hunter behaviors (Figure 2.1). Thus, it may be advantageous to traditional survey methods because it can directly use actual harvest metrics (e.g. days harvesting ducks) to infer actual hunter behaviors (e.g., effort). Further, hunter claims of harvest are substantiated by the parts (i.e., wings) collected. The use of the PCS to examine hunter behaviors also may have an advantage over traditional methods because the data has been collected annually since 1961 (Baldassarre and Bolen 2006). Thus, the data span across changes in regulation sets, which provides an opportunity to examine behavior changes that result from regulatory changes.

Additionally, the USFWS Harvest Information Program (HIP) diary data also may contain data relevant to measures of hunter behaviors. The HIP diary is an annual survey in which hunters voluntarily report daily harvest totals (e.g., duck total), or

seasonal totals of days hunted and duck harvest. The HIP diary data may compliment the PCS data because the HIP data includes hunters who do not harvest ducks on a daily or seasonal basis (i.e., record a “0”). The PCS only includes information from harvest events.

The purpose of this study was to use harvest data within the PCS, supplemented with HIP diary data comparisons, to understand how harvest regulations affect the behaviors of duck hunters. My objectives were to: (1) characterize measures of behavior for the sample of hunters in the PCS, (2) compare measures of hunter behaviors between different regulation sets across sets of stratified hunters, and (3) compare PCS and HIP behavior results to account the absence of hunters who do not harvest ducks seasonally or daily within the PCS.

Methods

Parts Collection Survey data and analyses

Hunters sampled by the PCS were chosen randomly from hunters who participated in the HIP diary survey. Hunters sampled for the PCS must indicate they hunted waterfowl the previous year, and be willing to participate in the PCS. I obtained the PCS data from the USFWS Branch of Harvest Surveys and edited the original PCS database to include only Central Flyway records on duck harvest during regular duck seasons (U.S. Department of Interior 2012). I removed mergansers (*Mergus* spp., *Lophodytes cucullatus*) from the data set because harvest of these species often adheres to separate regulations (U.S. Department of Interior 2012).

I then divided the PCS database into 3 time periods that represented different harvest regulations or frameworks in the Central Flyway: (1) 2002-2011, with a daily bag limit of 6 ducks and a 74-day seasons representing liberal harvest regulations; (2) 1975-1984, with a 5-duck daily bag and a 60-day season representing moderate harvest regulations; and (3) 1988-1993, with a 3-duck daily bag and 39-day season representing restrictive harvest regulations (Kruse et al. 2002, Kruse 2013).

I determined three hunter characteristics (i.e., skill/experience, persistence/dedication, and conservation concern) that could be seen as affective to hunter behaviors, and thus would help with the interpretation of results (Figure 2.1). Nested in the three hunter characteristics, I examined four hunter behaviors; effort, efficiency, movement, and selectivity using seven measures of hunter behaviors; days harvesting ducks, daily harvest, hunter mobility (i.e., counties where they harvested ducks), mallard selectivity (% mallard [*Anas platyrhynchos*] harvest), gender selectivity (% female mallard harvest), daily female mallard harvest, and timing of harvest (Figure 2.1). I examined effort, efficiency, movement, and selectivity because these behaviors may be insightful for harvest management and hunter recruitment and retention strategies (Enck et al. 1993, Miller and Vaske 2003, Van Deelen and Etter 2003, Stedman et al. 2004).

To examine measures of hunter behaviors in response to regulations, I stratified hunters to account for differences in harvest between the three time periods with different harvest regulations sets (Table 2.1). To account for variation in skill/experience and persistence characteristics of hunters, I ranked all hunters in the PCS sample in ascending order by seasonal harvest. I then split the ranking into 10 groups of hunters with a

roughly equivalent sample size in each (~10% of total sample) (Table 2.1). The use of deciles for stratification resulted in minor variations in the seasonal harvest among harvest groups in the three time periods (Table 2.1). For example, harvest group 8 (~80-89% of ranked sample) was comprised of hunters who harvested 18-23 ducks seasonally in 2002-2011, 11-14 ducks seasonally in 1975-1984, and 9-11 ducks seasonally in 1988-1993 (Table 2.1). The use of ranked harvest groups allowed the same relative group of hunters to be compared across regulation sets, because the 10th harvest group represented the top-ranked 10% of hunters (by seasonal harvest) for each harvest regulation period, whereas the 1st harvest group represented the bottom-ranked 10% of hunters for each regulation period. The use of ranked harvest groups also allowed trends across hunters that varied in skill/experience and/or persistence to be examined.

I calculated individual hunter estimates for each measure of behavior, except for daily female mallard harvest where total daily bags were used and individual hunter estimates were not first calculated. I then averaged individual hunter estimates for each harvest group for each harvest regulation set. To calculate average days harvesting ducks I quantified the total number of days an individual harvested at least one duck in a given season. To calculate average daily harvest, I first estimated individual hunter average daily bag, and then averaged those across harvest groups and regulation sets. To calculate hunter mobility I examined the number of counties where harvest occurred seasonally for any individual. Hunter mobility was only examined to the county level, as this is the smallest geographical scale the PCS data contains. Additionally, I could not account for hunters who moved between states, because I first stratified the data by state to account for repetitive county numbers between states. Thus, a hunter who harvested

ducks in multiple states would be considered a different hunter for each state they harvested ducks in for this analysis.

I calculated mallard selectivity and gender selectivity similarly. For mallard selectivity, I divided an individual hunter's seasonal harvest into mallard harvest and other duck harvest. To then calculate the percent mallard harvest for the hunter, I divided the individual's mallard harvest by their entire seasonal harvest. I only examined mallard selectivity because mallard may be preferred by hunters (Gilmer et al. 1989). For mallards only, I calculated percent female harvest to examine gender selectivity. Only mallards were considered for gender selectivity analyses because harvest regulations distinguish between mallard genders, whereas harvest regulations do not distinguish between genders for other species (U.S. Department of Interior 2012). I also calculated average percent female mallard harvest for individual Central Flyway states to examine potential monochromatic (i.e., when the male and female mallard look alike due to molt) influences on gender selectivity of mallard harvest. I calculated daily female mallard harvest as the average number of female mallards in individual hunter's daily bags for each harvest group and regulation set.

Finally, I calculated the timing of harvest as the mean seasonal day of harvest for any harvest group of hunters. I also examined mode and median seasonal day of harvest for all harvest groups and regulation sets, as well as the harvest distribution over time for ranked harvest groups 1, 5, and 10 from liberal seasons (2002-2011). Seasonal day of harvest was standardized among states, where it ran consecutively from the first day of the hunting season for a state to the last day of the hunting season for the same state for each year. Seasonal day of harvest did not account for splits or zones within a state,

except in Texas when early season splits were greater than 21 days earlier than other season days; these dates were removed from analyses. I conducted an initial assessment of the dataset and removed records with apparent errors as needed (e.g., daily bags that exceeded those legally allowed, data with omitted hunter or county information).

I used SAS® software (SAS Institute 2009) for data summaries and manipulation of the PCS dataset. I calculated 95% confidence intervals for estimates to determine if differences existed among harvest groups and harvest regulation sets. I considered non-overlapping confidence intervals to indicate strong evidence for differences among hunter groups or regulation sets (Johnson 1999).

Harvest Information Program data and analyses

Hunters sampled for the HIP diary survey were randomly selected from hunters who registered with the HIP in the state they intended to hunt waterfowl in. They must have indicated they hunted waterfowl the previous year to be eligible for selection in the HIP diary survey. I obtained USFWS HIP diary data from the USFWS Branch of Harvest Surveys and edited the original HIP database to include only Central Flyway records on duck harvest during regular duck seasons (U.S. Department of Interior 2012). I used the HIP diary data to compare relevant measures of behavior with those in the PCS; days hunted versus days harvesting ducks, daily harvest, and hunter mobility (# counties where duck harvest occurred and counties hunted). I could not examine other measures of behaviors such as those related to harvest compositions as HIP diary data does not contain species-specific attributes. I only compared PCS and HIP diary data from 2002-2011 because the HIP diary data started in 1999. I did not include 1999-2001

duck seasons because regulations differed (i.e., allowable start and end dates for duck hunting season were different) between 1999-2001 and 2002-2011.

I again constructed ranked harvest groups using the same seasonal harvest breakdowns for 2002-2011 used for the PCS (Table 2.1). I added an additional harvest group, harvest group zero, to account for individuals who hunted but did not harvest ducks within the HIP data. I calculated HIP diary data estimates similar to the PCS estimates; however the interpretation of these changed because the HIP diary data contains data related to no harvest.

For PCS analyses, I assumed that hunters turned in one wing from all ducks they shot and only they themselves harvested. I also assumed that hunters accurately recorded where and when the duck was harvested, and that wings were accurately identified to species and gender. For the HIP data, I assumed hunters accurately reported the number of ducks they themselves shot, when and where the ducks were harvested, and their hunting effort.

Results

Parts Collection Survey

The PCS data provided a total of 406,875 samples of individual ducks harvested, 165,147 from liberal seasons (2002-2011), 154,911 from moderate seasons (1975-1984), and 86,817 from restrictive seasons (1988-1993). The PCS also provided a total of 37,317 seasonal bags from hunters, 10,458 from liberal seasons, 16,303 from moderate seasons, and 10,556 from restrictive seasons. There were 86,081 total daily bags from hunters, 29,659 from liberal seasons, 32,432 from moderate season, and 23,990 from

restrictive seasons. Variations in sample size for each measure of hunter behavior existed due to removal of data errors relevant to each measure of hunter behavior (e.g., daily bags that exceeded those legally allowed were removed for mean daily harvest calculations, but not for mallard selectivity calculations), or differences in how the estimates were calculated (e.g., based on seasonal bags or daily bags).

Mean days harvesting ducks ($n = 37,208$ seasonal bags), daily harvest ($n = 35,107$ seasonal bags), and counties where duck harvest occurred ($n = 37,853$ seasonal bags) across all harvest groups and regulation periods were 4.23 [95% CI: 3.01, 5.45] days harvesting ducks, 2.42 [95% CI: 2.14, 2.69] ducks per day, and 1.34 [95% CI: 1.25, 1.43] counties, respectively. Mean percent mallard harvest ($n = 37,317$ seasonal bags), percent female mallard harvest ($n = 28,441$ seasonal bags), and daily female mallard harvest ($n = 86,061$ daily bags) across all harvest groups and regulation periods were 45.8% [95% CI: 44.1, 47.5], 26.9% [95% CI: 25.3, 28.5], and 0.41 [95% CI: 0.36, 0.45], respectively. The mean seasonal day of harvest ($n = 405,574$ ducks harvested) across all harvest groups and regulation periods was 34.20 [95% CI: 32.17, 36.23] days after the start of season in a given state.

The number of days a hunter harvested ducks increased as harvest group increased for all regulation periods (Figure 2.2A). Hunters also harvested ducks on average 0.44 [95% CI: 0.02, 0.87] more days when duck seasons were restrictive (restrictive season length: 39 days) relative to moderate duck seasons (moderate season length: 60 days) (Figure 2.2A). Hunters during liberal seasons (liberal season length: 74 days) harvested ducks the most days, 0.95 [95% CI: 0.49, 1.41] more days on average than restrictive seasons and 1.39 [95% CI: 0.54, 2.24] more days on average than

moderate seasons (Figure 2.2A). The maximum difference between regulation frameworks (i.e., liberal and moderate) was a difference of 4.95 days of harvest between the liberal and moderate seasons for the top-ranked harvest group of hunters; all other harvest groups varied by less than 2.06 days of harvest between regulation periods (Figure 2.2A).

Daily harvest trends increased up to the third-ranked harvest group and then remained relatively constant as harvest group increased (Figure 2.2B). Daily harvest trends remained relative to allowable daily bag limits. Samples for years with the highest daily bag limits had the highest daily harvest across all ranked harvest groups (i.e., liberal seasons, 2002-2011) (Figure 2.2B).

Although hunter mobility (# of counties where duck harvest occurred for a hunter) increased as a hunter's harvest group increased, minor differences existed between harvest groups and regulation periods (Figure 2.2C). The average number of counties used to harvest ducks across all regulation sets for the lowest-ranked group was 1.01 [95% CI: 0.99, 1.03] counties and for the highest-ranked group was 1.85 [95% CI: 1.62, 2.08] counties. Thus, the range of counties used to harvest ducks between all sampled hunters was relatively small.

The percent of mallards in the sample (i.e., mallard selectivity) decreased slightly as harvest group increased (Figure 2.3A). However, there was considerable overlap between the ranked harvest groups and regulation periods, which indicated similar mallard selectivity among hunters.

The percent of female mallards in the sample (i.e., gender selectivity) remained constant as harvest group increased, but shifted based upon regulation period (Figure

2.3B). Hunters during years with moderate seasons were the least selective when it came to gender selectivity, followed by liberal and restrictive season hunters, respectively (Figure 2.3B). Gender selectivity varied by state. The percent of female mallards in the sample decreased south from North Dakota to Kansas, but then increased in Oklahoma and Texas (Figure 2.4). Similarly, estimates of percent female mallard harvest decreased from Montana to Wyoming and then increased in Colorado and New Mexico (Figure 2.4).

Daily female mallard harvest increased initially from the first- to the second-ranked harvest group, however the number of female mallards harvested per day per hunter remained consistent for all remaining harvest groups (Figure 2.3C). Hunters from liberal and moderate harvest regulations harvested similar numbers of female mallards per day with a mean of 0.47 [95% CI: 0.44, 0.51] and 0.48 [95% CI: 0.44, 0.52], respectively. Hunters from the restrictive harvest regulation period harvested the lowest number of female mallards, 0.26 [95% CI: 0.24, 0.27] female mallards per day.

The mean day of harvest remained relatively constant across harvest groups with slight increases as harvest group increased (Figure 2.5A). Mode day of harvest was on the first day of hunting season for all harvest groups and regulations periods except harvest groups 7-10 during liberal seasons (Figure 2.5B). Median day of harvest also was equitable across harvest groups and regulation periods (Figure 2.5C).

The distributions of harvest suggested weekends are important for harvest, because spikes occurred on weekly intervals for all harvest groups examined (Figure 2.6). Additionally, lower-ranked harvest groups (exemplified by harvest group one and five) appeared to harvest more ducks at the start of the hunting season relative to the end of the

hunting season (Figure 2.6). In contrast, the top-ranked harvest group appeared to harvest ducks more uniformly across a hunting season (Figure 2.6).

Harvest Information Program diary data comparisons

The HIP diary data provided 38,591 seasonal bags from sampled hunters for days hunting ducks, 26,685 for daily harvest, and 23,059 for hunter mobility in the Central Flyway from 2002-2011. Trends of days hunting ducks were similar between HIP and PCS as harvest group increased. Hunters from the HIP dairy sample hunted a mean of 6.79 [95% CI: 4.07, 9.50] days, and on average 2.17 [95% CI: 1.85, 2.49] more days than PCS estimates (Figure 2.7A).

Mean daily bag and hunter mobility estimates exhibited similar trends in the PCS and HIP as harvest group increased. The lowest-ranked sample for harvest group (i.e., harvest group 1) in the HIP contained ~50% bags of “no harvest”, whereas the sample for the highest-ranked harvest group (i.e., harvest group 10) contained only ~10% bags of “no harvest”. Hunters in the HIP diary sample (contained bags of zero) harvested a mean of 2.59 [95% CI: 1.89, 3.30] ducks per day, and 0.25 [95% CI: 0.15, 0.36] fewer ducks per day than hunters from the PCS sample (did not contain bags of zero) (Figure 2.7B). Hunters from the HIP diary sample hunted a mean of 1.54 [95% CI: 1.37, 1.71] counties, and 0.15 [95% CI: 0.13, 0.18] more counties than PCS sampled hunters (Figure 2.7C). For both variables, the two datasets (i.e., HIP and PCS) contrasted the most for lower-ranked hunters (Figure 2.7B-C). Means converged as harvest group increased (Figure 2.7B-C).

Discussion

As expected, as harvest regulations changed, the number of days that a hunter harvested ducks responded. However, longer seasons did not result in more days of harvest. Hunters in restrictive seasons (season length = 39 days) harvested ducks on more days than hunters in moderate seasons (season length = 60 days). One possible explanation is a larger proportion of “avid” hunters (i.e., hunters with greater persistence and dedication, Figure 2.1) participated in the restrictive season relative to other frameworks. Similarly, Barro and Manfredo (1996) found that as constraints to hunting increase, participation decreases, but high investment in the sport may maintain participation. As such, managers should be aware that characteristics (harvest and non-harvest related, Figure 2.1) and values of hunters under different regulation sets may change, which may have implications for management and conservation.

Hunters harvested ducks on roughly the same number of days regardless of season length, relative to their harvest group. Although days afield, or days harvesting ducks, remained relatively consistent in our analyses, hunters have claimed season lengths may influence their participation (Ringelman 1997). Regulations may not affect the hunter behavior of effort, as measured by the number of days harvesting ducks, because the changes between season length and days harvesting ducks were not proportional. It is possible that hunters place limitations on themselves. These conditions suggest that more days available are desirable to hunters even though they may not actually spend more days afield during longer seasons. Thus, season length may have much less impact on harvest than previously perceived.

The mean, mode, and median day of harvest (i.e., timing of harvest) were similar across harvest groups; the distributions of harvest between harvest groups were not. Harvest distributions indicated hunters who harvested more ducks tended to hunt more uniformly across a season, and those who harvested few ducks tended to concentrate efforts at the beginning of the season. Thus, hunters who harvest few or many ducks may hunt in temporally distinct patterns. As such, different management actions could be implemented at different times of the hunting season to target different hunters. For example, daily bag limits with no species restriction could be allowed during the beginning of the hunting season for hunters who harvest few ducks, which could potentially eliminate duck identification constraints (Enck et al. 1993). Lastly, harvest on weekends (Figure 2.6) would be expected to be greater than on weekdays because participation would increase due to reduced constraints (e.g., employment).

Regulations did not appear to influence mallard selectivity among hunters. All hunters in the PCS sample, regardless of harvest rank, bagged mallards at the same level (Figure 2.3A). Non-mallard species may be important to most hunters with regard to success because non-mallard species may comprise up to 60% of an individual's seasonal harvest. My data support the conclusion of previous studies which have suggested that most hunters are opportunistic and may not actively select for any one particular species (Mikula et al. 1977, Hochbaum and Walters 1984). Although mallard dominate hunter bags and may be an important species to hunters and management, managers should increase their consideration for the importance of non-mallard stocks in terms of hunter success, and subsequently hunter satisfaction.

I anticipated that estimates of percent female mallard harvest would decrease as harvest group increased regardless of harvest regulations because many managers have heard apparently avid duck hunters say “we only shoot greenheads [male mallards] in our blind” (M. Vrtiska, NGPC, personal communication). This was not the case for the average duck hunter in the Central Flyway. Regulations were able to influence percent female mallard harvest, but this change may be driven by allowable limits on female mallards in each regulation set. Monochromatic (i.e., when male and female mallards look alike due to molt) factors would be expected to reduce selectivity in harvest earlier and further north (Metz and Ankney 1991). However, a simple decrease in estimates of percent female mallard harvest with latitude was not observed. Additionally, there appeared to be considerable overlap between the estimates which suggests monochromatic influences were irrelevant with regard to gender selectivity. Thus, mistakes in identification or shooting and opportunity to harvest female mallards appear to be comparable across hunters.

Regulations did affect hunter mobility. However, similar to days harvesting ducks, the changes were not proportional to season length. Specifically, restrictive seasons (39 day seasons) resulted in more mobile hunters relative to moderate seasons (60 day seasons). Most hunters only harvested ducks in one or two counties during a season, which suggests a localized hunting effort. Thus, the availability of multiple hunting zones may be inconsequential to an individual hunter, assuming hunters who harvest ducks in two or fewer counties do not cross zone boundaries or multiple zones do not occur in the same county. Yet, zones may still play an important part in hunter satisfaction (Alessi et al. 2012) or for the distribution of harvest based on migratory

patterns (Bellrose 1980). Because the PCS is limited to county inferences, hunters may be hunting in multiple locations within a county. Thus, additional studies may be warranted to address hunter mobility on a finer scale (e.g., type of land accessed and distance traveled from home).

Regulations can influence hunter behavior (e.g., effort, efficiency, movement, and selectivity) at least to some extent as evidenced by changes in measures of hunter behavior (Figure 2.1). The PCS data showed that regulation changes exhibited predicted outcomes (e.g., lower daily harvest during more restrictive regulations). Oddly, in other cases regulations exhibited non-predictable outcomes (e.g., more days harvesting ducks under more restrictive regulations). Lastly, regulations did not have much effect on mallard selectivity. Regulations also appeared to affect all duck hunters equally. Specifically, the relative measures of hunter behaviors exhibited across harvest groups (low to high ranked harvest) remained similar, regardless of harvest regulations.

PCS versus HIP comparisons

Mean daily bag estimates were greater in the PCS and lesser for estimated counties of harvest relative to the HIP simply because the PCS does not contain data related to no harvest. However, for daily bag and hunter mobility estimates the differences between the datasets were minimal. Unsuccessful days afield remained relatively constant across harvest groups in the HIP sample. That is, regardless of how many ducks a hunter harvests seasonally, they all failed to harvest ducks on approximately two hunting trips. Managers can use this result to explain to their constituents how hunting effort affects harvest, which could be important as harvest and

expectations can still be a large component of hunter satisfaction (Stankey et al. 1973, Brunke and Hunt 2007).

Management Implications

These results should help managers anticipate how hunters will respond to changes in regulations, and subsequently how harvest may be affected. I showed that changes in regulations affect all hunters, from low-ranked to high-ranked seasonal harvest, in a similar fashion. Thus, managers should consider how future regulations (i.e., liberal, moderate, or restrictive) may influence the behaviors and harvest of hunters as a whole.

Additionally, these data may provide inferences for harvest management. For example, season length may not have as large of an impact on harvest as previously perceived. Most hunters appeared to have a pre-determined amount of effort they are willing to expend regardless of hunting season length. As such, these data help reduce the uncertainty in harvest management with regards to partial controllability (Johnson and Case 2000, U.S. Fish and Wildlife Service 2001, Nichols et al. 2007). Specifically, the models currently used to predict the estimated impact on duck harvest from increases or decreases in season length should be adjusted based on how hunters respond to changes in season length. Managers should also increase their consideration for the importance of non-mallard species when making management decisions because hunters do not rely solely on mallard for harvest success (i.e., non-mallards may comprise up to 60% of a hunter's seasonal harvest).

Lastly, variability existed among hunters with different seasonal harvests with regard to hunter persistence and dedication (Figure 2.1). Characteristics (harvest and non-harvest related) and values of hunters may change as a result of regulation change as well. Thus, managers may implement different recruitment and retention strategies to address the differences among hunters within and between regulation sets. For example, managers may implement new and/or creative regulations, such as offering limited day hunting permits to entice hunters with limited investment in duck hunting to buy a license, which under other circumstances hunters may not. Additional studies to further examine differences among hunters (e.g., hunting constraints, participation, and satisfactions) may be beneficial for hunter recruitment and retention.

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Table 2.1: Stratification of Central Flyway duck hunters into harvest groups based on seasonal harvest for three harvest regulation periods, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

Ranked Harvest Group	Number of Ducks Harvested Seasonally					
	Liberal: 2002-2011		Moderate: 1975-1984		Restrictive: 1988-1993	
	Harvest	%	Harvest	%	Harvest	%
1	1-2	11.22	1	11.08	1	10.93
2	3-4	10.98	2	10.12	2	12.01
3	5-6	11.97	3	9.56	3	11.07
4	7-8	8.75	4	7.92	4	8.28
5	9-10	9.30	5-6	12.88	5	7.43
6	11-13	8.71	7-8	9.95	6	7.73
7	14-17	8.62	9-10	10.05	7-8	9.55
8	18-23	10.18	11-14	8.60	9-11	11.55
9	24-34	10.25	15-20	10.53	12-18	11.90
10	35+	10.11	21+	9.34	19+	9.61
	Totals	100.1		100.0		100.1

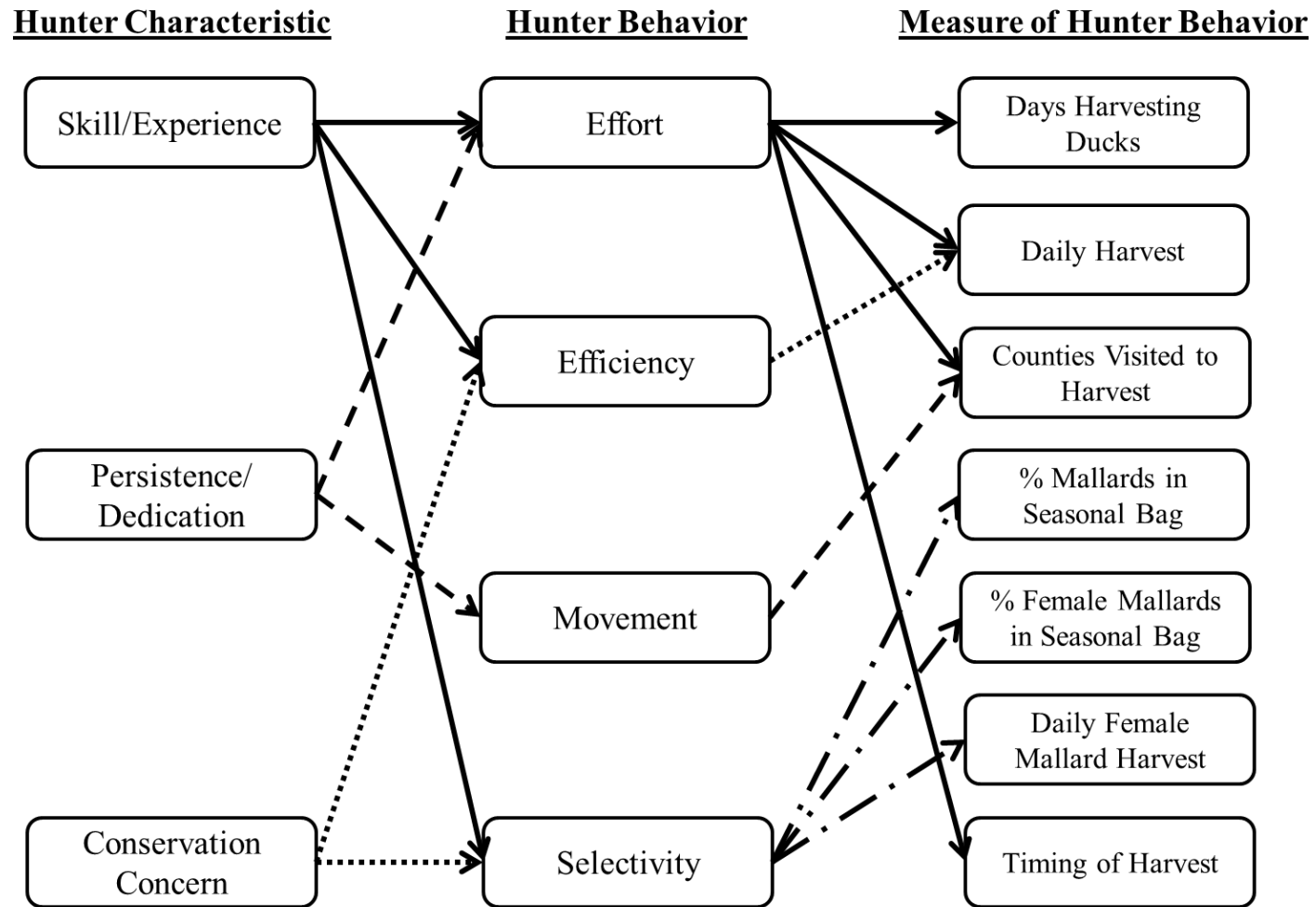


Figure 2.1: Conceptual framework for the relationships between duck hunter characteristics, behaviors, and measures of behaviors.

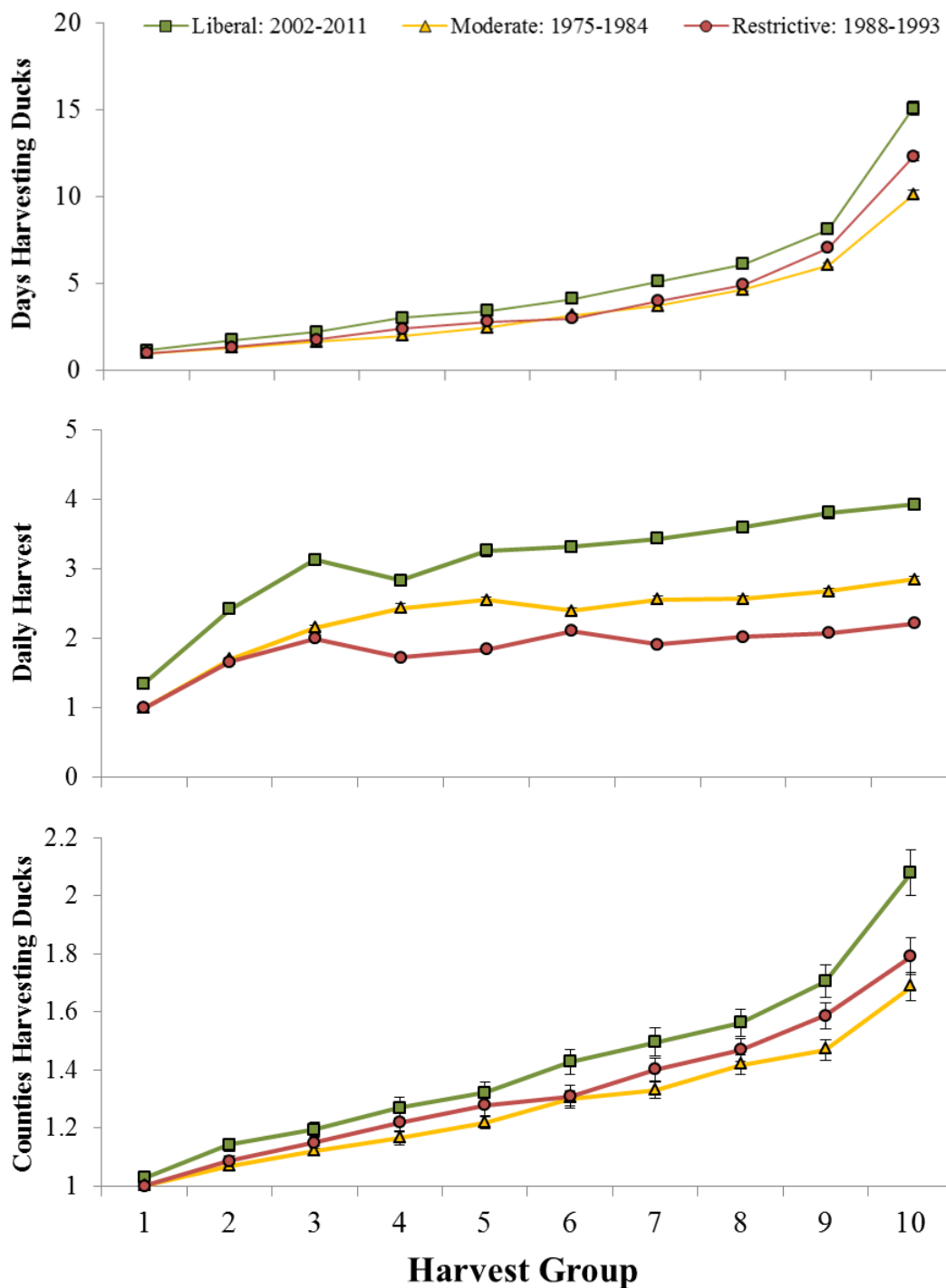


Figure 2.2: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) trends for the measures of duck hunter behaviors of (A) days harvesting duck (# of days when duck harvest occurred/hunter/season), (B) daily harvest (average daily bag/hunter/season), and (C) hunter mobility (# of counties where duck harvest occurred/hunter/season) for liberal (2002-2011), moderate (1975-1984) and restrictive (1988-1993) harvest regulations in the Central Flyway, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

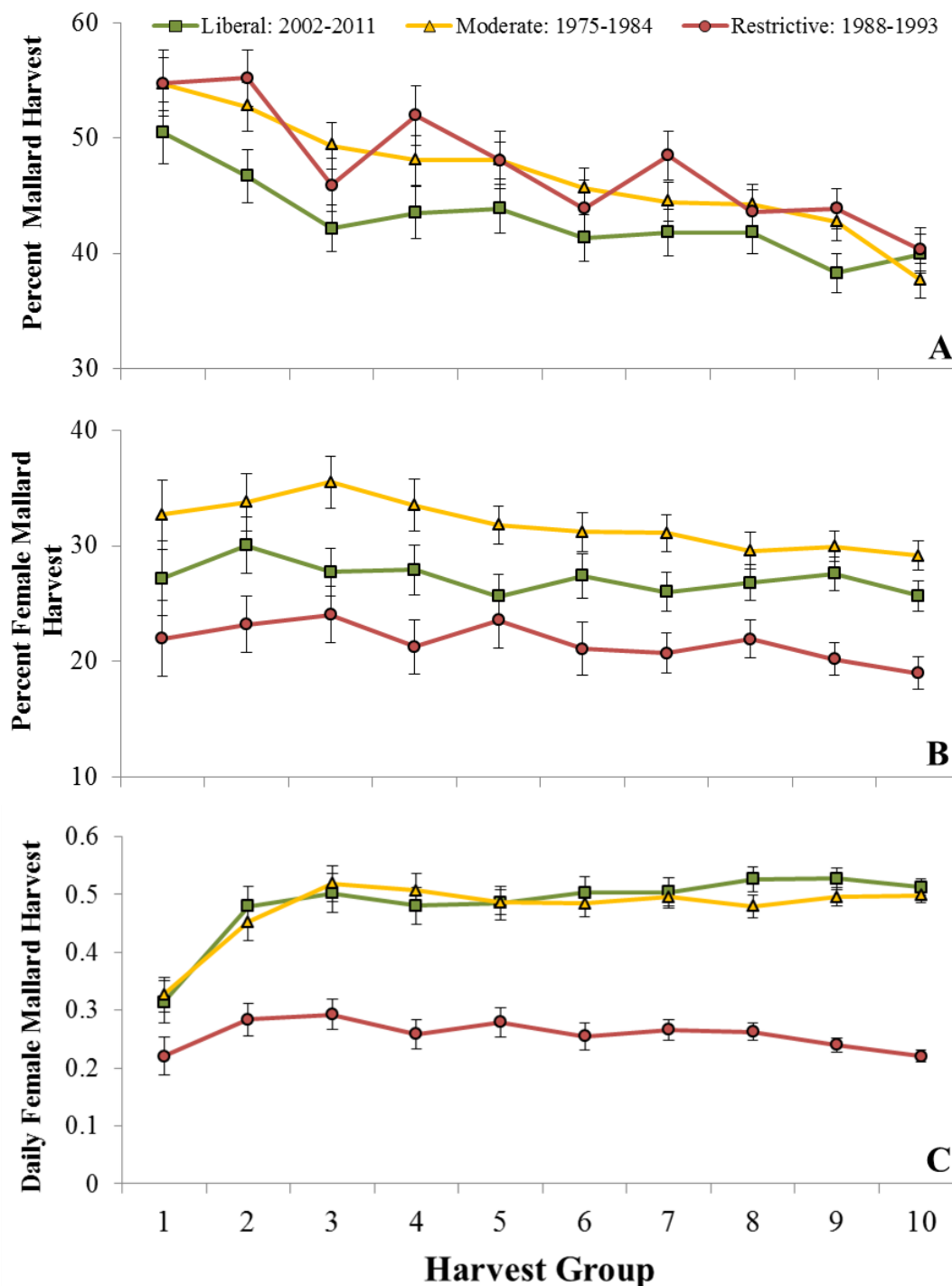


Figure 2.3: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) trends for duck hunter's (A) mallard selectivity (percent mallard harvest/hunter/season), (B) gender selectivity (percent female mallard harvest [mallards only] /hunter/season), and (C) daily female mallard harvest for liberal (2002-2011), moderate (1975-1984) and restrictive (1988-1993) harvest regulations in the Central Flyway, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

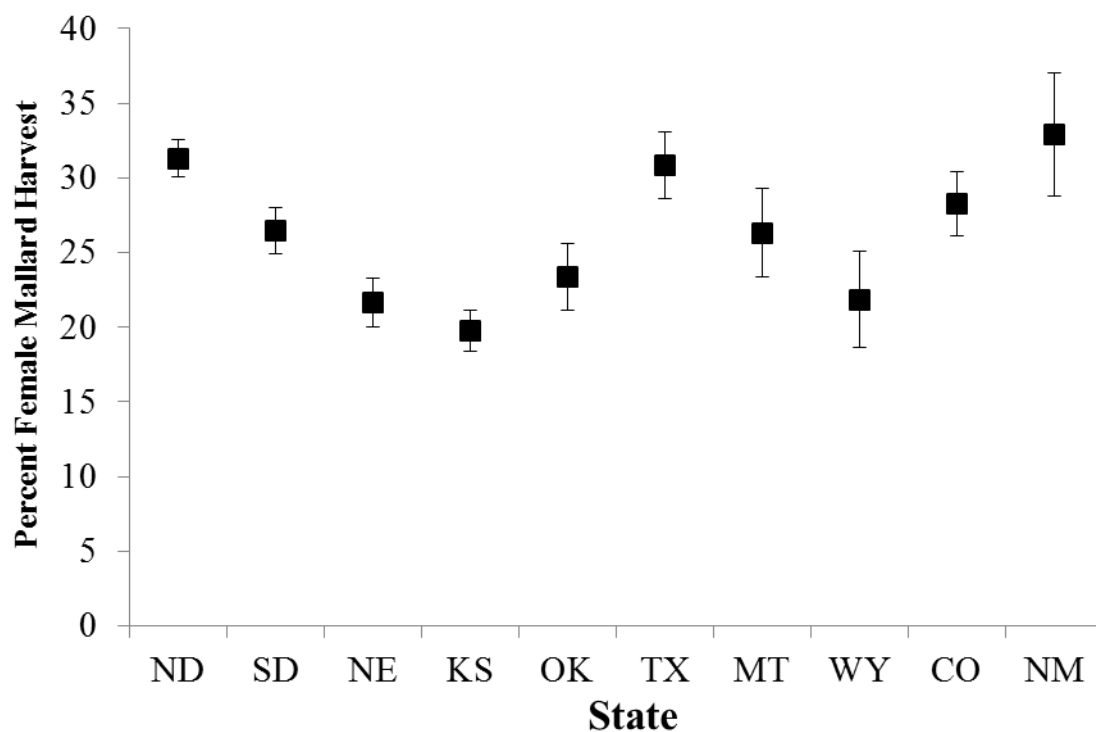


Figure 2.4: Mean and 95% confidence intervals of percent female mallard harvest/hunter/season (measure of gender selectivity) across all harvest groups of hunters (10% of sample set, stratified by seasonal harvest) for Central Flyway states. Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.

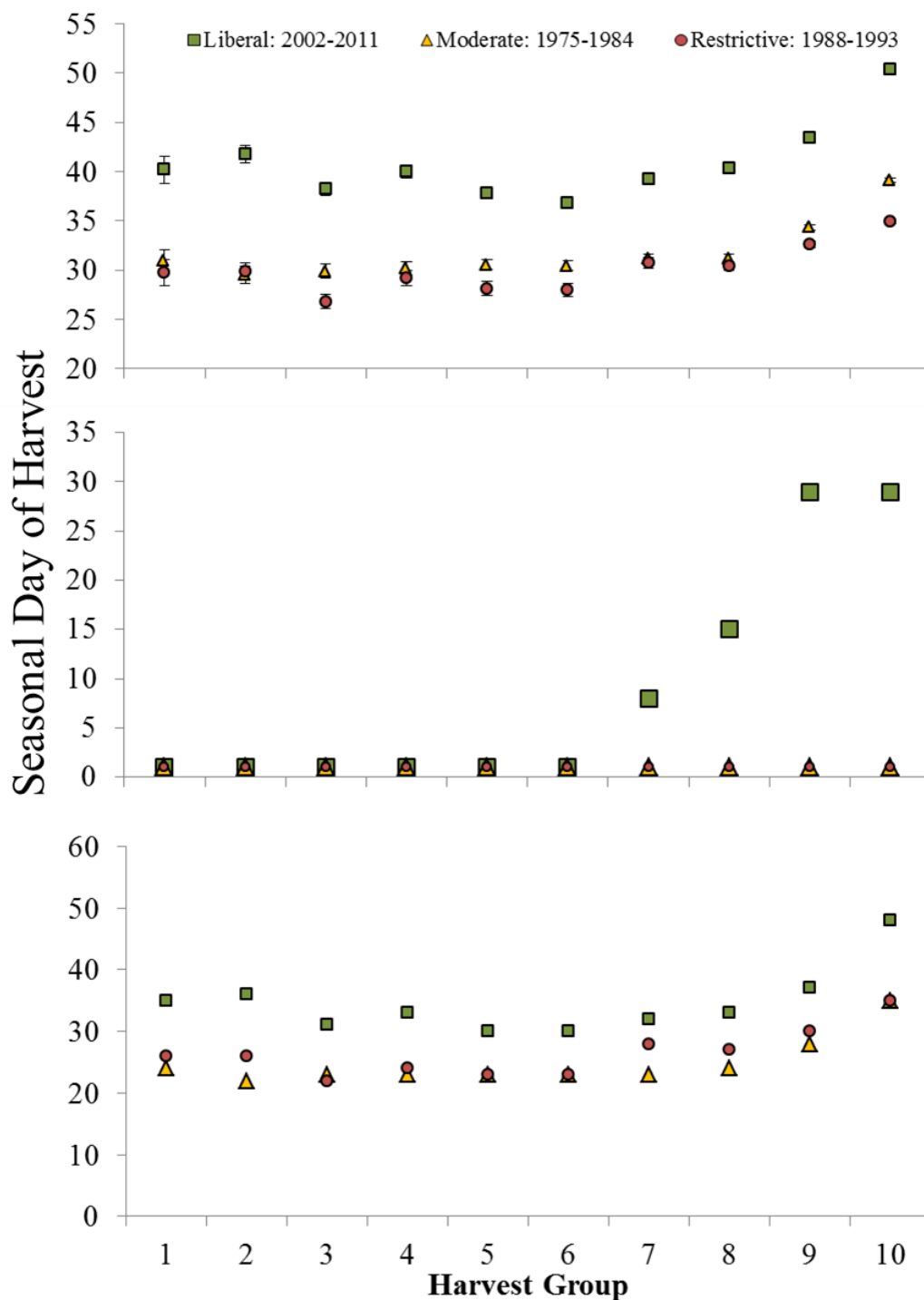


Figure 2.5: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) trends for the measure of duck hunter behavior of timing of harvest (standardized); (A) mean seasonal day of harvest with 95% confidence intervals, (B) mode seasonal day of harvest, and (C) median seasonal day of harvest for liberal (2002-2011), moderate (1975-1984) and restrictive (1988-1993) harvest regulations in the Central Flyway, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

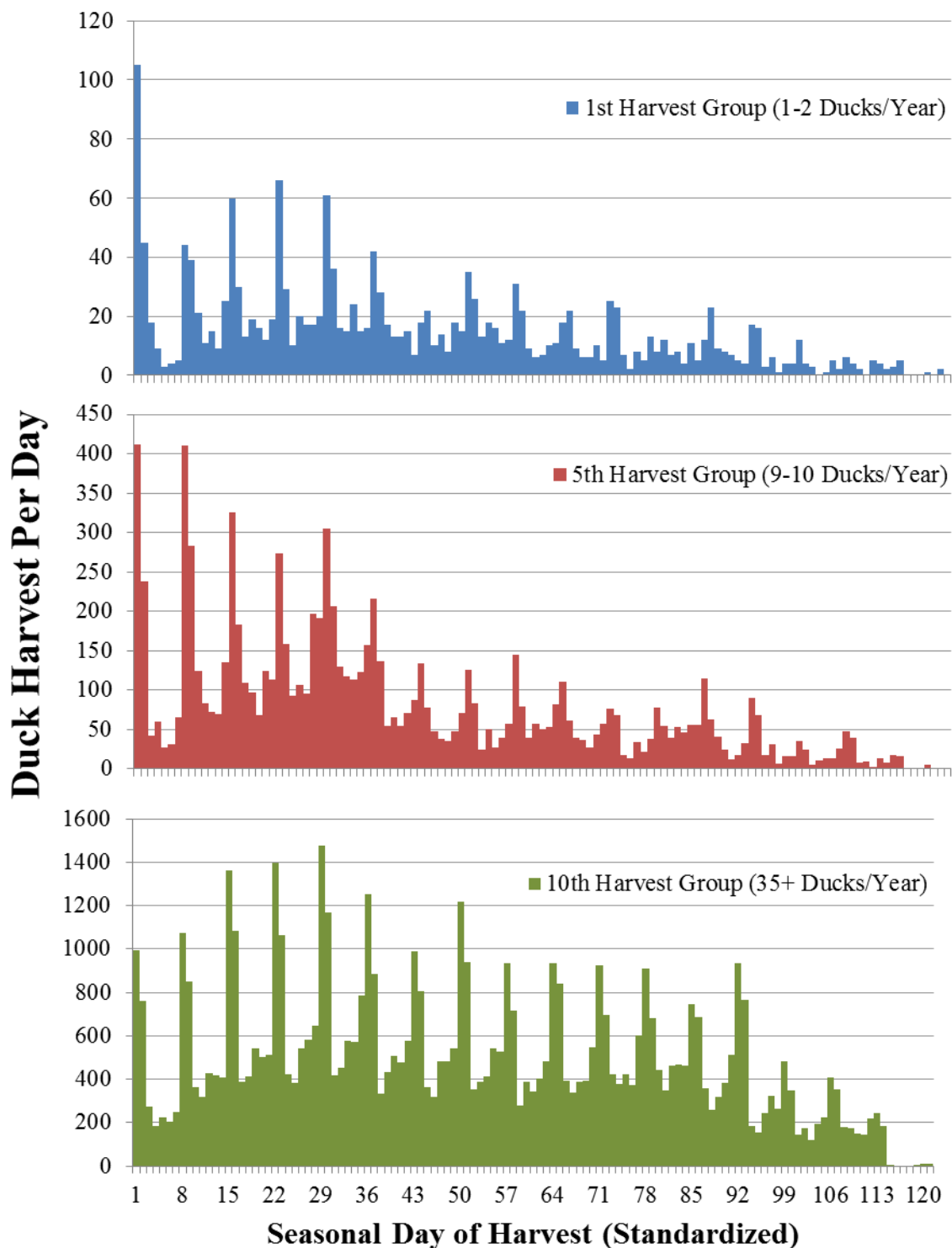


Figure 2.6: Duck harvest distribution for Central Flyway hunters stratified into harvest groups 1 (1-2 ducks/hunter/year), 5 (9-10 ducks/hunter/year), and 10 (35+ ducks/hunter/year) across hunting seasons (standardized for all states) during a liberal regulation period (2002-2011), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

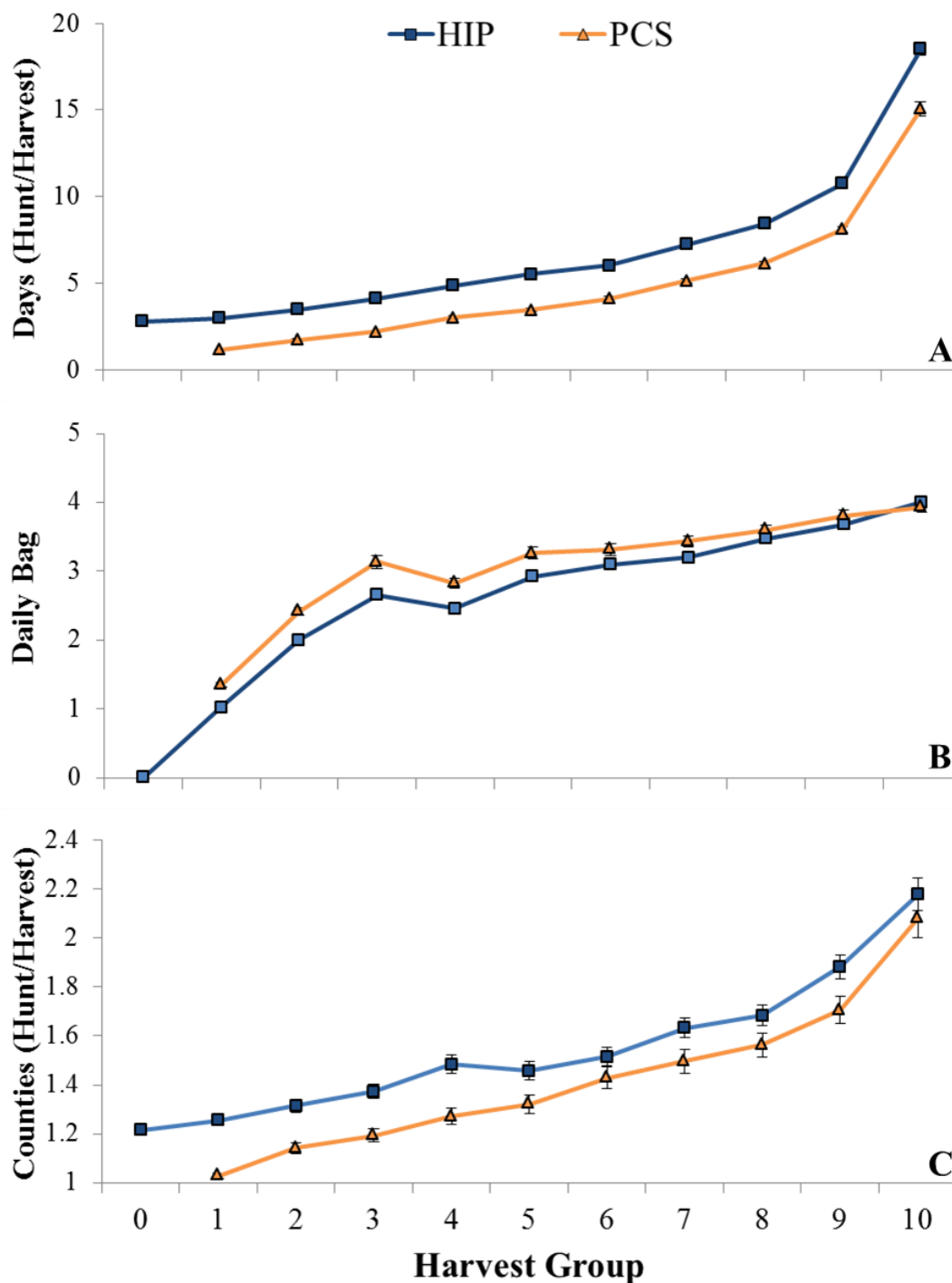


Figure 2.7: U.S. Fish and Wildlife Service Harvest Information Program (HIP) and Parts Collection Survey (PCS) data comparisons of harvest group (10% of each regulation period sample, stratified by seasonal harvest; additional 0 harvest group added for non-harvesting HIP hunters) estimates for the measures of duck hunter behaviors of (A) days hunted (HIP) versus days when duck harvest occurred (PCS), (B) daily harvest (average daily bag), and (C) hunter mobility (# of counties hunted [HIP] or # of counties where harvest occurred [PCS]), Central Flyway 2002-2011.

CHAPTER 3 : CO-OCCURRENCE OF DUCK SPECIES IN HUNTER DAILY BAGS.

Abstract

Duck species that occupy the same areas temporally and spatially during fall migration should, all else equal, be exposed to similar harvest pressures. However, managers lack information regarding species relationships in terms of harvest. As multi-stock harvest management (i.e., regulatory structure based on multiple duck species) gains support among waterfowl managers, a better understanding of these relationships is needed. I used U.S. Fish and Wildlife Service's Parts Collection Survey data from 2002-2011 to develop a matrix delineating relationships among duck species harvested in the Central Flyway. The matrix was seeded with conditional probabilities of co-occurrence in a hunter's bag (the probability that species B was in a hunter bag, given that species A was in the same bag). I then performed what-if scenarios using this matrix to demonstrate how managers may be able to predict the effects regulatory changes may have on harvest. For example, the probability a hunter harvested a pintail (*Anas acuta*) given that same hunter also harvested a mallard (*A. platyrhynchos*) on the same day is 0.078. Thus, managers may be able to predict how hypothetical bag limit reductions for mallards may impact the harvest of pintails. I used 2011 Central Flyway harvest estimates and probabilities of co-occurrence to predict how harvest could spread to co-occurring species under 11 scenarios of species-specific regulation change. For example, my model predicted that a regulation change that reduced daily mallard limits from 5 to 3 ducks could result in approximately 50,700 fewer mallards and 4,800 additional pintails being harvested, if harvest remained constant. Traditionally, managers have focused on

single stock assessments when considering regulatory changes, but harvest regulation changes have the potential to affect multiple duck stocks. Examination of the relationships among duck species during harvest provides critical insight for the development of appropriate regulations for multi-stock management because duck stocks appear not to be independent with regards to harvest.

Introduction

Mid-continent mallards (*Anas platyrhynchos*) have traditionally been a reliable indicator for the population statuses of other species (Johnson et al. 2002). However, some duck stocks (i.e., species and genders) have not been effectively managed using mallard population statuses as a surrogate for their own (Johnson et al. 2002).

Additionally, multiple duck species often occupy the same areas temporally and spatially during many parts of the annual life cycle, including those engaged in fall migration. As such, multiple duck species may be exposed to similar harvest pressures (Johnson and Moore 1996). Consequently, multi-stock management (i.e., regulatory structure based on multiple duck species) is gaining support among waterfowl managers.

Multi-stock management may rely heavily on the successful creation of duck guilds (i.e., groupings of ducks), which may attempt to maximize the long-term harvest utility of species within the guild (Johnson et al. 2002). Biologists have assessed duck species interactions with regard to community dynamics and migration co-occurrence (Nudds 1983; Dubowy 1988; Bethke 1993; Webb et al. 2010), but, few data exist with regard to harvest and species relationships (Gammonley et al. 2010). As such, knowledge of the relationships between duck species with regards to harvest is crucial to successful guild creation, and subsequently multi-stock management.

Managers have traditionally focused on single stock assessments when considering management change. However, regulation changes probably affect multiple duck species due to the aggregate nature of duck harvest. Thus, knowledge that pertains to how regulation changes for one species affect other species is needed. For example, if regulations limit the effort (i.e., harvest) hunters expend on one duck species then

managers need to anticipate where that hunter effort would be redistributed, assuming effort would remain constant.

Because duck stocks may not be independent with regards to harvest, examination of the relationships among duck species may provide better insight for the development of appropriate regulations for multi-stock management. Co-occurrence of duck species also may help managers consider the potential impact of regulatory change on multiple duck species. Thus, for the purposes of this study, I examined species co-occurrence in aggregate daily bags of hunters in the Central Flyway. My objectives were to: (1) document co-occurrence between pairs of duck species with regard to harvest, (2) develop models to predict how species-specific regulation change may affect both target and non-targeted species, and (3) provide relevant management implications based upon the relationships found.

Methods

I obtained U.S. Fish and Wildlife Service's (USFWS) Parts Collection Survey (PCS) data from the USFWS Branch of Harvest Surveys, and selected only Central Flyway PCS data from the 2002-2011 regular duck seasons (U.S. Department of Interior 2012). This period provided a relatively consistent aggregate daily bag regulation set, a biologically and managerially consistent area of inference, and a relevant time period inference. I removed mergansers (*Mergus* spp., *Lophodytes cucullatus*) from the data set as harvest of these species often abides by a separate regulation set (U.S. Department of Interior 2012). To examine daily bags from individual hunters, I quantified which ducks a hunter harvested for any given day on which they harvested at least one duck. I

conducted an initial assessment of the dataset and removed records with apparent errors (e.g., daily bags that exceeded those legally allowed), and used SAS® software (SAS Institute 2009) to manipulate and collate the database.

Although most species harvested can be reliably speciated by biologists from a wing sample (Carney 1992), blue-winged teal (*A. discors*) and cinnamon teal (*A. cyanoptera*) cannot be speciated based upon a wing alone. The PCS combines the two species into a blue-winged/cinnamon teal group (BCTE). However, given the low prevalence of cinnamon teal in the Central Flyway (Bellrose 1980) I simply referred to the BCTE group as blue-winged teal (BWTE). I also combined greater scaup (*Aythya marila*) and lesser scaup (*A. affinis*) harvest into one category (SCAUP) given hunting regulations do not specify separate regulations (U.S. Department of Interior 2012).

I examined 12 species of ducks commonly harvested in the Central Flyway: mallard (MALL), American green-winged teal (*A. crecca*, AGWT, hereafter green-winged teal), blue-winged teal (BWTE), American wigeon (*A. americana*, AMWI, hereafter wigeon), gadwall (*A. strepera*, GADW), northern shoveler (*A. clypeata*, NSHO, hereafter shoveler), northern pintail (*A. acuta*, NOPI, hereafter pintail), wood duck (*Aix sponsa*, WODU), redhead (*A. americana*, REDH), canvasback (*A. valisineria*, CANV), scaup (SCAUP), and ring-necked duck (*A. collaris*, RNDU). I combined all other ducks that were harvested in the sampling period (American black duck [*A. rubripes*], Mexican duck [*A. diazi*], Mexican-black duck hybrid, miscellaneous hybrids, Eurasian wigeon [*A. penelope*], mottled duck [*A. fulvigula*], domestic duck [*A. platyrhynchos domesticus*], Muscovy duck [*Cairina moschata*], common goldeneye [*Bucephala clangula*], Barrow's goldeneye [*B. islandica*], bufflehead [*B. albeola*], long-tailed duck [*Clangula hyemalis*],

black scoter [*Melanitta nigra*], surf scoter [*M. perspicillata*], white-winged scoter [*M. fusca*], and ruddy duck [*Oxyura jamaicensis*]) into one group (OTHER). I also examined mallard harvest at the gender level.

I followed the same assumptions made when the PCS is used for annual harvest estimates (Martin and Carney 1977). I assumed that (1) hunters turned in one wing for each duck that they harvested, (2) all reported ducks were harvested by only the PCS sampled hunter, and (3) hunters accurately recorded what day they harvested their ducks.

Co-occurrence in the daily bag

To examine co-occurrence of species, I defined the conditional probability of co-occurrence as the probability that species B was in a hunter's daily bag, given species A was in the same daily bag, $P(B|A)$. I calculated $P(B|A)$ as the number of daily bags in which species B was present given species A was also present, divided by the total number of bags in which species A was present. I repeated this process for all species combinations. Note that the $P(B|A)$ was not equal to the $P(A|B)$ by definition, because the denominators to calculate P were different.

To calculate the probability of harvesting two ducks of the same species, $P(A|A)$, I documented the frequency of bags in which species A was found at least twice, and I divided that quantity by total number of bags in which species A occurred. Finally, I calculated the probability of harvesting no other species other than species A in a single bag. I documented the number of daily bags in which only species A was harvested, and I divided that quantity by the total number of bags in which species A occurred.

Predicting effects of species-specific bag limit changes

Harvest Reduction Model.— I created a model (harvest reduction model) that allows managers to make predictions of how species-specific regulation changes may affect both target and non-targeted species. I developed 11 hypothetical, biologically-realistic scenarios where I subjectively selected a species of interest and created a new, smaller daily bag limit [l] (e.g., reducing daily limit from two ducks to one duck). I then determined the proportion of total bags for a given species [N_B] that contained b number of ducks ($b = 1, 2, 3, 4, 5, 6$), derived from 2002-2011 PCS data. I obtained an estimate of harvest [H] under a known regulatory limit for the target species (e.g., pintail harvest in 2011 under a two pintail daily limit) from the Central Flyway harvest and population survey book (Kruse 2013). I multiplied the proportion of total bags [N_B] (for a specific number of ducks of a specific-species harvested by a hunter in one day) by the total harvest [H] to get the total ducks harvested for a bag size of b [h_b] (e.g., the number of ducks harvested with either one duck in the daily bag or two ducks in the daily bag). Finally, I calculated the harvest reduction from a daily bag limit change [R_H] by summing the total duck harvest for a species-specific bag size b , minus the hypothetical limit [l] divided by the bag size of b multiplied by total ducks harvested for a bag size of b , for all bag sizes larger than the hypothetical limit (Appendix 3.A).

$$R_H = \sum_{b=l+1}^n h_b - [(l/b) \times h_b]$$

where:

b = species-specific bag size taken by a hunter in one day (e.g., 1-6).

n = maximum limit for target species.

I assumed hunters who had previously harvested over the proposed new limit would harvest the maximum for the new daily bag limit. Thus, duck harvest would be reduced by these “extra” ducks. For example, if a limit on gadwall was reduced from six to three, I assumed that hunters who harvested four, five, and six gadwall in a daily bag would, under new restrictions, harvest only three gadwall. Thus, there would be a reduction in harvest of one duck by a hunter who had shot four gadwall, two ducks by hunters who shot five, and three ducks by those who shot six gadwall in the database.

Harvest Redistribution Model.— I used the information from the harvest reduction model to parameterize another model (harvest redistribution model) to predict where the “extra” ducks may be redistributed through the harvest of non-target species [H_N]. The predicted reduction in harvest from previous harvest reduction model can be viewed as hunter effort. If hunter effort is assumed to remain constant, then harvest would likely be redistributed to duck species commonly harvested with the target species. Thus, I multiplied the predicted harvest reduction from [R_H] by the relative probability of a non-target species [B] being harvested given the presence of the target species [A] in the bag, divided by the probability of harvesting all other non-target species [B] given the target species (i.e., examining across the row for a target species in the conditional probability matrix) (Appendix 3.B).

$$H_N = R_H \times \frac{P(B|A)}{\sum_{i=1}^n P(B_i|A)}$$

where:

n = total number of non-target species.

I used pooled probabilities for mallards for the calculation of harvest redistribution as I did not consider mallard genders separately. However, because regulations distinguish

between mallard genders (U.S. Department of Interior 2012), harvest redistribution could be calculated for each gender if necessary. In such a case, the “any-mallard” probability should be removed from the calculation, and replaced with gender-specific measures. The $P(A|A)$ for a given hypothetical scenario and species (e.g., $P(\text{NOPI}|\text{NOPI})$, pintail scenario) were not included in the calculations for harvest redistribution because that species’ harvest change (i.e., harvest reduction) was accounted for in the harvest reduction model.

Results

Co-occurrence in the daily bag

The PCS database provided 51,154 total hunter daily bags in the Central Flyway from 2002-2011. Male mallards (48.88%), gadwall (29.76%), female mallards (23.80%), and green-winged teal (19.92%) were found in the most daily bags (Figure 3.1). Wood ducks (5.13%), scaup (4.58%), other ducks (4.56%), and canvasbacks (2.00%) were found in the fewest daily bags (Figure 3.1). The mean probability of co-occurrence between any species pair was 0.1466 [95% CI: 0.1326, 0.1606]. Male and female mallard were most likely to be harvested together ($P = 0.6468$), whereas canvasback and wood duck were least likely to be harvested together ($P = 0.0069$) (Table 3.1). Mallard and male mallard were most likely harvested alone ($P = 0.1888$ and 0.1605 , respectively) (Table 3.1). Whereas, blue-winged teal were least likely to be harvested without another species in the bag ($P = 0.0725$) (Table 3.1).

Hunters were more likely to harvest either two dabbling duck ($\bar{P} = 0.1988$, 95% CI: 0.1711, 0.2266) or two diving ducks ($\bar{P} = 0.1270$, 95% CI: 0.0917, 0.1624) in the

same daily bag. Contrastingly, the probability a hunter harvested a dabbling duck and diving duck in the same daily bag was smaller ($\bar{P} = 0.1013$, 95% CI: 0.0995, 0.1031). Hunters also were more likely to harvest two ducks of the same species (and gender in the case of mallards) within a daily bag ($\bar{P} = 0.3150$, 95% CI: 0.2421, 0.3879) than two ducks of different species ($\bar{P} = 0.1343$, 95% CI: 0.1195, 0.1486).

Predicting effects of species-specific bag limit changes

For all species examined, the distribution of species-specific bag sizes was: one duck: 0.6573 [95% CI: 0.5871, 0.7275], two ducks: 0.2273 [95% CI: 0.1946, 0.2600], three ducks: 0.0822 [95% CI: 0.0608, 0.1036], four ducks: 0.0429 [95% CI: 0.0251, 0.0607], five ducks: 0.0281 [95% CI: 0.0013, 0.0548], and six ducks: 0.0055 [95% CI: 0.0027, 0.0083], respectively (Table 3.2). As such, less than 8% of hunter daily bags contained more than three ducks of any one species.

Eight out of 11 limit reduction scenarios (daily bag limit reductions of 40%-66%) resulted in harvest reductions of less than eight percent (Table 3.2). Only redhead, scaup, and wood duck harvest were predicted to decrease by greater than ten percent under hypothetical bag limit reductions. For the pintail scenario, my model predicted a 6% (10,702 ducks) reduction in pintail harvest, if the daily bag was reduced from two pintails to one pintail (Table 3.2). The harvest redistribution model for the pintail scenario predicted wigeon harvest to increase the most (0.77% or 1,268 extra ducks), and other duck harvest to increase the least (0.23% or 204 extra ducks) (Table 3.3). For the redhead scenario, when redhead daily bag limits were hypothetically reduced from two redheads to one redhead, my model predicted a 14% (17,709 ducks) reduction in redhead

harvest (Table 3.2). The harvest redistribution model for the redhead scenario predicted scaup harvest would increase the most (2.57% or 1,210 extra ducks), and wood duck harvest the least (0.38% or 172 extra birds) (Table 3.3).

Discussion

The segregation of harvest between dabbling and diving ducks seems intuitive, however this may be one of the first studies that quantifies this relationship. Diving ducks are likely to be harvested together because their migration chronology, corridors, and habitat use is similar in the Central Flyway (Bellrose 1980). Additionally, hunters may use different strategies to hunt diving duck species than dabbling ducks (e.g., hunting diving ducks in large open bodies of water and hunting dabbling ducks in shallow marshes).

Daily bag limit changes may affect the harvest reductions of diving ducks more relative to dabbling ducks due to the relative abundance of species at any given hunting location (e.g., 7 dabbling duck species vs. 4 diving duck species with regard to species used in this study; Kruse 2013). Diving ducks also may be more influenced by daily bag limit changes because bag limit changes have greater effect on harvest when daily bag limits are low (Martin and Carney 1977). However, pintails also were bounded by low daily bags limits during the same sampling period (Kruse 2013), but daily bag limit reductions were not predicted to affect the harvest reduction of pintails to the same extent. Overall, my results provide a basis to consider the harvest management of diving and dabbling duck as more distinct entities. Thus, management actions could be

modified to account for the segregation between the guilds both in terms of species and hunter interactions.

Hunters were more likely to harvest two ducks of the same species within a daily bag relative to harvesting two different species. Truly aggregate or mixed bags of ducks, ones which there are no repeat of species, are far less common than bags that contain similar species, which could be important for future management decisions. For example, severe reductions in species-specific daily limits (i.e., 1 duck limit for any species) may result in reduced harvest for hunters because they may not be legally allowed to harvest multiples of the same species. Such reduction in success could reduce satisfaction (Stankey et al. 1973) and subsequently retention (Case 2004).

Predictions related to how species-specific limit liberalizations (e.g., increasing a two duck per day limit to four duck per day limit) may affect the harvest of non-target species may be possible using these data. For example, a limit increase on redhead could result in harvest reductions for species harvested with redhead (e.g., scaup and canvasback). However, managers should exercise caution as assumptions related to harvest redistribution may be violated. Specifically, effort may increase (instead of remain constant) on diving ducks if redhead limits are increased. Consequently, non-target species harvest may actually increase (e.g., scaup and canvasback).

Regulatory Alternatives

Given the probability that a hunter would harvest more than three ducks of any one species in a single daily bag was low, regulatory alternatives may be possible. For example, managers may be able to implement a simple fixed (i.e., a fixed limit of an n

number of ducks) daily bag limit with no species restrictions because I show that the “effective” daily bag limit for any one species could be considered three (less than 8% of daily bags contained more than three ducks of any one species). Although actual daily bag limits would increase for certain species (e.g., redheads and pintails), it may not affect flyway-wide harvest based on the “effective” daily bag limit. A simple fixed daily limit, however, lacks the ability to differentially manipulate duck harvest for multiple species (Mikula et al. 1972). Thus, a simple fixed daily limit may not be suitable under all conditions. Yet, uniform application of a regulatory system may not be necessary. For example, hunters in Texas harvest an average of 52,667 pintails annually, whereas hunters in Wyoming only harvest an estimated 470 pintails annually (Kruse 2013). Hunters in Wyoming also are noticeably less likely to achieve a two pintail limit relative to Texas hunters (Appendix 3.C). In such a case, it seems unwarranted to impose a two pintail limit uniformly across these two states.

Multi-stock management may rely heavily on the successful creation of duck guilds. The Hunter’s Choice experiment in the Central Flyway employed ducks guilds which allowed hunters to select between a single female mallard, pintail, canvasback, or mottled duck for a hunter’s choice daily bag (Gammonley et al. 2010). The intention of the experiment was to reduce the harvest of female mallards, pintails, canvasbacks, and mottled ducks by buffering (i.e. reduce the harvest of all other duck stocks in an aggregate) their harvest with each other, expecting the more common stocks to provide the greatest buffering effects (Gammonley et al. 2010). However, based on my co-occurrence data, other combinations of ducks may have more effectively achieved this goal (Appendix 3.D). As such, my data on co-occurrence between duck species may be

beneficial and instructive to managers creating duck guilds under potential multi-stock management regulations. For example, mallard and gadwall are found in the most daily bags. Thus, mallard and gadwall may be good buffers against the harvest of all species because they may be encountered first and fill a hunter's choice bag before other species (e.g., pintail and canvasback) are encountered by hunters.

Other Flyways

The relationships between hunted duck species, as measured by the PCS data, provide an initial point for managers to examine potential multi-species harvest dynamics and effects regulatory changes may have on target and non-target species. However, regulations, hunter behaviors, and duck availability (i.e., relative abundance of duck species) may simultaneously influence the species that co-occur in a hunter's daily bag. For example, regulations dictate hunter daily bag composition through allowable daily limits, and hunters may choose to select certain species to harvest. Last, duck availability may override a hunter's preference or a given regulation if that species of duck is not present on a given day. As such, co-occurrence relationships between duck species in other flyways may differ from the Central Flyway's co-occurrence relationships because other flyways differ in their species composition, hunters, and regulations. Thus, replication of this study to other flyways may be beneficial to waterfowl managers.

Management Implications

These data provide the information needed to simultaneously consider duck populations and hunters as management changes are discussed. Managers should

strongly consider implementing a simple fixed limit (i.e., a fixed daily bag of an n number of ducks with no species restrictions). Although a simple fixed limit would reduce regulation complexity, such implementation would require monitoring and evaluation to ensure the assumptions of how harvest may respond hold true, especially for species of concern. However, less than 8% of all bags contained more than three ducks of any one species regardless if the species was abundant (e.g., mallard) or less abundant (e.g., wigeon). Thus, a simple fixed limit may still be feasible with species of concern.

Managers also should consider how a change in a species-specific regulation may influence the harvest of other species. My models can be used to predict how effort and harvest may be redistributed to other species, which should aid managers in the discussion of regulatory alternatives.

Additionally, these data suggest that the effects that regulatory changes have on hunters may be of greater concern to managers than the effects on duck populations (e.g., reducing the mallard limit by 40% only resulted in a predicted 7% reduction in mallard harvest). Specifically, increasingly complex regulations and reduced harvest potential may cause hunter disassociation (Enck et al. 1993). This may be of major concern as hunters already exhibit a decreasing participatory trend (Enck et al. 2000, Vrtiska et al. 2013), which has implications for funding waterfowl management activities (Vrtiska et al. 2013).

The differences predicted between reduced limits and reduced harvests lend insight to Adaptive Harvest Management with regards to the partial controllability of regulations to influence harvest (Johnson and Case 2000, U.S. Fish and Wildlife Service

2001, Nichols et al. 2007). For example, reductions in limits might be predicted to produce comparable reductions in harvest. However, my daily bag limit reduction models predicted minor reductions in harvest for most species examined (e.g., 6% reduction in pintail harvest from a scenario of reducing a daily bag pintail from two to one duck). As such, reductions in daily bag limits to accommodate fluctuations in waterfowl populations may not have the desired effect, because of the limited impact these limits have on total harvest.

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Table 3.1: Conditional harvest probability (probability species B [row] is harvested given species A [column] also was harvested) matrix for Central Flyway duck species. Derived from Central Flyway daily bags from U.S. Fish and Wildlife Service's Parts Collection Survey data, 2002-2011.

		Conditional on Harvesting:															
Species ¹		MALL			AGWT	BWTE	AMWI	GADW	NSHO	NOPI	WODU	REDH	CANV	SCAUP	RNDU	OTHER	
		ANY	MALE	FEMALE													
Probability of Harvesting:	MALL	ANY	0.5765	-	-	0.3824	0.3164	0.4524	0.4123	0.3299	0.4744	0.3698	0.3068	0.3141	0.2948	0.3207	0.3503
		MALE	-	0.5142	0.6468	0.3118	0.2275	0.3804	0.3336	0.2523	0.4150	0.2982	0.2353	0.2564	0.2338	0.2523	0.2856
		FEMALE	-	0.3150	0.1828	0.1596	0.1521	0.1822	0.1716	0.1476	0.1881	0.1657	0.1287	0.1174	0.1165	0.1245	0.1458
		AGWT	0.1323	0.1271	0.1335	0.4055	0.3382	0.2049	0.2023	0.2600	0.2437	0.1668	0.1651	0.1370	0.1468	0.1884	0.1685
		BWTE	0.0483	0.0409	0.0562	0.1493	0.3940	0.0825	0.0951	0.1608	0.1154	0.0925	0.1143	0.0978	0.0926	0.0636	0.0926
		AMWI	0.1206	0.1194	0.1174	0.1578	0.1439	0.3085	0.2088	0.1405	0.2003	0.0754	0.1721	0.1380	0.1139	0.1903	0.1093
		GADW	0.2131	0.2031	0.2145	0.3022	0.3218	0.4050	0.4523	0.3540	0.2815	0.1980	0.3036	0.2857	0.2730	0.3648	0.2376
		NSHO	0.0568	0.0512	0.0615	0.1295	0.1815	0.0909	0.1180	0.2779	0.1266	0.0487	0.1481	0.1399	0.1634	0.1222	0.1389
		NOPI	0.0776	0.0800	0.0744	0.1152	0.1236	0.1230	0.0891	0.1202	0.1142	0.0358	0.1453	0.1008	0.0768	0.0681	0.0665
		WODU	0.0330	0.0313	0.0357	0.0430	0.0540	0.0252	0.0342	0.0252	0.0195	0.3458	0.0169	0.0176	0.0094	0.0337	0.0206
		REDH	0.0326	0.0295	0.0331	0.0507	0.0796	0.0687	0.0625	0.0914	0.0945	0.0202	0.2880	0.1986	0.1587	0.1077	0.1033
	CANV	0.0109	0.0105	0.0099	0.0137	0.0222	0.0180	0.0192	0.0282	0.0214	0.0069	0.0648	0.0421	0.0704	0.0415	0.0399	
	SCAUP	0.0235	0.0219	0.0224	0.0338	0.0483	0.0340	0.0420	0.0755	0.0374	0.0084	0.1188	0.1614	0.3490	0.0820	0.1329	
	RNDU	0.0336	0.0311	0.0315	0.0570	0.0436	0.0748	0.0739	0.0743	0.0436	0.0396	0.1060	0.1252	0.1079	0.2581	0.0587	
	OTHER	0.0277	0.0266	0.0279	0.0386	0.0480	0.0325	0.0364	0.0639	0.0322	0.0183	0.0769	0.0910	0.1323	0.0444	0.2161	
	NONE	0.1888	0.1605	0.1231	0.0987	0.0725	0.0811	0.1058	0.0981	0.1113	0.1824	0.0961	0.1546	0.0866	0.1206	0.1505	
	# of bags containing conditional species		29,447	25,003	12,176	10,189	4,497	7,847	15,221	5,074	4,817	2,626	3,132	1,022	2,344	3,084	2,332

¹ MALL = mallard (*Anas platyrhynchos*); AGWT = American green-winged teal (*A. crecca*); BWTE = blue-winged teal (*A. discors*); AMWI = American wigeon (*A. americana*); GADW = gadwall (*A. strepera*); NSHO = northern shoveler (*A. clypeata*); NOPI = northern pintail (*A. acuta*); WODU = wood duck (*Aix sponsa*); REDH = redhead (*Aythya americana*); CANV = canvasback (*A. valisineria*); SCAUP = lesser and greater scaup combined (*A. affinis* and *A. marila*); RNDU = ring-necked duck (*A. collaris*); OTHER = any other duck harvested in sampling frame not already specified; NONE = no other duck occurred in daily bag.

* Central Flyway: 2002-2011.

* The $P(B|A)$ for any species pair is at the convergence of the conditional species column (A) and probability of harvesting a specific-species row (B).

Table 3.2: Predicted harvest reductions (shaded = known data) resulted from 11 hypothetical daily bag limit reductions. Derived from Central Flyway daily bags from U.S. Fish and Wildlife Service's Parts Collection Survey data, 2002-2011.

Target Species ¹	2011 daily bag limit [n] ²	Hypothetical new limit [l]	% reduction in limit	2011 regular season harvest [H] ²	Proportion of total daily bags of size <i>b</i> for target species [N _B] ³						Harvest of target species with <i>b</i> in daily bag [<i>h_b</i>]						Predicted Harvest Reduction [R _H] ⁴	% reduction in harvest ⁵
					1	2	3	4	5	6	1	2	3	4	5	6		
MALL	5	3	40%	773,210	0.4235	0.2414	0.1373	0.0898	0.1080	-	327,454	186,653	106,162	69,434	83,507	-	50,761	7%
GADW	6	3	50%	555,983	0.5475	0.2461	0.1179	0.0514	0.0273	0.0097	304,401	136,827	65,550	28,578	15,178	5,393	15,912	3%
AGWT	6	3	50%	309,642	0.5943	0.2352	0.0966	0.0449	0.0199	0.0091	184,020	72,828	29,911	13,903	6,162	2,818	7,349	2%
AMWI	6	3	50%	165,715	0.6915	0.2038	0.0666	0.0257	0.0093	0.0031	114,592	33,773	11,037	4,259	1,541	514	1,938	1%
BWTE	6	3	50%	145,919	0.6060	0.2264	0.0976	0.0449	0.0185	0.0067	88,427	33,036	14,242	6,552	2,700	978	3,207	2%
NSHO	6	3	50%	174,747	0.7221	0.1888	0.0605	0.0193	0.0073	0.0020	126,185	32,992	10,572	3,373	1,276	349	1,528	1%
WODU	3	1	66%	46,556	0.6542	0.3085	0.0373	-	-	-	30,457	14,363	1,737	-	-	-	8,339	18%
NOPI	2	1	50%	187,587	0.8858	0.1141	-	-	-	-	166,165	21,404	-	-	-	-	10,702	6%
REDH	2	1	50%	122,976	0.7120	0.2880	-	-	-	-	87,559	35,417	-	-	-	-	17,709	14%
SCAUP	2	1	50%	46,992	0.6510	0.2735	0.0755	-	-	-	30,592	12,852	3,548	-	-	-	6,426	14%
RNDU	6	3	50%	86,517	0.7419	0.1748	0.0506	0.0243	0.0062	0.0023	64,187	15,123	4,378	2,102	536	199	840	1%
Mean					0.6573	0.2273	0.0822	0.0429	0.0281	0.0055								
Standard Error					0.0358	0.0167	0.0109	0.0091	0.0136	0.0014								

¹ MALL = mallard (*Anas platyrhynchos*); GADW = gadwall (*A. strepera*); AGWT = American green-winged teal (*A. crecca*); AMWI = American wigeon (*A. americana*); BWTE = blue-winged teal (*A. discors*);

NSHO = northern shoveler (*A. clypeata*); WODU = Wood duck (*Aix sponsa*); NOPI = northern pintail (*Anas acuta*); REDH = redhead (*Aythya americana*); SCAUP = lesser and greater scaup combined (*A. affinis* and *A. marila*);

RNDU = ring-necked duck (*A. collaris*).

² Kruse 2013

³ Based on frequencies of daily bags of target species, 2002-2011

⁴ Harvest Reduction Model $R_H = \sum_{b=l+1}^n h_b - [l/b * h_b]$

⁵ R_H/H x 100

Table 3.3: Predicted redistribution of harvest (using a relative probability of species-specific harvest) onto non-target species based on predicted reduction in harvest from 11 hypothetical daily bag limit reductions (columns). Harvest was assumed to remain constant. Based on 2011 regular season species-specific harvest estimates, U.S. Fish and Wildlife Service Parts Collection Survey 2002-2011 daily bags, and the probabilities of co-occurrence.

Non-Target Species	Scenario: Species and ducks to redistribute ¹										
	MALL	GADW	AGWT	AMWI	BWTE	NSHO	WODU	NOPI	REDH	SCAUP	RNDU
Harvest Increases ²	50,761	15,912	7,349	1,938	3,207	1,528	8,339	10,702	17,709	6,426	840
MALL # of ducks	-	4,707	1,908	544	589	292	2,854	3,003	3,125	1,155	165
MALL %	-	0.62	0.25	0.07	0.08	0.04	0.37	0.39	0.41	0.15	0.02
AGWT # of ducks	8,291	2,310	-	246	630	230	1,287	1,543	1,682	575	97
AGWT %	2.68	0.75	-	0.08	0.20	0.07	0.42	0.50	0.54	0.19	0.03
BWTE # of ducks	3,027	1,086	745	99	-	143	714	731	1,164	363	33
BWTE %	2.07	0.74	0.51	0.07	-	0.10	0.49	0.50	0.80	0.25	0.02
AMWI # of ducks	7,558	2,384	787	-	268	125	582	1,268	1,753	446	98
AMWI %	4.56	1.44	0.48	-	0.16	0.08	0.35	0.77	1.06	0.27	0.06
GADW # of ducks	13,355	-	1,508	487	600	314	1,528	1,782	3,092	1,070	188
GADW %	2.40	-	0.27	0.09	0.11	0.06	0.27	0.32	0.56	0.19	0.03
NSHO # of ducks	3,560	1,347	646	109	338	-	376	801	1,508	640	63
NSHO %	2.04	0.77	0.37	0.06	0.19	-	0.22	0.46	0.86	0.37	0.04
NOPI # of ducks	4,863	1,017	575	148	230	107	276	-	1,480	301	35
NOPI %	2.59	0.54	0.31	0.08	0.12	0.06	0.15	-	0.79	0.16	0.02
WODU # of ducks	2,068	390	215	30	101	22	-	123	172	37	17
WODU %	4.54	0.86	0.47	0.07	0.22	0.05	-	0.27	0.38	0.08	0.04
REDH # of ducks	2,043	714	253	83	148	81	156	598	-	622	56
REDH %	1.66	0.58	0.21	0.07	0.12	0.07	0.13	0.49	-	0.51	0.05
CANV # of ducks	683	219	68	22	41	25	53	135	660	276	21
CANV %	1.62	0.52	0.16	0.05	0.10	0.06	0.13	0.32	1.57	0.66	0.05
SCAUP # of ducks	1,473	479	169	41	90	67	65	237	1,210	-	42
SCAUP %	3.13	1.02	0.36	0.09	0.19	0.14	0.14	0.50	2.57	-	0.09
RNDU # of ducks	2,106	844	284	90	81	66	306	276	1,080	423	-
RNDU %	2.43	0.98	0.33	0.10	0.09	0.08	0.35	0.32	1.25	0.49	-
OTHER # of ducks	1,736	416	193	39	89	57	141	204	783	518	23
OTHER %	1.92	0.46	0.21	0.04	0.10	0.06	0.16	0.23	0.87	0.57	0.03

¹ Ducks to redistribute, derived from the 11 hypothetical scenarios in Table 3.2, are predicted as ducks not shot when new bags limits hold hunters to lower limits.

² Column shows redistribution of ducks of target species not shot because of lower limits. Redistribution based on known co-occurrence of ducks in hunter bags.

MALL = mallard (*Anas platyrhynchos*); AGWT = American green-winged teal (*A. crecca*); BWTE = blue-winged teal (*A. discors*);

AMWI = American wigeon (*A. americana*); GADW = gadwall (*A. strepera*); NSHO = northern shoveler (*A. clypeata*);

NOPI = northern pintail (*A. acuta*); WODU = wood duck (*Aix sponsa*); REDH = redhead (*Aythya americana*);

CANV = canvasback (*A. valisineria*); SCAUP = lesser and greater scaup combined (*A. affinis* and *A. marila*);

RNDU = ring-necked duck (*A. collaris*); OTHER = any other duck harvested in sampling frame not already specified.

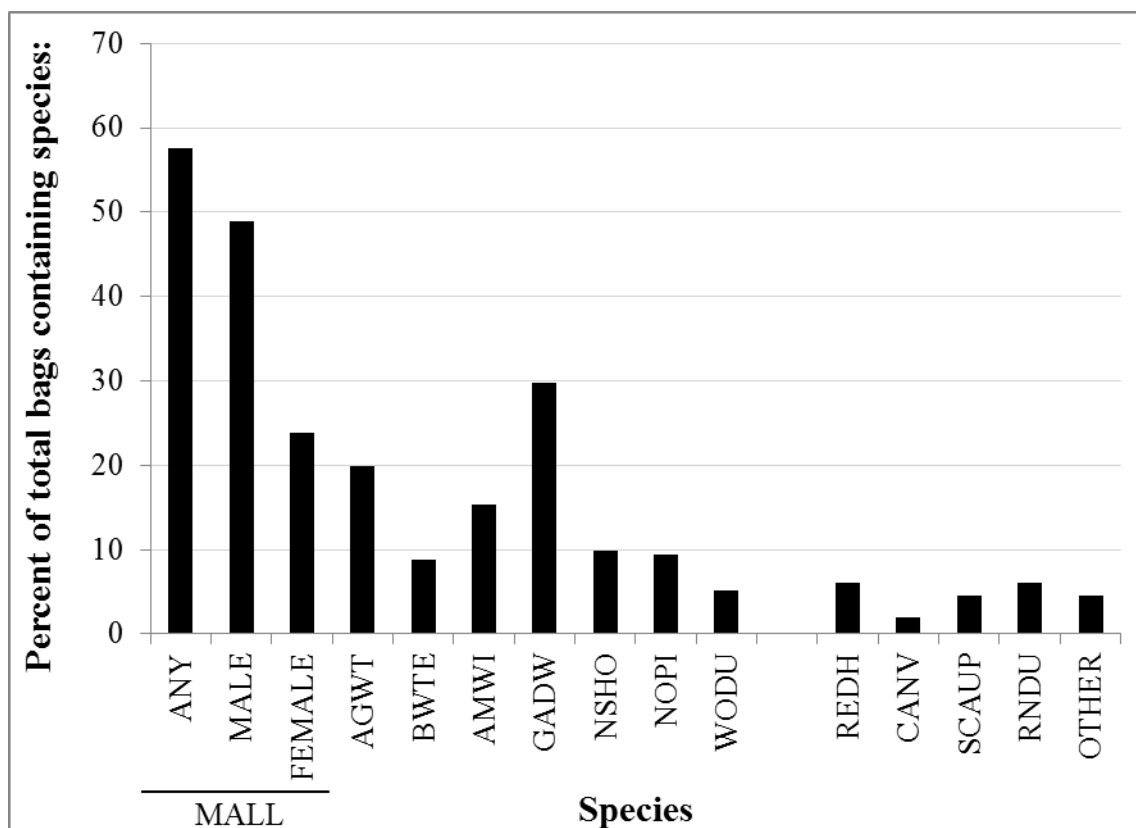


Figure 3.1: Percent of total bags for duck species (MALL = mallard [*Anas platyrhynchos*], AGWT = American green-winged teal [*A. crecca*], BWTE = blue-winged teal [*A. discors*], AMWI = American wigeon [*A. americana*], GADW = gadwall [*A. strepera*], NSHO = northern shoveler [*A. clypeata*], NOPI = northern pintail [*A. acuta*], WODU = wood duck [*Aix sponsa*], REDH = redhead [*Aythya americana*], CANV = canvasback [*A. valisineria*], SCAUP = lesser and greater scaup combined [*A. affinis* and *A. marila*], RNDU = ring-necked duck [*A. collaris*], and OTHER = any other duck harvested in sampling frame not already specified) found in U.S. Fish and Wildlife Service's Parts Collection Survey sampled daily bags, Central Flyway 2002-2011.

SYNTHESIS

The purpose of my thesis was to examine regulatory influences on duck hunters and duck harvest. Specifically, I examined competing explanations for the variation in harvest distribution for ducks in chapter 1. In chapter 2, I examined the effects that regulations have on behaviors of duck hunters. Finally, chapter 3 examined the co-occurrence of duck species in hunter daily bags. I used U.S. Fish and Wildlife Service's Parts Collection Survey (PCS) data from the Central Flyway to accomplish my chapter objectives.

In chapter 1, I used a model selection process to find the best explanation for the daily variation in spatial distribution of harvest during the hunting season for mallard (*Anas platyrhynchos*), dabbling ducks (*Anas* spp.), and diving ducks (*Aythya* spp.). Mean latitude of harvest (i.e., weighted county centroids of duck harvest by day) was used as the response variable and a quadratic ordinal day was used in all models. I fit a candidate set of models to each duck group based on an initial model selection which determined if principle hypotheses were best represented as additive or interaction parameters. The six principle hypotheses I tested included food availability, weather, water on the landscape, competition via population density, hunting pressure, and regulatory influences. Model selection analyses determined regulation changes (i.e., federal framework changes in potential start and end dates for duck seasons) had the biggest influence on dabbling and diving duck harvest distribution. Mallard harvest distribution was best explained by hunting pressure (Central Flyway active hunter estimates), water on the landscape (mean Palmer Drought Severity Indices from June-September at southern latitudes [Oklahoma and Texas]), and mallard density (Fall population index/ U.S. May ponds). However,

because model selection analyses are limited to the candidate model set, alternative hypotheses may better explain the variation in duck harvest. Still, my results should be instructive to managers when setting duck seasons dates. Additionally, managers should be able to explain and educate constituents as to what factors may influence duck harvest.

In chapter 2, I stratified Central Flyway duck hunters based on their seasonal harvest for three time periods which represented different harvest regulations. I examined seven measures of duck hunter behaviors: days harvesting ducks, daily harvest, hunter mobility, mallard selectivity, gender selectivity, daily female mallard harvest, and timing of harvest. I determined that regulations (represented by time periods) had the potential to affect certain measures of duck hunter behavior (e.g., average daily harvest, gender selectivity of mallards). Regulations also appeared to affect all hunters equally. My results should help managers with hunter recruitment and retention efforts, and potentially aid in harvest management. My research may help managers devise and implement new and/or creative regulations aimed to increase hunter recruitment and retention. My study was limited, however, to the measures of duck hunter behaviors I examined. Thus, studies that address other behaviors and hunter metrics (e.g., hunting identity, hunting constraints, participation, and satisfaction) may be useful for waterfowl management as well.

In chapter 3, I documented co-occurrence of pairs of duck species found in the daily bags of Central Flyway hunters. Although some species relationships that I documented may be intuitive (e.g., diving ducks are more likely harvested with other diving ducks), my study was further able to quantify the relationships in terms of harvest. I also developed models to predict the effects hypothetical regulation change may have

on target and non-target species. My analyses suggest species-specific bags limit reduction may not adequately reduce harvest for a target species. However, the effects of such actions on hunters and non-target species are often overlooked. Co-occurrence relationships may provide managers with harvest inferences for non-target species. Future studies should address hunter responses to potential regulatory changes (e.g., implementation of hunter choice guilds). My data also provide crucial insight for the development of appropriate regulations for multi-stock management.

Regulations may affect the harvest distribution of dabbling and diving ducks, and may influence certain behaviors of ducks hunter, but may not differentially affect hunters. Regulation change may affect target and non-target species differently. In conclusion, my work should aid in harvest management, because I provide inference into the relationships among regulations, duck hunters, and duck harvest. My work also may allow managers to better address or develop hunter recruitment and retention strategies. However, replication and future studies, when new information becomes available, are needed because the relationships between regulations, duck hunters, and duck harvest are likely different across flyways and most likely dynamic.

APPENDIX

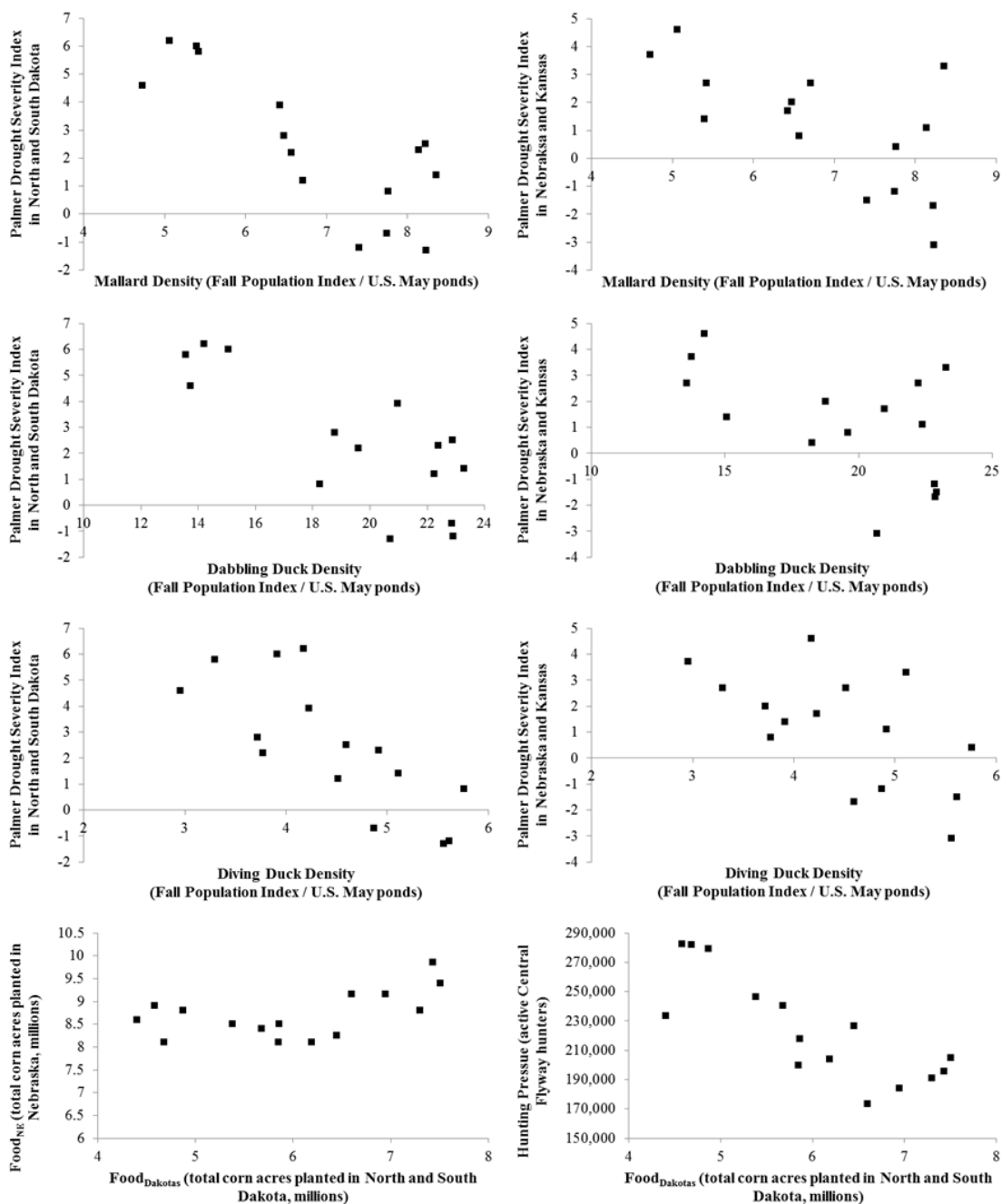
Appendix 1:

Appendix 1.A: Pearson correlation coefficients and associated *P*-values (significant values shaded, $\alpha < 0.05$) for the principle hypotheses that may explain the variation in duck harvest distribution in the Central Flyway. Principle hypotheses include: FOOD_{DAKOTAS} (total corn acres planted in North and South Dakota), FOOD_{NE} (total corn acres planted in Nebraska), WEATHER (maximum weather severity index for North and South Dakota in October and November), PRESSURE (active Central Flyway hunter estimates), Mallard, dabbling, and diving duck DENSITY (Fall Population Index/U.S. May ponds), Palmer Drought Severity Index (PDSI; mean June-September PDSI for North Dakota and South Dakota [NORTH], Nebraska and Kansas [MID], and Oklahoma and Texas [SOUTH]).

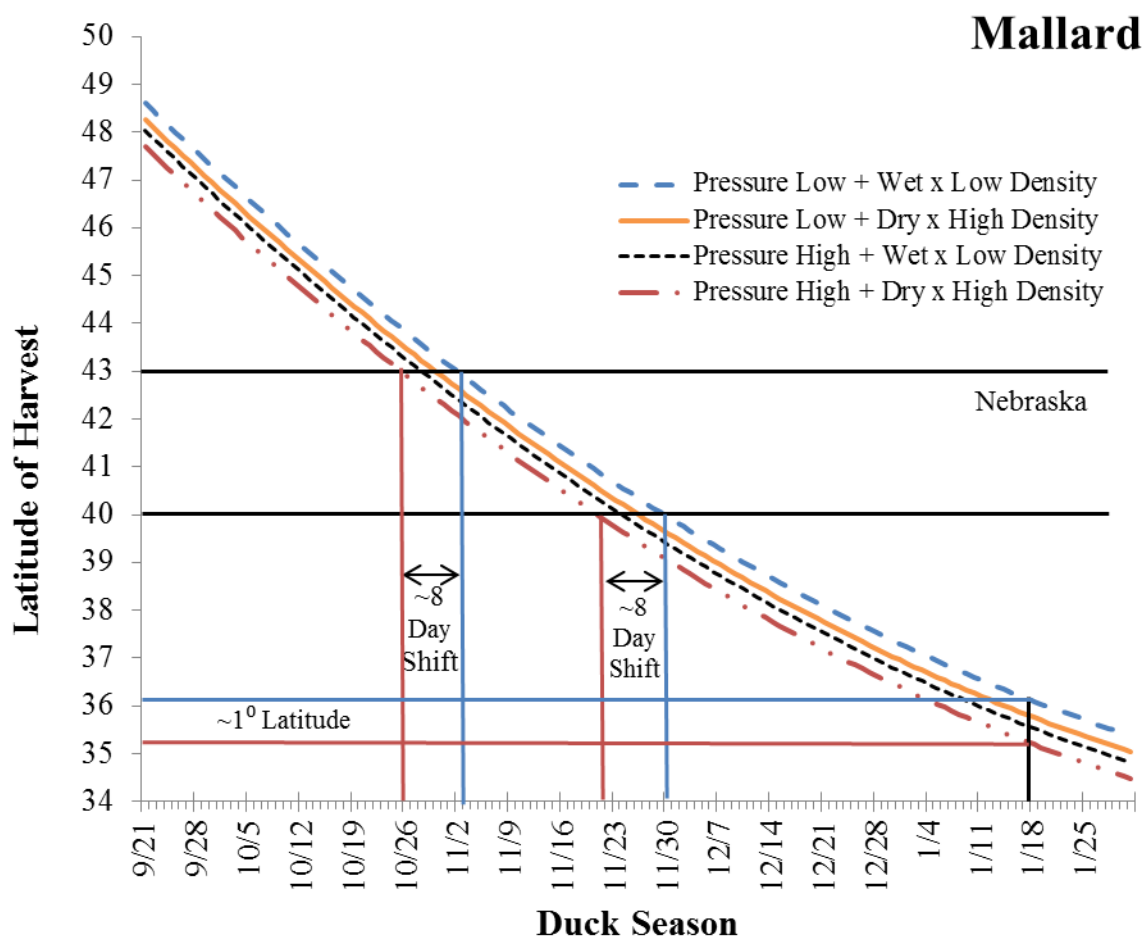
Pearson's Correlation Coefficients (<i>r</i>)										
	FOOD _{DAKOTAS}	FOOD _{NE}	WEATHER	PRESSURE	Mallard DENSITY	Dabbling DENSITY	Diving DENSITY	PDSI NORTH	PDSI MID	PDSI SOUTH
FOOD _{DAKOTAS}	1.000	0.540	-0.070	-0.820	-0.040	-0.020	0.220	-0.030	0.270	-0.030
FOOD _{NE}	0.540	1.000	-0.030	-0.350	-0.590	-0.450	-0.470	0.660	0.610	-0.070
WEATHER	-0.070	-0.030	1.000	0.060	0.240	0.440	0.190	-0.090	-0.260	-0.080
PRESSURE	-0.820	-0.350	0.060	1.000	0.170	0.200	-0.120	-0.090	-0.300	0.060
Mallard DENSITY	-0.040	-0.590	0.240	0.170	1.000	0.870	0.820	-0.800	-0.660	0.120
Dabbling DENSITY	-0.020	-0.450	0.440	0.200	0.870	1.000	0.700	-0.780	-0.550	0.160
Diving DENSITY	0.220	-0.470	0.190	-0.120	0.820	0.700	1.000	-0.780	0.140	-0.600
PDSI _{NORTH}	-0.030	0.660	-0.090	-0.090	-0.800	-0.780	-0.780	1.000	-0.090	0.720
PDSI _{MID}	0.270	0.610	-0.260	-0.300	-0.660	-0.550	0.140	-0.090	1.000	0.320
PDSI _{SOUTH}	-0.030	-0.070	-0.080	0.060	0.120	0.160	-0.600	0.720	0.320	1.000

Pearson's Correlation <i>P</i> -values										
	FOOD _{DAKOTAS}	FOOD _{NE}	WEATHER	PRESSURE	Mallard DENSITY	Dabbling DENSITY	Diving DENSITY	PDSI NORTH	PDSI MID	PDSI SOUTH
FOOD _{DAKOTAS}	-	0.039	0.800	< 0.001	0.874	0.941	0.437	0.913	0.328	0.927
FOOD _{NE}	0.039	-	0.915	0.199	0.018	0.085	0.077	0.008	0.016	0.817
WEATHER	0.800	0.915	-	0.837	0.391	0.105	0.497	0.756	0.343	0.766
PRESSURE	< 0.001	0.199	0.837	-	0.542	0.483	0.680	0.759	0.276	0.838
Mallard DENSITY	0.874	0.018	0.391	0.542	-	< 0.001	< 0.001	< 0.001	0.007	0.662
Dabbling DENSITY	0.941	0.085	0.105	0.483	< 0.001	-	0.006	< 0.001	0.017	0.624
Diving DENSITY	0.437	0.077	0.497	0.680	< 0.001	0.006	-	< 0.001	0.017	0.624
PDSI _{NORTH}	0.913	0.008	0.756	0.759	< 0.001	< 0.001	< 0.001	-	0.003	0.743
PDSI _{MID}	0.328	0.016	0.343	0.276	0.007	0.017	0.017	0.003	-	0.250
PDSI _{SOUTH}	0.927	0.817	0.766	0.838	0.662	0.624	0.624	0.743	0.250	-

Appendix 1.B: Plots of correlated principle hypotheses that may explain the variation in duck harvest distribution in the Central Flyway. Principle hypotheses include: $FOOD_{DAKOTAS}$ (total corn acres planted in North and South Dakota), $FOOD_{NE}$ (total corn acres planted in Nebraska), $WEATHER$ (maximum weather severity index for North and South Dakota in October and November), $PRESSURE$ (active Central Flyway hunter estimates), Mallard, dabbling, and diving duck $DENSITY$ (Fall Population Index/U.S. May ponds), Palmer Drought Severity Index (PDSI; mean June-September PDSI for North Dakota and South Dakota [NORTH], Nebraska and Kansas [MID], and Oklahoma and Texas [SOUTH]).



Appendix 1.C: Example of how changes in hunting pressure, water on the landscape, and mallard density may affect mallard (*Anas platyrhynchos*) harvest distribution in Nebraska, and harvest distribution for a particular date. If hunting pressure is low (less than 224,000 active Central Flyway hunters), Oklahoma and Texas are wet (mean Palmer Drought Severity from June-September is greater than 0.0), and mallard density is low (mallard fall flight index/U.S. May ponds less than 6,800) then harvest patterns for mallards may shift approximately 8 days later, or approximately 1 degree latitude north relative to harvest patterns under high hunting pressure, dry conditions, and high mallard density years. Model derived from U.S. Fish and Wildlife Service Parts Collection Survey data for the Central Flyway, 1997-2011.



Appendix 2:

Appendix 2.A: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) estimates for the measures of duck hunter behaviors of days harvesting ducks (# of days when duck harvest occurred/hunter/season), daily harvest (average daily bag/hunter/season), hunter mobility (# of counties where harvest occurred/hunter/season), mallard selectivity (percent mallard harvest/hunter/season), gender selectivity (percent female mallard harvest [mallards only] /hunter/season), and daily female mallard harvest in the Central Flyway for liberal (2002-2011), moderate (1975-1984), and restrictive (1988-1993) harvest regulations, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Days Harvesting Ducks (# of days when duck harvest occurred)	Liberal: 2002-2011	1	1166	1.15 (\pm 0.01)	2	1	1.17	1.13
		2	1140	1.73 (\pm 0.02)	4	1	1.78	1.69
		3	1239	2.20 (\pm 0.03)	6	1	2.26	2.14
		4	911	3.01 (\pm 0.04)	8	1	3.09	2.94
		5	969	3.44 (\pm 0.05)	9	1	3.54	3.35
		6	907	4.12 (\pm 0.05)	13	1	4.23	4.01
		7	898	5.13 (\pm 0.07)	17	2	5.26	5.00
		8	1062	6.13 (\pm 0.06)	15	2	6.25	6.01
		9	1071	8.12 (\pm 0.09)	23	1	8.29	7.95
		10	1047	15.07 (\pm 0.21)	61	3	15.48	14.67
	Moderate: 1975-1984	1	1800	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	1647	1.30 (\pm 0.01)	2	1	1.32	1.27
		3	1559	1.64 (\pm 0.02)	3	1	1.67	1.61
		4	1291	2.01 (\pm 0.02)	4	1	2.06	1.96
		5	2101	2.47 (\pm 0.02)	6	1	2.52	2.42
		6	1622	3.18 (\pm 0.03)	8	1	3.24	3.11
		7	1638	3.73 (\pm 0.04)	10	1	3.80	3.65
		8	1403	4.63 (\pm 0.05)	13	1	4.73	4.54
		9	1716	6.06 (\pm 0.06)	16	1	6.18	5.95
		10	1516	10.12 (\pm 0.12)	48	1	10.37	9.88
	Restrictive: 1988-1993	1	1140	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	1253	1.34 (\pm 0.01)	2	1	1.36	1.31
		3	1165	1.77 (\pm 0.02)	3	1	1.81	1.73
		4	869	2.39 (\pm 0.02)	4	1	2.43	2.34
		5	780	2.82 (\pm 0.03)	5	1	2.88	2.76
		6	813	3.00 (\pm 0.03)	6	1	3.07	2.94
		7	1007	3.99 (\pm 0.03)	8	1	4.06	3.93
		8	1215	4.92 (\pm 0.04)	10	1	5.00	4.84
		9	1256	7.04 (\pm 0.05)	17	1	7.15	6.94
		10	1007	12.30 (\pm 0.14)	38	1	12.57	12.03

Appendix 2.A (continued)

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Daily Harvest (Daily Bag)	Liberal: 2002-2011	1	1085	1.35 (\pm 0.01)	2.00	1.00	1.37	1.32
		2	1059	2.42 (\pm 0.03)	4.00	1.00	2.48	2.36
		3	1159	3.13 (\pm 0.05)	6.00	1.00	3.22	3.04
		4	874	2.83 (\pm 0.03)	4.00	1.00	2.90	2.76
		5	890	3.27 (\pm 0.05)	5.00	1.00	3.36	3.17
		6	852	3.32 (\pm 0.04)	6.00	1.00	3.41	3.23
		7	822	3.43 (\pm 0.04)	6.00	1.00	3.51	3.35
		8	946	3.60 (\pm 0.04)	6.00	1.36	3.67	3.53
		9	886	3.81 (\pm 0.05)	6.00	1.00	3.90	3.72
		10	698	3.93 (\pm 0.04)	6.00	1.02	4.01	3.85
	Moderate: 1975-1984	1	1806	1.00 (\pm 0.00)	1.00	1.00	1.00	1.00
		2	1650	1.70 (\pm 0.01)	2.00	1.00	1.73	1.68
		3	1559	2.15 (\pm 0.02)	3.00	1.00	2.19	2.11
		4	1292	2.44 (\pm 0.03)	4.00	1.00	2.50	2.37
		5	1985	2.55 (\pm 0.03)	6.00	1.00	2.60	2.50
		6	1498	2.39 (\pm 0.02)	4.00	1.00	2.44	2.35
		7	1550	2.56 (\pm 0.03)	5.00	1.00	2.61	2.51
		8	1357	2.57 (\pm 0.02)	6.00	1.00	2.62	2.52
		9	1640	2.68 (\pm 0.02)	6.00	1.00	2.72	2.64
		10	1501	2.85 (\pm 0.02)	6.00	1.00	2.89	2.81
	Restrictive: 1988-1993	1	1124	1.00 (\pm 0.00)	1.00	1.00	1.00	1.00
		2	1244	1.66 (\pm 0.01)	2.00	1.00	1.69	1.63
		3	1140	1.99 (\pm 0.02)	3.00	1.00	2.04	1.95
		4	818	1.72 (\pm 0.01)	2.00	1.00	1.75	1.70
		5	746	1.84 (\pm 0.02)	2.50	1.00	1.88	1.80
		6	792	2.11 (\pm 0.02)	3.00	1.00	2.15	2.06
		7	965	1.91 (\pm 0.01)	3.00	1.00	1.94	1.88
		8	1152	2.02 (\pm 0.01)	3.00	1.00	2.05	1.99
		9	1168	2.07 (\pm 0.01)	3.00	1.00	2.10	2.05
		10	849	2.21 (\pm 0.01)	3.00	1.05	2.24	2.19

Appendix 2.A (continued)

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Hunter Mobility (# of counties where harvest occurred)	Liberal: 2002-2011	1	1166	1.03 (\pm 0.00)	2	1	1.04	1.02
		2	1145	1.14 (\pm 0.01)	4	1	1.16	1.12
		3	1249	1.19 (\pm 0.01)	4	1	1.22	1.17
		4	923	1.27 (\pm 0.02)	4	1	1.30	1.24
		5	982	1.32 (\pm 0.02)	5	1	1.36	1.28
		6	933	1.43 (\pm 0.02)	6	1	1.47	1.39
		7	933	1.50 (\pm 0.02)	5	1	1.54	1.45
		8	1108	1.56 (\pm 0.02)	5	1	1.61	1.52
		9	1118	1.71 (\pm 0.03)	6	1	1.76	1.65
		10	1188	2.08 (\pm 0.04)	10	1	2.16	2.00
	Moderate: 1975-1984	1	1800	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	1652	1.07 (\pm 0.01)	2	1	1.08	1.06
		3	1562	1.12 (\pm 0.01)	3	1	1.14	1.10
		4	1292	1.16 (\pm 0.01)	3	1	1.19	1.14
		5	2110	1.22 (\pm 0.01)	4	1	1.24	1.20
		6	1635	1.30 (\pm 0.01)	4	1	1.33	1.27
		7	1655	1.33 (\pm 0.01)	5	1	1.36	1.30
		8	1429	1.42 (\pm 0.02)	5	1	1.45	1.38
		9	1749	1.47 (\pm 0.02)	6	1	1.51	1.43
		10	1585	1.69 (\pm 0.02)	8	1	1.73	1.64
	Restrictive: 1988-1993	1	1140	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	1256	1.09 (\pm 0.01)	2	1	1.10	1.07
		3	1168	1.15 (\pm 0.01)	3	1	1.17	1.13
		4	871	1.22 (\pm 0.02)	3	1	1.25	1.19
		5	785	1.28 (\pm 0.02)	4	1	1.31	1.24
		6	819	1.31 (\pm 0.02)	4	1	1.35	1.27
		7	1022	1.40 (\pm 0.02)	4	1	1.44	1.36
		8	1230	1.47 (\pm 0.02)	6	1	1.51	1.43
		9	1293	1.59 (\pm 0.02)	5	1	1.63	1.54
		10	1055	1.79 (\pm 0.03)	7	1	1.85	1.73

Appendix 2.A (continued)

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Species Selectivity (Percent Mallard Harvest)	Liberal: 2002-2011	1	1172	50.47 (\pm 1.38)	100	0	53.17	47.77
		2	1148	46.71 (\pm 1.16)	100	0	48.98	44.44
		3	1252	42.16 (\pm 1.03)	100	0	44.18	40.15
		4	915	43.54 (\pm 1.15)	100	0	45.80	41.27
		5	973	43.93 (\pm 1.08)	100	0	46.05	41.81
		6	911	41.35 (\pm 1.05)	100	0	43.41	39.30
		7	902	41.82 (\pm 1.01)	100	0	43.81	39.84
		8	1065	41.82 (\pm 0.94)	100	0	43.66	39.99
		9	1073	38.32 (\pm 0.86)	100	0	39.99	36.64
		10	1047	39.98 (\pm 0.87)	100	0	41.69	38.27
	Moderate: 1975-1984	1	1806	54.65 (\pm 1.17)	100	0	56.95	52.35
		2	1650	52.76 (\pm 1.08)	100	0	54.87	50.64
		3	1559	49.37 (\pm 1.03)	100	0	51.39	47.34
		4	1292	48.08 (\pm 1.09)	100	0	50.22	45.95
		5	2101	48.08 (\pm 0.82)	100	0	49.69	46.47
		6	1622	45.65 (\pm 0.89)	100	0	47.39	43.92
		7	1638	44.49 (\pm 0.87)	100	0	46.19	42.80
		8	1403	44.23 (\pm 0.90)	100	0	45.99	42.48
		9	1716	42.75 (\pm 0.81)	100	0	44.35	41.16
		10	1516	37.68 (\pm 0.77)	100	0	39.19	36.16
	Restrictive: 1988-1993	1	1154	54.77 (\pm 1.47)	100	0	57.64	51.89
		2	1268	55.21 (\pm 1.23)	100	0	57.62	52.79
		3	1169	45.94 (\pm 1.17)	100	0	48.23	43.64
		4	874	51.97 (\pm 1.32)	100	0	54.55	49.39
		5	784	48.09 (\pm 1.27)	100	0	50.58	45.60
		6	816	43.93 (\pm 1.24)	100	0	46.36	41.51
		7	1009	48.51 (\pm 1.08)	100	0	50.63	46.39
		8	1219	43.62 (\pm 0.96)	100	0	45.50	41.74
		9	1256	43.89 (\pm 0.90)	100	0	45.66	42.13
		10	1007	40.35 (\pm 0.95)	100	0	42.21	38.49

Appendix 2.A (continued)

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Gender Selectivity (Percent Female Mallard Harvest)	Liberal: 2002-2011	1	649	27.20 (\pm 1.64)	100	0	30.40	23.99
		2	795	30.05 (\pm 1.25)	100	0	32.50	27.61
		3	902	27.72 (\pm 1.06)	100	0	29.80	25.63
		4	725	27.92 (\pm 1.11)	100	0	30.09	25.74
		5	817	25.65 (\pm 0.98)	100	0	27.56	23.73
		6	775	27.41 (\pm 0.97)	100	0	29.32	25.50
		7	787	26.03 (\pm 0.86)	100	0	27.71	24.34
		8	954	26.81 (\pm 0.78)	100	0	28.33	25.28
		9	970	27.61 (\pm 0.74)	100	0	29.06	26.16
		10	988	25.67 (\pm 0.66)	100	0	26.97	24.37
	Moderate: 1975-1984	1	945	32.70 (\pm 1.53)	100	0	35.69	29.71
		2	1029	33.77 (\pm 1.25)	100	0	36.22	31.32
		3	1041	35.49 (\pm 1.16)	100	0	37.76	33.23
		4	920	33.51 (\pm 1.15)	100	0	35.77	31.26
		5	1604	31.80 (\pm 0.82)	100	0	33.41	30.19
		6	1282	31.19 (\pm 0.86)	100	0	32.87	29.51
		7	1315	31.11 (\pm 0.83)	100	0	32.72	29.49
		8	1198	29.57 (\pm 0.81)	100	0	31.15	27.99
		9	1486	29.94 (\pm 0.66)	100	0	31.24	28.64
		10	1334	29.17 (\pm 0.66)	100	0	30.45	27.88
	Restrictive: 1988-1993	1	614	21.99 (\pm 1.67)	100	0	25.27	18.71
		2	834	23.20 (\pm 1.25)	100	0	25.65	20.75
		3	772	24.05 (\pm 1.25)	100	0	26.50	21.60
		4	656	21.28 (\pm 1.20)	100	0	23.64	18.92
		5	614	23.59 (\pm 1.26)	100	0	26.06	21.12
		6	625	21.09 (\pm 1.17)	100	0	23.38	18.80
		7	838	20.71 (\pm 0.89)	100	0	22.46	18.97
		8	1002	21.95 (\pm 0.83)	100	0	23.58	20.31
		9	1088	20.20 (\pm 0.72)	100	0	21.61	18.79
		10	882	19.00 (\pm 0.73)	100	0	20.42	17.57

Appendix 2.A (continued)

Measure of Behavior	Harvest Regulation	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Daily Female Mallard Harvest	Liberal: 2002-2011	1	708	0.31 (\pm 0.02)	2	0	0.35	0.28
		2	1102	0.48 (\pm 0.02)	2	0	0.51	0.44
		3	1484	0.50 (\pm 0.02)	2	0	0.54	0.47
		4	1554	0.48 (\pm 0.02)	2	0	0.51	0.45
		5	1972	0.48 (\pm 0.01)	2	0	0.51	0.46
		6	2170	0.50 (\pm 0.01)	2	0	0.53	0.47
		7	2659	0.50 (\pm 0.01)	2	0	0.53	0.48
		8	3836	0.53 (\pm 0.01)	2	0	0.55	0.50
		9	5045	0.53 (\pm 0.01)	2	0	0.55	0.51
		10	9129	0.51 (\pm 0.01)	2	0	0.53	0.50
	Moderate: 1975-1984	1	945	0.33 (\pm 0.02)	1	0	0.36	0.30
		2	1207	0.45 (\pm 0.02)	2	0	0.48	0.42
		3	1431	0.52 (\pm 0.02)	2	0	0.55	0.49
		4	1457	0.51 (\pm 0.02)	2	0	0.54	0.48
		5	2960	0.49 (\pm 0.01)	2	0	0.51	0.47
		6	2945	0.48 (\pm 0.01)	2	0	0.51	0.46
		7	3501	0.50 (\pm 0.01)	2	0	0.52	0.48
		8	3775	0.48 (\pm 0.01)	2	0	0.50	0.46
		9	5960	0.50 (\pm 0.01)	2	0	0.51	0.48
		10	8251	0.50 (\pm 0.01)	2	0	0.51	0.48
	Restrictive: 1988-1993	1	614	0.22 (\pm 0.02)	1	0	0.25	0.19
		2	1000	0.28 (\pm 0.01)	1	0	0.31	0.26
		3	1164	0.29 (\pm 0.01)	1	0	0.32	0.27
		4	1211	0.26 (\pm 0.01)	1	0	0.28	0.23
		5	1276	0.28 (\pm 0.01)	1	0	0.30	0.25
		6	1381	0.25 (\pm 0.01)	1	0	0.28	0.23
		7	2357	0.27 (\pm 0.01)	1	0	0.28	0.25
		8	3299	0.26 (\pm 0.01)	1	0	0.28	0.25
		9	4933	0.24 (\pm 0.01)	1	0	0.25	0.23
		10	6755	0.22 (\pm 0.01)	1	0	0.23	0.21

Appendix 2.B: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) estimates for timing of harvest (standardized) [mode, median, and mean seasonal day of harvest], in the Central Flyway for liberal (2002-2011), moderate (1975-1984), and restrictive (1988-1993) harvest regulations, derived from U.S. Fish and Wildlife Service Parts Collection Survey data.

Harvest Regulation	Harvest Group	n	Ordinal Day of Harvest (Standardized)			Max	Min	95% UCL	95% LCL
			Mode	Median	Mean (\pm SE)				
Liberal: 2002-2011	1	1745	1	35	40.19 (\pm 0.69)	120	1	41.53	38.84
	2	4016	1	36	41.78 (\pm 0.47)	121	1	42.70	40.87
	3	6850	1	31	38.23 (\pm 0.35)	121	1	38.92	37.54
	4	6865	1	33	40.01 (\pm 0.35)	120	1	40.70	39.32
	5	9280	1	30	37.79 (\pm 0.29)	120	1	38.37	37.22
	6	10860	1	30	36.85 (\pm 0.27)	121	1	37.37	36.33
	7	13926	8	32	39.20 (\pm 0.24)	121	1	39.67	38.73
	8	21356	15	33	40.33 (\pm 0.20)	121	1	40.71	39.95
	9	30114	29	37	43.43 (\pm 0.17)	120	1	43.76	43.11
	10	59797	29	48	50.44 (\pm 0.12)	121	1	50.68	50.20
Moderate: 1975-1984	1	1803	1	24	30.93 (\pm 0.59)	110	1	32.08	29.78
	2	3299	1	22	29.49 (\pm 0.44)	111	1	30.36	28.62
	3	4663	1	23	29.88 (\pm 0.37)	111	1	30.61	29.16
	4	5158	1	23	30.18 (\pm 0.36)	111	1	30.87	29.48
	5	11442	1	23	30.55 (\pm 0.25)	111	1	31.03	30.07
	6	12081	1	23	30.44 (\pm 0.24)	110	1	30.90	29.97
	7	15599	1	23	31.21 (\pm 0.21)	111	1	31.62	30.79
	8	17292	1	24	31.21 (\pm 0.20)	111	1	31.61	30.82
	9	30216	1	28	34.33 (\pm 0.15)	111	1	34.63	34.03
	10	53213	1	35	39.12 (\pm 0.11)	111	1	39.35	38.90
Restrictive: 1988-1993	1	1144	1	26	29.75 (\pm 0.67)	93	1	31.07	28.43
	2	2522	1	26	29.87 (\pm 0.47)	93	1	30.79	28.95
	3	3492	1	22	26.82 (\pm 0.38)	93	1	27.56	26.07
	4	3481	1	24	29.21 (\pm 0.40)	93	1	29.99	28.42
	5	3889	1	23	28.14 (\pm 0.37)	91	1	28.87	27.41
	6	4862	1	23	28.00 (\pm 0.32)	93	1	28.63	27.36
	7	7459	1	28	30.75 (\pm 0.27)	93	1	31.29	30.21
	8	11841	1	27	30.42 (\pm 0.21)	93	1	30.83	30.00
	9	18102	1	30	32.57 (\pm 0.17)	93	1	32.91	32.24
	10	29207	1	35	34.95 (\pm 0.13)	93	1	35.20	34.69

Appendix 2.C: Comparison of mean harvest group (10% of each regulation period sample, stratified by seasonal harvest; additional 0 harvest grouped added for non-harvestings Harvest Information Program [HIP] hunters) estimates between HIP results on days hunted (# of days hunted/hunter/season) and Parts Collection Survey's (PCS) results on days harvesting ducks (# of days when duck harvest occurred/hunter/season) for the Central Flyway from 2002-2011.

	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
HIP	0	2786	2.80 (\pm 0.06)	60	0	2.92	2.69
	1	3937	2.96 (\pm 0.06)	99	0	3.09	2.84
	2	3755	3.47 (\pm 0.08)	99	0	3.63	3.31
	3	3748	4.11 (\pm 0.07)	99	0	4.25	3.96
	4	2612	4.85 (\pm 0.08)	99	1	5.01	4.69
	5	3111	5.51 (\pm 0.10)	99	0	5.71	5.31
	6	3261	6.01 (\pm 0.11)	99	1	6.22	5.81
	7	3314	7.25 (\pm 0.11)	99	0	7.45	7.04
	8	3607	8.42 (\pm 0.11)	99	3	8.64	8.20
	9	3897	10.74 (\pm 0.12)	99	0	10.98	10.50
	10	4563	18.52 (\pm 0.17)	99	0	18.86	18.19
PCS	0	N/A	N/A	N/A	N/A	N/A	N/A
	1	1166	1.15 (\pm 0.01)	2	1	1.17	1.13
	2	1140	1.73 (\pm 0.02)	4	1	1.78	1.69
	3	1239	2.20 (\pm 0.03)	6	1	2.26	2.14
	4	911	3.01 (\pm 0.04)	8	1	3.09	2.94
	5	969	3.44 (\pm 0.05)	9	1	3.54	3.35
	6	907	4.12 (\pm 0.05)	13	1	4.23	4.01
	7	898	5.13 (\pm 0.07)	17	2	5.26	5.00
	8	1062	6.13 (\pm 0.06)	15	2	6.25	6.01
	9	1071	8.12 (\pm 0.09)	23	1	8.29	7.95
	10	1047	15.07 (\pm 0.21)	61	3	15.48	14.67

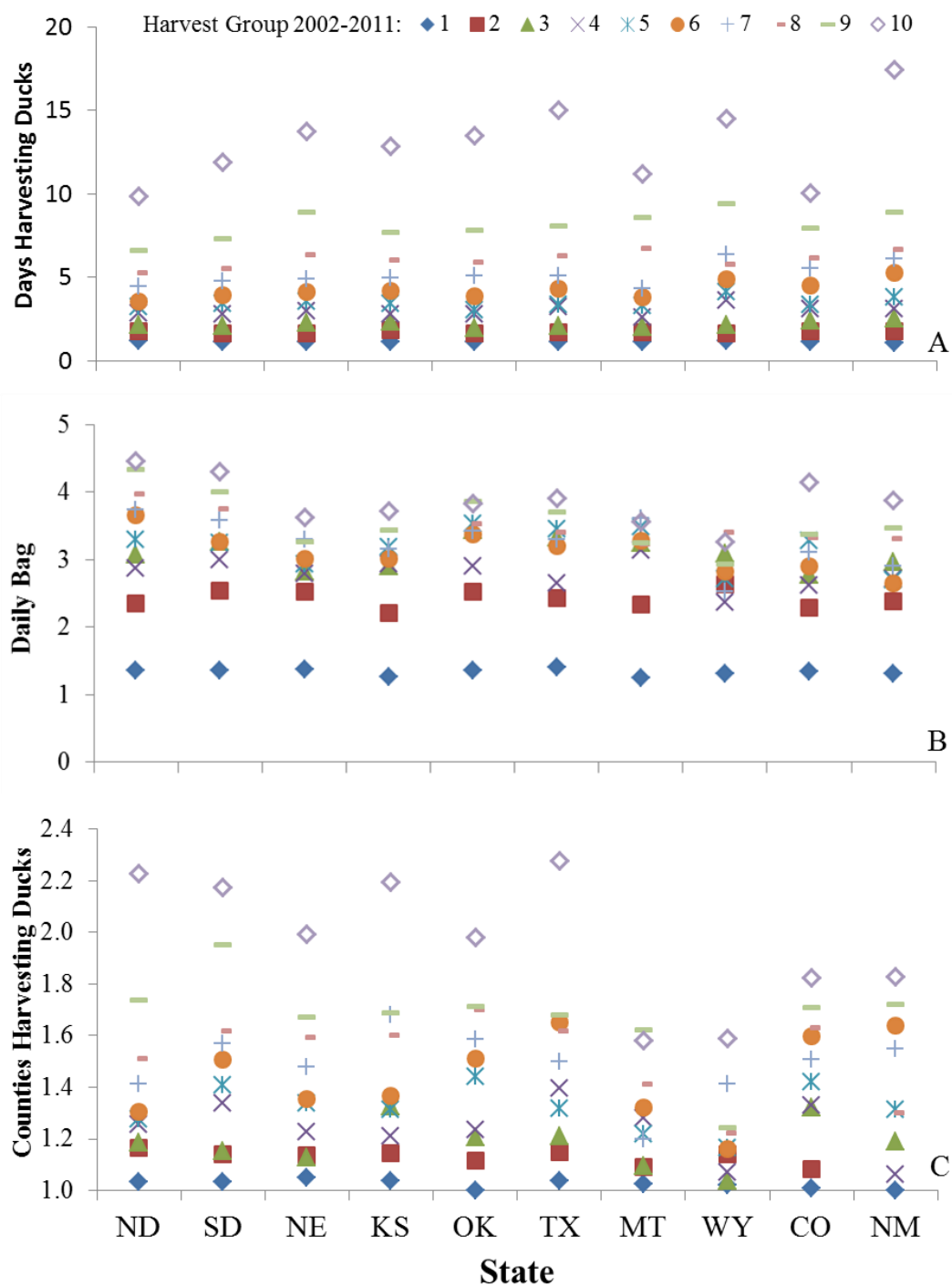
Appendix 2.D: Comparison of mean harvest group (10% of each regulation period sample, stratified by seasonal harvest; additional 0 harvest grouped added for non-harvestings Harvest Information Program [HIP] hunters) estimates between HIP results on daily harvest (average daily bag/hunter/season) and Parts Collection Survey's (PCS) results on daily harvest (average daily bag/hunter/season) for the Central Flyway from 2002-2011.

	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
HIP	0	1749	0.01 (\pm 0.00)	5.00	0.00	0.02	0.00
	1	2842	1.02 (\pm 0.01)	3.00	0.00	1.05	1.00
	2	2543	2.00 (\pm 0.02)	4.00	0.07	2.05	1.96
	3	2425	2.66 (\pm 0.03)	6.00	0.21	2.72	2.59
	4	1757	2.46 (\pm 0.03)	8.00	0.20	2.52	2.40
	5	1824	2.92 (\pm 0.03)	5.00	0.24	2.98	2.87
	6	2119	3.10 (\pm 0.03)	6.50	0.22	3.15	3.04
	7	1981	3.20 (\pm 0.03)	7.50	0.00	3.25	3.14
	8	2153	3.47 (\pm 0.03)	7.00	0.68	3.53	3.42
	9	2245	3.68 (\pm 0.03)	8.33	0.00	3.73	3.63
	10	2047	4.00 (\pm 0.02)	7.33	0.77	4.05	3.95
PCS	0	N/A	N/A	N/A	N/A	N/A	N/A
	1	1085	1.35 (\pm 0.01)	2.00	1.00	1.37	1.32
	2	1059	2.42 (\pm 0.03)	4.00	1.00	2.48	2.36
	3	1159	3.13 (\pm 0.05)	6.00	1.00	3.22	3.04
	4	874	2.83 (\pm 0.03)	4.00	1.00	2.90	2.76
	5	890	3.27 (\pm 0.05)	5.00	1.00	3.36	3.17
	6	852	3.32 (\pm 0.04)	6.00	1.00	3.41	3.23
	7	822	3.43 (\pm 0.04)	6.00	1.00	3.51	3.35
	8	946	3.60 (\pm 0.04)	6.00	1.36	3.67	3.53
	9	886	3.81 (\pm 0.05)	6.00	1.00	3.90	3.72
	10	698	3.93 (\pm 0.04)	6.00	1.02	4.01	3.85

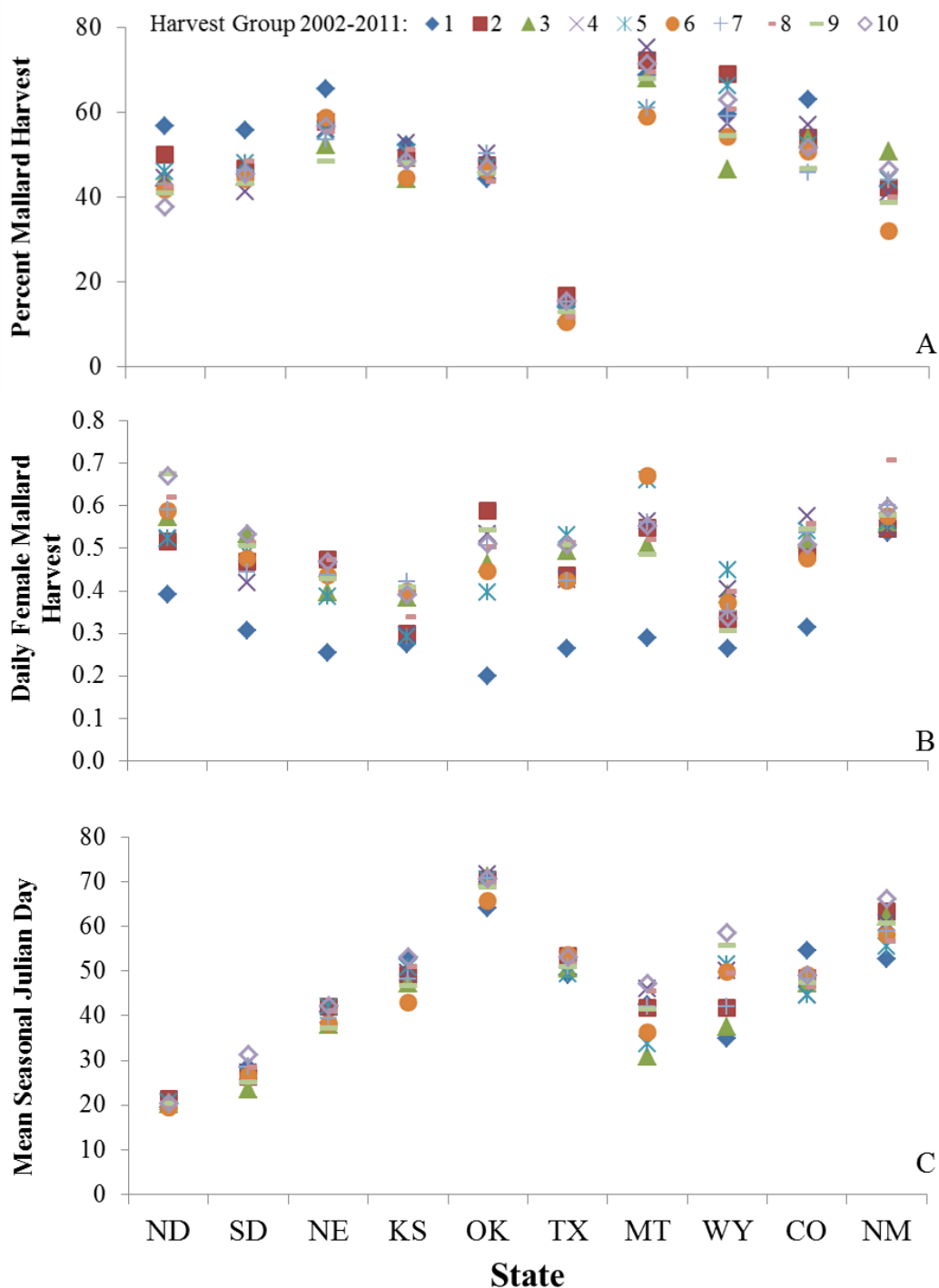
Appendix 2.E: Comparison of mean harvest group (10% of each regulation period sample, stratified by seasonal harvest; additional 0 harvest grouped added for non-harvestings Harvest Information Program [HIP] hunters) estimates between HIP results on hunter mobility (# number of counties hunted/hunter/season) and Parts Collection Survey's (PCS) results on hunter mobility (# of counties where duck harvest occurred/hunter/season) for the Central Flyway from 2002-2011.

	Harvest Group	<i>n</i>	Mean (\pm SE)	\pm SE	Max	Min	95% UCL	95% LCL
HIP	0	1731	1.22 (\pm 0.01)	0.01	5	1	1.24	1.19
	1	2782	1.26 (\pm 0.01)	0.01	6	1	1.28	1.23
	2	2479	1.31 (\pm 0.01)	0.01	6	1	1.34	1.29
	3	2344	1.37 (\pm 0.01)	0.01	7	1	1.40	1.34
	4	1708	1.48 (\pm 0.02)	0.02	7	1	1.52	1.45
	5	1766	1.46 (\pm 0.02)	0.02	6	1	1.49	1.42
	6	2051	1.51 (\pm 0.02)	0.02	9	1	1.55	1.48
	7	1907	1.63 (\pm 0.02)	0.02	8	1	1.67	1.59
	8	2089	1.68 (\pm 0.02)	0.02	7	1	1.72	1.64
	9	2180	1.88 (\pm 0.02)	0.02	9	1	1.93	1.83
	10	2022	2.18 (\pm 0.03)	0.03	15	1	2.24	2.11
PCS	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1	1166	1.03 (\pm 0.00)	0.00	2	1	1.04	1.02
	2	1145	1.14 (\pm 0.01)	0.01	4	1	1.16	1.12
	3	1249	1.19 (\pm 0.01)	0.01	4	1	1.22	1.17
	4	923	1.27 (\pm 0.02)	0.02	4	1	1.30	1.24
	5	982	1.32 (\pm 0.02)	0.02	5	1	1.36	1.28
	6	933	1.43 (\pm 0.02)	0.02	6	1	1.47	1.39
	7	933	1.50 (\pm 0.02)	0.02	5	1	1.54	1.45
	8	1108	1.56 (\pm 0.02)	0.02	5	1	1.61	1.52
	9	1118	1.71 (\pm 0.03)	0.03	6	1	1.76	1.65
	10	1188	2.08 (\pm 0.04)	0.04	10	1	2.16	2.00

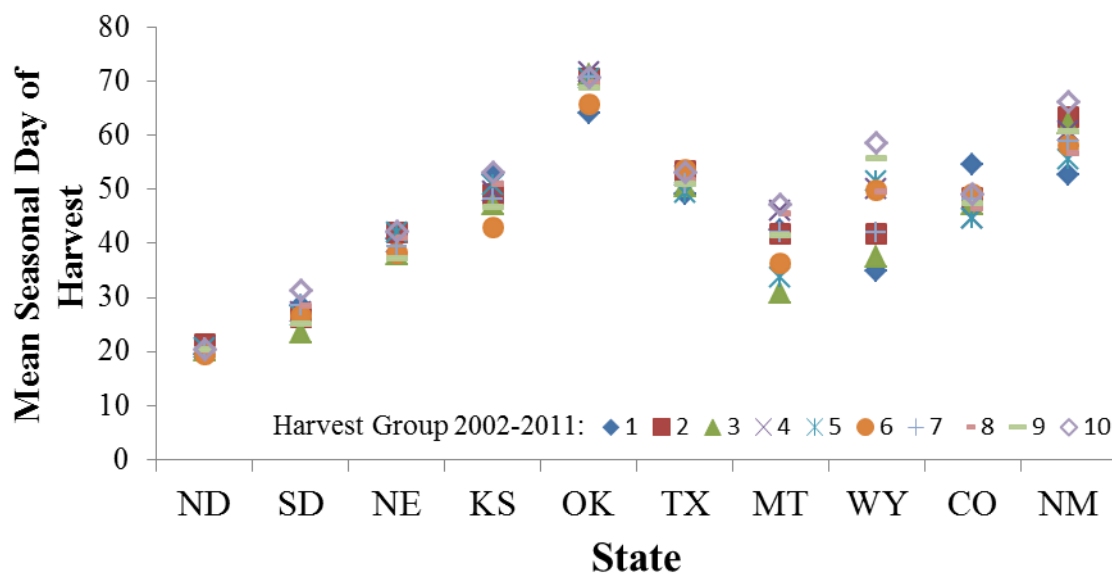
Appendix 2.F: Harvest group (10% of regulation period sample, stratified by seasonal harvest) estimates of individual Central Flyway states for measures of duck hunters behaviors of (A) days harvesting ducks (# of days when duck harvest occurred/hunter/season), (B) daily harvest (average daily bag/hunter/season), and (C) hunter mobility (# of counties where duck harvest occurred/hunter/season), derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.



Appendix 2.G: Harvest group (10% of regulation period sample, stratified by seasonal harvest) estimates for Central Flyway states for measures of duck hunters behaviors of (A) mallard selectivity (percent mallard harvest/hunter/season), (B) gender selectivity (percent female mallard harvest [mallards only] /hunter/season), and (C) daily female mallard harvest, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.



Appendix 2.H: Mean seasonal day of harvest (standardized for all states) for harvest groups (10% of each regulation period sample, stratified by seasonal harvest) for Central Flyway states, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.



Appendix 2.I: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) estimates for Central Flyway states for the measures of duck hunter behaviors of days harvesting ducks (# of days when duck harvest occurred/hunter/season), daily harvest (average daily bag/hunter/season), hunter mobility (# of counties where harvest occurred/hunter/season), mallard selectivity (percent mallard harvest/hunter/season), gender selectivity (percent female mallard harvest [mallards only] /hunter/season), and daily female mallard harvest, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
North Dakota	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	232	1.18 (\pm 0.03)	2	1	1.23	1.13
		2	252	1.76 (\pm 0.05)	4	1	1.85	1.67
		3	330	2.15 (\pm 0.05)	5	1	2.26	2.05
		4	268	2.90 (\pm 0.06)	6	1	3.02	2.77
		5	308	3.27 (\pm 0.07)	7	1	3.41	3.13
		6	299	3.56 (\pm 0.08)	9	1	3.71	3.41
		7	283	4.49 (\pm 0.09)	11	2	4.66	4.32
		8	308	5.26 (\pm 0.10)	10	1	5.45	5.07
		9	248	6.64 (\pm 0.14)	17	1	6.91	6.37
		10	145	9.86 (\pm 0.35)	22	1	10.55	9.16
	Daily Harvest: (Daily Bag)	1	216	1.35 (\pm 0.03)	2.00	1.00	1.41	1.29
		2	236	2.35 (\pm 0.06)	4.00	1.00	2.47	2.23
		3	314	3.08 (\pm 0.08)	6.00	1.00	3.25	2.92
		4	263	2.88 (\pm 0.07)	8.00	1.17	3.01	2.75
		5	275	3.30 (\pm 0.07)	9.00	1.20	3.45	3.16
		6	277	3.66 (\pm 0.08)	11.00	1.00	3.82	3.50
		7	248	3.75 (\pm 0.07)	8.00	1.45	3.89	3.61
		8	262	3.97 (\pm 0.07)	10.00	1.00	4.11	3.83
		9	216	4.34 (\pm 0.09)	15.00	1.93	4.52	4.17
		10	101	4.47 (\pm 0.15)	15.00	2.00	4.75	4.18
	Hunter Mobility: (# of counties where harvest occurred)	1	232	1.03 (\pm 0.01)	2	1	1.06	1.01
		2	252	1.17 (\pm 0.03)	4	1	1.22	1.12
		3	330	1.18 (\pm 0.02)	4	1	1.23	1.14
		4	268	1.25 (\pm 0.03)	4	1	1.31	1.20
		5	308	1.28 (\pm 0.03)	3	1	1.33	1.22
		6	299	1.30 (\pm 0.03)	5	1	1.37	1.24
		7	283	1.41 (\pm 0.04)	4	1	1.49	1.33
		8	308	1.51 (\pm 0.04)	5	1	1.59	1.43
		9	248	1.74 (\pm 0.06)	7	1	1.86	1.62
		10	145	2.23 (\pm 0.11)	6	1	2.44	2.01

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
North Dakota	Species Selectivity: (Percent Mallard)	1	235	56.81 (\pm 3.03)	100.00	0.00	62.74	50.87
		2	257	50.10 (\pm 2.34)	100.00	0.00	54.68	45.51
		3	337	44.62 (\pm 1.91)	100.00	0.00	48.36	40.87
		4	271	44.44 (\pm 1.98)	100.00	0.00	48.33	40.56
		5	311	46.02 (\pm 1.86)	100.00	0.00	49.66	42.38
		6	302	41.66 (\pm 1.72)	100.00	0.00	45.03	38.29
		7	284	42.95 (\pm 1.72)	100.00	0.00	46.33	39.58
		8	310	42.58 (\pm 1.61)	100.00	0.00	45.74	39.42
		9	251	41.03 (\pm 1.65)	100.00	0.00	44.26	37.80
		10	145	37.81 (\pm 2.12)	100.00	0.00	41.96	33.66
	Gender Selectivity: (Percent Female Mallard)	1	145	30.69 (\pm 3.57)	100.00	0.00	37.68	23.69
		2	196	34.14 (\pm 2.59)	100.00	0.00	39.22	29.06
		3	263	31.17 (\pm 2.09)	100.00	0.00	35.27	27.08
		4	235	32.34 (\pm 2.19)	100.00	0.00	36.62	28.06
		5	275	27.52 (\pm 1.73)	100.00	0.00	30.91	24.13
		6	275	30.94 (\pm 1.73)	100.00	0.00	34.33	27.55
		7	264	29.39 (\pm 1.55)	100.00	0.00	32.44	26.35
		8	297	30.42 (\pm 1.48)	100.00	0.00	33.32	27.51
		9	246	33.19 (\pm 1.57)	100.00	0.00	36.26	30.12
		10	142	33.22 (\pm 1.99)	100.00	0.00	37.11	29.33
	Daily Female Mallard Harvest	1	156	0.39 (\pm 0.05)	2	0	0.48	0.30
		2	267	0.52 (\pm 0.04)	2	0	0.59	0.45
		3	415	0.57 (\pm 0.03)	4	0	0.64	0.51
		4	470	0.52 (\pm 0.03)	3	0	0.58	0.46
		5	648	0.52 (\pm 0.03)	3	0	0.58	0.47
		6	708	0.59 (\pm 0.03)	4	0	0.64	0.54
		7	801	0.59 (\pm 0.02)	4	0	0.64	0.54
		8	1091	0.62 (\pm 0.02)	4	0	0.66	0.58
		9	1143	0.68 (\pm 0.02)	5	0	0.72	0.63
		10	909	0.67 (\pm 0.03)	7	0	0.72	0.62

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
South Dakota	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	156	1.15 (\pm 0.03)	2	1	1.21	1.10
		2	138	1.67 (\pm 0.07)	4	1	1.80	1.53
		3	165	2.10 (\pm 0.08)	5	1	2.26	1.94
		4	103	2.79 (\pm 0.10)	6	1	2.98	2.59
		5	123	3.44 (\pm 0.15)	9	1	3.73	3.15
		6	132	3.96 (\pm 0.14)	11	1	4.25	3.68
		7	123	4.79 (\pm 0.16)	11	1	5.10	4.48
		8	129	5.55 (\pm 0.18)	14	1	5.91	5.19
		9	100	7.31 (\pm 0.21)	15	3	7.72	6.90
		10	116	11.92 (\pm 0.50)	31	3	12.91	10.93
	Daily Harvest: (Daily Bag)	1	145	1.36 (\pm 0.04)	2.00	1.00	1.44	1.28
		2	133	2.54 (\pm 0.09)	4.00	1.00	2.72	2.37
		3	158	3.27 (\pm 0.12)	6.00	1.00	3.51	3.03
		4	100	3.00 (\pm 0.11)	8.00	1.17	3.22	2.77
		5	117	3.25 (\pm 0.14)	10.00	1.00	3.52	2.99
		6	118	3.27 (\pm 0.11)	6.50	1.00	3.48	3.05
		7	112	3.58 (\pm 0.11)	7.50	1.36	3.79	3.36
		8	116	3.75 (\pm 0.10)	6.67	1.36	3.95	3.54
		9	83	4.01 (\pm 0.10)	6.00	1.80	4.21	3.81
		10	77	4.30 (\pm 0.11)	8.53	2.60	4.52	4.08
	Hunter Mobility: (# of counties where harvest occurred)	1	156	1.03 (\pm 0.01)	2	1	1.06	1.00
		2	138	1.17 (\pm 0.04)	3	1	1.24	1.10
		3	165	1.15 (\pm 0.03)	3	1	1.21	1.09
		4	103	1.34 (\pm 0.06)	4	1	1.47	1.21
		5	123	1.41 (\pm 0.06)	4	1	1.53	1.28
		6	132	1.51 (\pm 0.06)	3	1	1.62	1.40
		7	123	1.57 (\pm 0.08)	5	1	1.72	1.42
		8	129	1.62 (\pm 0.07)	4	1	1.76	1.48
		9	100	1.95 (\pm 0.11)	5	1	2.17	1.73
		10	116	2.17 (\pm 0.16)	12	1	2.49	1.85

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
South Dakota	Species Selectivity: (Percent Mallard)	1	157	55.73 (\pm 3.78)	100.00	0.00	63.14	48.32
		2	139	46.76 (\pm 3.24)	100.00	0.00	53.11	40.41
		3	166	44.76 (\pm 2.92)	100.00	0.00	50.48	39.04
		4	103	41.19 (\pm 3.36)	100.00	0.00	47.78	34.61
		5	123	48.05 (\pm 2.82)	100.00	0.00	53.57	42.53
		6	132	44.33 (\pm 2.80)	100.00	0.00	49.82	38.83
		7	124	46.35 (\pm 2.68)	100.00	0.00	51.62	41.09
		8	129	48.56 (\pm 2.60)	100.00	0.00	53.65	43.47
		9	100	43.32 (\pm 2.71)	100.00	0.00	48.62	38.01
		10	116	45.46 (\pm 2.55)	100.00	3.57	50.46	40.46
	Gender Selectivity: (Percent Female Mallard)	1	94	26.06 (\pm 4.12)	100.00	0.00	34.15	17.98
		2	98	30.10 (\pm 3.65)	100.00	0.00	37.26	22.94
		3	123	29.13 (\pm 3.00)	100.00	0.00	35.02	23.24
		4	86	24.42 (\pm 3.23)	100.00	0.00	30.76	18.08
		5	114	27.25 (\pm 2.45)	100.00	0.00	32.05	22.45
		6	122	28.96 (\pm 2.77)	100.00	0.00	34.39	23.53
		7	114	23.69 (\pm 2.24)	100.00	0.00	28.08	19.31
		8	128	25.15 (\pm 2.27)	100.00	0.00	29.60	20.70
		9	98	27.23 (\pm 2.35)	100.00	0.00	31.83	22.62
		10	116	22.61 (\pm 1.48)	75.00	0.00	25.50	19.71
	Daily Female Mallard Harvest	1	104	0.31 (\pm 0.05)	1	0	0.40	0.22
		2	141	0.47 (\pm 0.05)	2	0	0.57	0.37
		3	199	0.53 (\pm 0.05)	3	0	0.63	0.44
		4	172	0.42 (\pm 0.05)	3	0	0.51	0.33
		5	289	0.49 (\pm 0.03)	2	0	0.55	0.42
		6	321	0.48 (\pm 0.04)	3	0	0.55	0.41
		7	393	0.44 (\pm 0.03)	2	0	0.50	0.38
		8	473	0.51 (\pm 0.03)	4	0	0.58	0.45
		9	476	0.51 (\pm 0.03)	3	0	0.57	0.45
		10	882	0.53 (\pm 0.02)	7	0	0.58	0.48

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Nebraska	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	125	1.14 (\pm 0.03)	2	1	1.21	1.08
		2	120	1.68 (\pm 0.07)	4	1	1.81	1.54
		3	95	2.31 (\pm 0.11)	5	1	2.51	2.10
		4	88	3.02 (\pm 0.14)	6	1	3.29	2.75
		5	74	3.58 (\pm 0.18)	9	1	3.93	3.24
		6	82	4.17 (\pm 0.18)	8	1	4.53	3.81
		7	67	4.93 (\pm 0.28)	12	1	5.46	4.39
		8	121	6.36 (\pm 0.24)	14	1	6.82	5.89
		9	97	8.90 (\pm 0.36)	18	1	9.59	8.20
		10	123	13.75 (\pm 0.60)	35	1	14.92	12.58
	Daily Harvest: (Daily Bag)	1	116	1.38 (\pm 0.04)	2.00	1.00	1.47	1.29
		2	113	2.52 (\pm 0.10)	4.00	1.00	2.72	2.33
		3	86	2.82 (\pm 0.14)	6.00	1.20	3.10	2.54
		4	84	2.80 (\pm 0.12)	8.00	1.00	3.03	2.57
		5	71	2.93 (\pm 0.16)	10.00	1.00	3.25	2.61
		6	80	3.02 (\pm 0.14)	6.00	1.00	3.29	2.75
		7	63	3.29 (\pm 0.17)	8.00	1.00	3.62	2.96
		8	107	3.26 (\pm 0.11)	6.00	1.00	3.48	3.04
		9	82	3.27 (\pm 0.13)	9.00	1.00	3.52	3.02
		10	90	3.63 (\pm 0.11)	9.00	2.00	3.83	3.42
	Hunter Mobility: (# of counties where harvest occurred)	1	125	1.05 (\pm 0.02)	2	1	1.09	1.01
		2	120	1.14 (\pm 0.04)	3	1	1.21	1.07
		3	95	1.13 (\pm 0.04)	3	1	1.21	1.04
		4	88	1.23 (\pm 0.06)	4	1	1.34	1.12
		5	74	1.34 (\pm 0.08)	5	1	1.49	1.18
		6	82	1.35 (\pm 0.07)	4	1	1.48	1.22
		7	67	1.48 (\pm 0.09)	4	1	1.65	1.30
		8	121	1.60 (\pm 0.08)	4	1	1.76	1.43
		9	97	1.67 (\pm 0.09)	5	1	1.84	1.50
		10	123	1.99 (\pm 0.10)	6	1	2.18	1.80

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Nebraska	Species Selectivity: (Percent Mallard)	1	125	65.60 (\pm 3.99)	100.00	0.00	73.43	57.77
		2	121	57.71 (\pm 3.65)	100.00	0.00	64.88	50.55
		3	97	52.37 (\pm 3.91)	100.00	0.00	60.03	44.71
		4	88	56.07 (\pm 3.71)	100.00	0.00	63.34	48.79
		5	74	55.46 (\pm 4.11)	100.00	0.00	63.51	47.41
		6	82	58.82 (\pm 3.74)	100.00	0.00	66.15	51.48
		7	68	53.49 (\pm 4.13)	100.00	0.00	61.59	45.39
		8	121	55.39 (\pm 2.86)	100.00	0.00	61.00	49.79
		9	97	48.46 (\pm 2.93)	100.00	0.00	54.21	42.71
		10	123	56.85 (\pm 2.38)	100.00	0.00	61.51	52.20
	Gender Selectivity: (Percent Female Mallard)	1	89	23.60 (\pm 4.31)	100.00	0.00	32.04	15.15
		2	93	26.97 (\pm 3.41)	100.00	0.00	33.66	20.28
		3	76	21.49 (\pm 3.19)	100.00	0.00	27.75	15.24
		4	81	24.10 (\pm 2.89)	100.00	0.00	29.77	18.43
		5	66	18.25 (\pm 3.20)	100.00	0.00	24.52	11.99
		6	74	19.50 (\pm 2.19)	66.67	0.00	23.79	15.21
		7	60	18.91 (\pm 2.53)	100.00	0.00	23.87	13.96
		8	116	21.20 (\pm 1.63)	100.00	0.00	24.40	18.00
		9	92	21.31 (\pm 1.90)	100.00	0.00	25.03	17.59
		10	122	21.29 (\pm 1.61)	100.00	0.00	24.46	18.13
	Daily Female Mallard Harvest	1	98	0.26 (\pm 0.05)	2	0	0.35	0.16
		2	129	0.47 (\pm 0.05)	2	0	0.58	0.37
		3	129	0.40 (\pm 0.05)	3	0	0.50	0.29
		4	182	0.45 (\pm 0.05)	2	0	0.54	0.36
		5	179	0.39 (\pm 0.05)	3	0	0.48	0.29
		6	238	0.44 (\pm 0.04)	3	0	0.52	0.35
		7	223	0.43 (\pm 0.04)	2	0	0.52	0.35
		8	527	0.47 (\pm 0.03)	3	0	0.53	0.42
		9	568	0.43 (\pm 0.03)	3	0	0.48	0.38
		10	1265	0.47 (\pm 0.02)	4	0	0.51	0.43

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Kansas	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	109	1.16 (\pm 0.03)	2	1	1.22	1.09
		2	103	1.83 (\pm 0.08)	4	1	1.99	1.68
		3	104	2.35 (\pm 0.11)	6	1	2.57	2.12
		4	57	2.79 (\pm 0.12)	6	1	3.03	2.55
		5	73	3.44 (\pm 0.16)	7	1	3.76	3.12
		6	57	4.23 (\pm 0.19)	9	1	4.59	3.86
		7	66	4.95 (\pm 0.24)	10	1	5.43	4.48
		8	85	6.06 (\pm 0.26)	13	1	6.56	5.56
		9	83	7.73 (\pm 0.36)	15	1	8.44	7.03
		10	108	12.88 (\pm 0.55)	32	1	13.95	11.81
	Daily Harvest: (Daily Bag)	1	103	1.27 (\pm 0.04)	2.00	1.00	1.36	1.19
		2	93	2.22 (\pm 0.10)	4.00	1.00	2.42	2.02
		3	94	2.91 (\pm 0.15)	6.00	1.00	3.20	2.61
		4	54	2.93 (\pm 0.14)	7.00	1.00	3.20	2.66
		5	68	3.18 (\pm 0.15)	5.00	1.43	3.48	2.89
		6	56	3.01 (\pm 0.12)	5.50	1.33	3.25	2.77
		7	61	3.16 (\pm 0.13)	5.67	1.00	3.41	2.91
		8	78	3.45 (\pm 0.12)	6.00	1.46	3.69	3.20
		9	76	3.45 (\pm 0.12)	6.11	1.00	3.68	3.21
		10	75	3.72 (\pm 0.09)	5.72	2.00	3.90	3.54
	Hunter Mobility: (# of counties where harvest occurred)	1	109	1.04 (\pm 0.02)	2	1	1.07	1.00
		2	103	1.14 (\pm 0.03)	2	1	1.20	1.07
		3	104	1.33 (\pm 0.05)	3	1	1.43	1.23
		4	57	1.21 (\pm 0.05)	2	1	1.32	1.10
		5	73	1.32 (\pm 0.06)	3	1	1.43	1.20
		6	57	1.37 (\pm 0.08)	3	1	1.52	1.22
		7	66	1.68 (\pm 0.10)	4	1	1.88	1.49
		8	85	1.60 (\pm 0.08)	4	1	1.75	1.45
		9	83	1.69 (\pm 0.11)	6	1	1.90	1.47
		10	108	2.19 (\pm 0.13)	7	1	2.45	1.94

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Kansas	Species Selectivity: (Percent Mallard)	1	109	52.29 (\pm 4.58)	100.00	0.00	61.27	43.32
		2	103	49.27 (\pm 3.96)	100.00	0.00	57.03	41.51
		3	104	44.13 (\pm 3.58)	100.00	0.00	51.16	37.11
		4	57	52.73 (\pm 4.64)	100.00	0.00	61.82	43.63
		5	73	50.62 (\pm 3.92)	100.00	0.00	58.31	42.93
		6	57	44.44 (\pm 3.91)	100.00	0.00	52.10	36.77
		7	66	48.39 (\pm 3.65)	100.00	0.00	55.54	41.24
		8	85	51.27 (\pm 3.43)	100.00	0.00	57.99	44.55
		9	84	48.13 (\pm 3.18)	100.00	3.85	54.36	41.89
		10	108	48.46 (\pm 2.53)	100.00	0.00	53.42	43.50
	Gender Selectivity: (Percent Female Mallard)	1	62	23.39 (\pm 4.97)	100.00	0.00	33.14	13.64
		2	72	19.10 (\pm 3.23)	100.00	0.00	25.43	12.76
		3	78	21.84 (\pm 3.28)	100.00	0.00	28.27	15.41
		4	49	17.77 (\pm 3.61)	100.00	0.00	24.83	10.70
		5	66	17.52 (\pm 3.17)	100.00	0.00	23.73	11.31
		6	48	19.61 (\pm 2.72)	66.67	0.00	24.94	14.28
		7	61	21.34 (\pm 2.77)	100.00	0.00	26.78	15.91
		8	83	17.60 (\pm 2.26)	100.00	0.00	22.02	13.18
		9	84	21.76 (\pm 2.42)	100.00	0.00	26.50	17.02
		10	103	17.33 (\pm 1.43)	100.00	0.00	20.14	14.52
	Daily Female Mallard Harvest	1	69	0.28 (\pm 0.05)	1	0	0.38	0.17
		2	107	0.30 (\pm 0.05)	2	0	0.39	0.21
		3	125	0.38 (\pm 0.05)	2	0	0.48	0.29
		4	111	0.30 (\pm 0.04)	1	0	0.38	0.21
		5	147	0.29 (\pm 0.04)	2	0	0.37	0.22
		6	143	0.40 (\pm 0.05)	2	0	0.49	0.31
		7	207	0.42 (\pm 0.04)	2	0	0.49	0.35
		8	331	0.34 (\pm 0.03)	2	0	0.40	0.28
		9	409	0.41 (\pm 0.03)	3	0	0.46	0.35
		10	958	0.39 (\pm 0.02)	2	0	0.43	0.36

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Oklahoma	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	69	1.13 (\pm 0.04)	2	1	1.21	1.05
		2	96	1.64 (\pm 0.08)	4	1	1.79	1.48
		3	107	2.00 (\pm 0.09)	4	1	2.17	1.83
		4	76	2.78 (\pm 0.13)	6	1	3.02	2.53
		5	68	3.07 (\pm 0.17)	7	1	3.40	2.75
		6	84	3.88 (\pm 0.17)	7	1	4.21	3.56
		7	92	5.10 (\pm 0.20)	10	1	5.49	4.70
		8	110	5.94 (\pm 0.18)	11	2	6.29	5.58
		9	189	7.81 (\pm 0.25)	34	1	8.29	7.33
		10	192	13.47 (\pm 0.55)	48	1	14.54	12.40
	Daily Harvest: (Daily Bag)	1	64	1.36 (\pm 0.06)	2.00	1.00	1.48	1.25
		2	90	2.52 (\pm 0.10)	4.00	1.00	2.73	2.32
		3	103	3.44 (\pm 0.17)	6.00	1.25	3.77	3.12
		4	76	2.91 (\pm 0.10)	4.00	1.00	3.10	2.71
		5	67	3.54 (\pm 0.17)	10.00	1.29	3.87	3.21
		6	85	3.37 (\pm 0.14)	6.50	1.00	3.64	3.10
		7	90	3.42 (\pm 0.14)	7.50	1.56	3.69	3.14
		8	104	3.54 (\pm 0.10)	6.33	1.82	3.74	3.34
		9	152	3.86 (\pm 0.16)	25.00	1.00	4.18	3.53
		10	135	3.83 (\pm 0.08)	6.00	1.00	3.99	3.66
	Hunter Mobility: (# of counties where harvest occurred)	1	69	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	96	1.15 (\pm 0.04)	3	1	1.22	1.07
		3	107	1.21 (\pm 0.05)	4	1	1.30	1.11
		4	76	1.24 (\pm 0.06)	3	1	1.35	1.13
		5	68	1.44 (\pm 0.09)	4	1	1.63	1.26
		6	84	1.51 (\pm 0.08)	5	1	1.67	1.36
		7	92	1.59 (\pm 0.08)	4	1	1.74	1.43
		8	110	1.70 (\pm 0.09)	5	1	1.87	1.53
		9	189	1.71 (\pm 0.07)	7	1	1.86	1.57
		10	192	1.98 (\pm 0.08)	8	1	2.14	1.82

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Oklahoma	Species Selectivity: (Percent Mallard)	1	69	44.20 (\pm 5.42)	100.00	0.00	54.82	33.59
		2	96	47.57 (\pm 3.71)	100.00	0.00	54.84	40.30
		3	111	47.84 (\pm 3.23)	100.00	0.00	54.17	41.51
		4	77	50.32 (\pm 4.04)	100.00	0.00	58.24	42.41
		5	69	47.05 (\pm 3.95)	100.00	0.00	54.80	39.30
		6	85	46.18 (\pm 3.15)	100.00	0.00	52.35	40.01
		7	93	50.30 (\pm 2.84)	100.00	0.00	55.86	44.73
		8	110	43.69 (\pm 2.46)	100.00	0.00	48.51	38.88
		9	190	45.71 (\pm 1.85)	100.00	0.00	49.34	42.07
		10	192	46.92 (\pm 1.75)	100.00	0.00	50.35	43.50
	Gender Selectivity: (Percent Female Mallard)	1	35	22.86 (\pm 7.20)	100.00	0.00	36.97	8.74
		2	73	30.37 (\pm 4.24)	100.00	0.00	38.68	22.05
		3	92	22.64 (\pm 2.87)	100.00	0.00	28.26	17.03
		4	65	25.11 (\pm 2.99)	100.00	0.00	30.97	19.25
		5	64	15.48 (\pm 2.48)	80.00	0.00	20.35	10.61
		6	75	23.65 (\pm 2.62)	100.00	0.00	28.78	18.52
		7	88	23.81 (\pm 2.17)	100.00	0.00	28.05	19.57
		8	106	22.89 (\pm 1.71)	66.67	0.00	26.24	19.54
		9	186	23.49 (\pm 1.24)	83.33	0.00	25.92	21.05
		10	190	23.57 (\pm 1.34)	100.00	0.00	26.19	20.95
	Daily Female Mallard Harvest	1	40	0.20 (\pm 0.06)	1	0	0.33	0.07
		2	90	0.59 (\pm 0.07)	2	0	0.73	0.45
		3	147	0.46 (\pm 0.05)	2	0	0.56	0.37
		4	131	0.53 (\pm 0.06)	2	0	0.65	0.42
		5	134	0.40 (\pm 0.06)	4	0	0.51	0.28
		6	217	0.45 (\pm 0.04)	3	0	0.53	0.36
		7	311	0.50 (\pm 0.04)	4	0	0.59	0.42
		8	405	0.50 (\pm 0.03)	4	0	0.57	0.44
		9	974	0.54 (\pm 0.02)	4	0	0.59	0.50
		10	1700	0.51 (\pm 0.02)	5	0	0.54	0.48

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Texas	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	186	1.12 (\pm 0.02)	2	1	1.17	1.08
		2	187	1.70 (\pm 0.06)	4	1	1.81	1.59
		3	205	2.11 (\pm 0.08)	6	1	2.25	1.96
		4	152	3.23 (\pm 0.10)	7	1	3.43	3.03
		5	157	3.39 (\pm 0.12)	8	1	3.63	3.16
		6	126	4.30 (\pm 0.15)	9	1	4.60	4.00
		7	156	5.06 (\pm 0.17)	12	1	5.39	4.74
		8	183	6.32 (\pm 0.15)	13	1	6.62	6.02
		9	233	8.10 (\pm 0.18)	18	1	8.45	7.75
		10	295	15.02 (\pm 0.43)	52	1	15.85	14.18
	Daily Harvest: (Daily Bag)	1	174	1.40 (\pm 0.04)	2.00	1.00	1.47	1.33
		2	173	2.44 (\pm 0.07)	4.00	1.00	2.58	2.29
		3	192	3.32 (\pm 0.12)	6.00	1.00	3.55	3.10
		4	145	2.66 (\pm 0.09)	7.00	1.14	2.83	2.49
		5	145	3.45 (\pm 0.14)	10.00	1.13	3.72	3.18
		6	120	3.20 (\pm 0.13)	12.00	1.00	3.46	2.93
		7	148	3.30 (\pm 0.10)	7.50	1.00	3.50	3.10
		8	173	3.41 (\pm 0.08)	6.33	1.77	3.57	3.25
		9	190	3.70 (\pm 0.08)	10.00	1.00	3.86	3.54
		10	193	3.91 (\pm 0.07)	6.50	1.16	4.04	3.78
	Hunter Mobility: (# of counties where harvest occurred)	1	186	1.04 (\pm 0.01)	2	1	1.07	1.01
		2	187	1.12 (\pm 0.02)	2	1	1.16	1.07
		3	205	1.21 (\pm 0.03)	3	1	1.28	1.14
		4	152	1.39 (\pm 0.05)	3	1	1.49	1.30
		5	157	1.32 (\pm 0.05)	5	1	1.42	1.22
		6	126	1.65 (\pm 0.08)	6	1	1.80	1.50
		7	156	1.50 (\pm 0.06)	5	1	1.62	1.38
		8	183	1.62 (\pm 0.07)	5	1	1.75	1.49
		9	233	1.68 (\pm 0.06)	6	1	1.80	1.56
		10	295	2.28 (\pm 0.09)	10	1	2.46	2.10

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Texas	Species Selectivity: (Percent Mallard)	1	186	13.98 (\pm 2.34)	100.00	0.00	18.57	9.39
		2	187	16.84 (\pm 2.12)	100.00	0.00	20.99	12.70
		3	205	12.05 (\pm 1.54)	100.00	0.00	15.06	9.04
		4	152	12.48 (\pm 1.74)	100.00	0.00	15.89	9.06
		5	157	12.57 (\pm 1.64)	90.00	0.00	15.79	9.35
		6	126	10.61 (\pm 1.62)	92.31	0.00	13.78	7.44
		7	157	15.36 (\pm 1.85)	100.00	0.00	18.98	11.73
		8	184	11.80 (\pm 1.29)	77.78	0.00	14.33	9.27
		9	233	12.91 (\pm 1.22)	100.00	0.00	15.30	10.52
		10	295	15.57 (\pm 1.12)	94.34	0.00	17.76	13.38
	Gender Selectivity: (Percent Female Mallard)	1	32	25.00 (\pm 7.45)	100.00	0.00	39.59	10.41
		2	60	32.36 (\pm 5.05)	100.00	0.00	42.25	22.47
		3	65	32.21 (\pm 4.89)	100.00	0.00	41.78	22.63
		4	53	29.78 (\pm 5.02)	100.00	0.00	39.62	19.95
		5	65	33.04 (\pm 4.36)	100.00	0.00	41.58	24.49
		6	50	28.02 (\pm 4.78)	100.00	0.00	37.40	18.64
		7	82	25.90 (\pm 3.38)	100.00	0.00	32.53	19.26
		8	91	35.74 (\pm 3.27)	100.00	0.00	42.15	29.33
		9	136	34.26 (\pm 2.69)	100.00	0.00	39.54	28.99
		10	227	32.16 (\pm 2.02)	100.00	0.00	36.13	28.19
	Daily Female Mallard Harvest	1	34	0.26 (\pm 0.08)	1	0	0.42	0.11
		2	78	0.44 (\pm 0.06)	2	0	0.56	0.31
		3	83	0.49 (\pm 0.08)	4	0	0.64	0.35
		4	94	0.43 (\pm 0.06)	3	0	0.55	0.31
		5	109	0.53 (\pm 0.06)	2	0	0.64	0.42
		6	106	0.42 (\pm 0.06)	3	0	0.54	0.31
		7	193	0.42 (\pm 0.04)	2	0	0.51	0.34
		8	245	0.51 (\pm 0.04)	3	0	0.59	0.44
		9	453	0.51 (\pm 0.03)	3	0	0.56	0.45
		10	1236	0.51 (\pm 0.02)	3	0	0.54	0.47

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Montana	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	75	1.13 (\pm 0.04)	2	1	1.21	1.06
		2	67	1.75 (\pm 0.09)	3	1	1.92	1.57
		3	52	2.04 (\pm 0.13)	5	1	2.29	1.79
		4	43	2.58 (\pm 0.15)	6	1	2.87	2.29
		5	41	3.29 (\pm 0.25)	8	1	3.79	2.79
		6	34	3.79 (\pm 0.21)	6	2	4.21	3.38
		7	20	4.30 (\pm 0.33)	8	1	4.95	3.65
		8	29	6.72 (\pm 0.55)	14	1	7.81	5.64
		9	29	8.62 (\pm 0.75)	23	1	10.09	7.15
		10	43	11.21 (\pm 0.75)	22	3	12.69	9.73
	Daily Harvest: (Daily Bag)	1	70	1.25 (\pm 0.05)	2.00	1.00	1.35	1.16
		2	59	2.34 (\pm 0.13)	4.00	1.00	2.59	2.09
		3	49	3.24 (\pm 0.20)	6.00	1.20	3.64	2.85
		4	40	3.13 (\pm 0.16)	7.00	1.60	3.44	2.83
		5	38	3.48 (\pm 0.27)	10.00	1.25	4.01	2.95
		6	31	3.28 (\pm 0.19)	6.00	1.83	3.65	2.90
		7	19	3.61 (\pm 0.24)	5.67	1.88	4.09	3.13
		8	25	3.24 (\pm 0.24)	6.67	1.50	3.71	2.76
		9	25	3.26 (\pm 0.15)	4.33	1.35	3.55	2.96
		10	26	3.57 (\pm 0.17)	5.00	2.00	3.91	3.22
	Hunter Mobility: (# of counties where harvest occurred)	1	75	1.03 (\pm 0.02)	2	1	1.06	0.99
		2	67	1.15 (\pm 0.04)	2	1	1.24	1.06
		3	52	1.10 (\pm 0.04)	2	1	1.18	1.02
		4	43	1.28 (\pm 0.08)	3	1	1.44	1.12
		5	41	1.22 (\pm 0.07)	2	1	1.35	1.09
		6	34	1.32 (\pm 0.09)	3	1	1.50	1.14
		7	20	1.20 (\pm 0.09)	2	1	1.38	1.02
		8	29	1.41 (\pm 0.12)	3	1	1.64	1.19
		9	29	1.62 (\pm 0.14)	4	1	1.90	1.34
		10	43	1.58 (\pm 0.14)	5	1	1.86	1.30

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Montana	Species Selectivity: (Percent Mallard)	1	77	68.83 (\pm 4.98)	100.00	0.00	78.59	59.07
		2	67	72.14 (\pm 4.24)	100.00	0.00	80.45	63.83
		3	52	68.01 (\pm 4.85)	100.00	0.00	77.52	58.51
		4	43	75.12 (\pm 4.38)	100.00	0.00	83.72	66.53
		5	41	60.43 (\pm 5.06)	100.00	0.00	70.36	50.51
		6	34	59.09 (\pm 5.28)	100.00	9.09	69.43	48.75
		7	20	61.03 (\pm 7.25)	100.00	6.25	75.24	46.82
		8	29	69.55 (\pm 5.78)	100.00	5.56	80.87	58.23
		9	29	67.93 (\pm 5.67)	100.00	0.00	79.04	56.82
		10	43	71.45 (\pm 4.56)	100.00	0.00	80.40	62.51
	Gender Selectivity: (Percent Female Mallard)	1	57	26.32 (\pm 5.47)	100.00	0.00	37.04	15.59
		2	60	35.69 (\pm 4.74)	100.00	0.00	44.98	26.41
		3	47	21.45 (\pm 3.47)	100.00	0.00	28.25	14.66
		4	41	26.24 (\pm 3.72)	100.00	0.00	33.54	18.94
		5	40	28.92 (\pm 4.65)	100.00	0.00	38.03	19.80
		6	34	26.66 (\pm 4.19)	100.00	0.00	34.87	18.45
		7	20	27.83 (\pm 5.30)	100.00	0.00	38.22	17.45
		8	29	27.97 (\pm 4.56)	100.00	0.00	36.91	19.04
		9	28	24.67 (\pm 4.56)	100.00	0.00	33.61	15.73
		10	42	17.33 (\pm 2.29)	50.00	0.00	21.81	12.85
	Daily Female Mallard Harvest	1	62	0.29 (\pm 0.06)	1	0	0.40	0.18
		2	93	0.55 (\pm 0.07)	2	0	0.68	0.41
		3	85	0.51 (\pm 0.07)	2	0	0.64	0.37
		4	96	0.56 (\pm 0.08)	2	0	0.71	0.42
		5	100	0.66 (\pm 0.08)	4	0	0.82	0.50
		6	94	0.67 (\pm 0.08)	3	0	0.83	0.51
		7	66	0.56 (\pm 0.08)	3	0	0.73	0.40
		8	150	0.52 (\pm 0.05)	2	0	0.63	0.41
		9	210	0.49 (\pm 0.04)	3	0	0.57	0.40
		10	415	0.55 (\pm 0.04)	6	0	0.63	0.48

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Wyoming	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	48	1.21 (\pm 0.06)	2	1	1.32	1.09
		2	33	1.64 (\pm 0.16)	4	1	1.94	1.33
		3	52	2.15 (\pm 0.14)	4	1	2.43	1.88
		4	42	3.64 (\pm 0.26)	8	1	4.15	3.14
		5	42	4.17 (\pm 0.27)	9	2	4.70	3.63
		6	37	4.89 (\pm 0.34)	12	2	5.56	4.22
		7	29	6.34 (\pm 0.55)	15	1	7.42	5.27
		8	45	5.82 (\pm 0.43)	14	1	6.66	4.98
		9	45	9.40 (\pm 0.53)	17	1	10.43	8.37
		10	39	14.49 (\pm 1.21)	37	1	16.86	12.11
	Daily Harvest: (Daily Bag)	1	44	1.31 (\pm 0.07)	2.00	1.00	1.44	1.17
		2	33	2.63 (\pm 0.19)	4.00	1.00	3.00	2.26
		3	44	3.09 (\pm 0.24)	6.00	1.00	3.56	2.61
		4	40	2.36 (\pm 0.14)	4.00	1.00	2.63	2.10
		5	39	2.71 (\pm 0.19)	5.00	1.00	3.09	2.33
		6	33	2.83 (\pm 0.18)	5.50	1.08	3.19	2.47
		7	27	2.52 (\pm 0.16)	4.25	1.00	2.83	2.21
		8	41	3.41 (\pm 0.18)	6.33	1.50	3.78	3.05
		9	37	2.94 (\pm 0.15)	4.83	1.00	3.23	2.65
		10	26	3.27 (\pm 0.17)	5.00	1.00	3.60	2.93
	Hunter Mobility: (# of counties where harvest occurred)	1	48	1.02 (\pm 0.02)	2	1	1.06	0.98
		2	33	1.09 (\pm 0.05)	2	1	1.19	0.99
		3	52	1.04 (\pm 0.03)	2	1	1.09	0.99
		4	42	1.07 (\pm 0.04)	2	1	1.15	0.99
		5	42	1.17 (\pm 0.06)	2	1	1.28	1.05
		6	37	1.16 (\pm 0.06)	2	1	1.28	1.04
		7	29	1.41 (\pm 0.12)	3	1	1.64	1.19
		8	45	1.22 (\pm 0.07)	3	1	1.36	1.08
		9	45	1.24 (\pm 0.08)	3	1	1.40	1.09
		10	39	1.59 (\pm 0.14)	5	1	1.86	1.32

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Wyoming	Species Selectivity: (Percent Mallard)	1	48	59.38 (\pm 6.43)	100.00	0.00	71.98	46.77
		2	34	68.87 (\pm 6.82)	100.00	0.00	82.23	55.51
		3	52	46.47 (\pm 4.85)	100.00	0.00	55.98	36.97
		4	42	57.19 (\pm 5.01)	100.00	0.00	67.01	47.38
		5	42	66.35 (\pm 4.48)	100.00	10.00	75.12	57.58
		6	37	54.30 (\pm 4.85)	100.00	0.00	63.81	44.78
		7	29	58.97 (\pm 5.99)	100.00	0.00	70.72	47.22
		8	45	60.67 (\pm 4.72)	100.00	0.00	69.92	51.43
		9	45	54.61 (\pm 4.01)	100.00	0.00	62.46	46.75
		10	39	62.91 (\pm 5.00)	100.00	0.00	72.72	53.11
	Gender Selectivity: (Percent Female Mallard)	1	33	22.73 (\pm 6.91)	100.00	0.00	36.28	9.18
		2	28	15.18 (\pm 4.58)	100.00	0.00	24.15	6.21
		3	42	22.98 (\pm 4.55)	100.00	0.00	31.89	14.06
		4	39	29.17 (\pm 4.68)	100.00	0.00	38.34	19.99
		5	42	27.70 (\pm 4.40)	100.00	0.00	36.33	19.08
		6	35	25.22 (\pm 4.48)	100.00	0.00	34.00	16.43
		7	27	23.40 (\pm 5.56)	100.00	0.00	34.29	12.50
		8	43	22.01 (\pm 3.57)	100.00	0.00	29.00	15.02
		9	43	15.38 (\pm 2.16)	53.85	0.00	19.62	11.14
		10	35	14.50 (\pm 1.88)	44.44	0.00	18.18	10.82
	Daily Female Mallard Harvest	1	34	0.26 (\pm 0.08)	1	0	0.42	0.11
		2	39	0.33 (\pm 0.09)	2	0	0.51	0.15
		3	74	0.39 (\pm 0.07)	2	0	0.52	0.26
		4	109	0.40 (\pm 0.05)	2	0	0.51	0.30
		5	136	0.45 (\pm 0.05)	2	0	0.54	0.35
		6	124	0.37 (\pm 0.05)	2	0	0.47	0.27
		7	128	0.35 (\pm 0.05)	3	0	0.45	0.25
		8	198	0.40 (\pm 0.04)	4	0	0.48	0.31
		9	313	0.31 (\pm 0.03)	4	0	0.37	0.24
		10	477	0.34 (\pm 0.03)	5	0	0.39	0.28

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Colorado	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	112	1.13 (\pm 0.03)	2	1	1.19	1.06
		2	101	1.78 (\pm 0.08)	4	1	1.93	1.63
		3	97	2.40 (\pm 0.12)	6	1	2.63	2.17
		4	61	3.10 (\pm 0.14)	6	2	3.37	2.83
		5	64	3.41 (\pm 0.17)	7	1	3.75	3.07
		6	57	4.51 (\pm 0.27)	10	1	5.03	3.98
		7	57	5.54 (\pm 0.33)	15	1	6.19	4.89
		8	68	6.21 (\pm 0.30)	15	1	6.79	5.62
		9	58	7.98 (\pm 0.34)	14	1	8.65	7.31
		10	51	10.06 (\pm 0.87)	24	1	11.76	8.35
	Daily Harvest: (Daily Bag)	1	106	1.34 (\pm 0.05)	2.00	1.00	1.43	1.25
		2	88	2.29 (\pm 0.10)	4.00	1.00	2.49	2.09
		3	92	2.78 (\pm 0.15)	6.00	1.00	3.08	2.48
		4	54	2.61 (\pm 0.11)	4.00	1.33	2.82	2.41
		5	56	3.28 (\pm 0.20)	10.00	1.29	3.67	2.88
		6	53	2.91 (\pm 0.18)	6.00	1.09	3.26	2.56
		7	52	3.10 (\pm 0.16)	5.33	1.13	3.42	2.78
		8	60	3.32 (\pm 0.15)	6.33	1.33	3.62	3.02
		9	48	3.37 (\pm 0.15)	6.00	1.00	3.66	3.08
		10	36	4.15 (\pm 0.16)	6.00	2.54	4.46	3.84
	Hunter Mobility: (# of counties where harvest occurred)	1	112	1.01 (\pm 0.01)	2	1	1.03	0.99
		2	101	1.14 (\pm 0.03)	2	1	1.21	1.07
		3	97	1.32 (\pm 0.06)	4	1	1.43	1.21
		4	61	1.33 (\pm 0.08)	3	1	1.48	1.18
		5	64	1.42 (\pm 0.09)	3	1	1.59	1.25
		6	57	1.60 (\pm 0.11)	5	1	1.82	1.38
		7	57	1.51 (\pm 0.09)	3	1	1.69	1.33
		8	68	1.63 (\pm 0.10)	4	1	1.83	1.44
		9	58	1.71 (\pm 0.12)	5	1	1.95	1.47
		10	51	1.82 (\pm 0.17)	6	1	2.16	1.49

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
Colorado	Species Selectivity: (Percent Mallard)	1	112	62.95 (\pm 4.38)	100.00	0.00	71.54	54.36
		2	101	53.88 (\pm 3.63)	100.00	0.00	61.00	46.76
		3	98	53.71 (\pm 3.48)	100.00	0.00	60.54	46.88
		4	61	56.94 (\pm 4.09)	100.00	0.00	64.95	48.93
		5	64	52.15 (\pm 3.93)	100.00	0.00	59.86	44.44
		6	57	50.79 (\pm 4.46)	100.00	0.00	59.53	42.05
		7	57	45.83 (\pm 3.29)	92.86	0.00	52.28	39.38
		8	68	50.96 (\pm 3.26)	100.00	0.00	57.35	44.56
		9	58	46.70 (\pm 3.31)	100.00	3.33	53.19	40.20
		10	51	51.72 (\pm 3.99)	100.00	0.00	59.53	43.90
	Gender Selectivity: (Percent Female Mallard)	1	75	27.33 (\pm 4.87)	100.00	0.00	36.87	17.79
		2	82	31.91 (\pm 3.96)	100.00	0.00	39.68	24.14
		3	81	30.39 (\pm 3.51)	100.00	0.00	37.28	23.50
		4	56	31.66 (\pm 3.64)	100.00	0.00	38.79	24.52
		5	61	28.58 (\pm 3.55)	100.00	0.00	35.54	21.62
		6	51	27.26 (\pm 3.42)	100.00	0.00	33.97	20.55
		7	54	30.28 (\pm 3.11)	100.00	0.00	36.37	24.18
		8	64	25.39 (\pm 2.89)	100.00	0.00	31.05	19.72
		9	58	29.64 (\pm 3.20)	100.00	0.00	35.92	23.36
		10	48	20.42 (\pm 2.51)	80.00	0.00	25.34	15.51
	Daily Female Mallard Harvest	1	83	0.31 (\pm 0.06)	2	0	0.42	0.20
		2	114	0.49 (\pm 0.06)	2	0	0.60	0.38
		3	152	0.52 (\pm 0.05)	3	0	0.63	0.41
		4	134	0.57 (\pm 0.06)	2	0	0.69	0.46
		5	159	0.54 (\pm 0.05)	2	0	0.64	0.44
		6	160	0.48 (\pm 0.05)	3	0	0.58	0.37
		7	202	0.53 (\pm 0.05)	3	0	0.63	0.44
		8	289	0.56 (\pm 0.04)	5	0	0.64	0.47
		9	313	0.55 (\pm 0.04)	3	0	0.62	0.47
		10	375	0.51 (\pm 0.03)	3	0	0.58	0.44

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
New Mexico	Days Harvesting Ducks: (# of days when duck harvest occurred)	1	54	1.07 (\pm 0.04)	2	1	1.14	1.00
		2	48	1.77 (\pm 0.11)	4	1	1.99	1.55
		3	42	2.52 (\pm 0.20)	5	1	2.91	2.13
		4	33	3.12 (\pm 0.22)	7	2	3.55	2.70
		5	32	3.84 (\pm 0.28)	8	1	4.39	3.30
		6	25	5.28 (\pm 0.46)	10	2	6.18	4.38
		7	40	6.10 (\pm 0.41)	12	1	6.91	5.29
		8	30	6.70 (\pm 0.34)	10	3	7.37	6.03
		9	36	8.89 (\pm 0.72)	26	1	10.29	7.49
		10	76	17.46 (\pm 1.29)	61	1	19.99	14.93
	Daily Harvest: (Daily Bag)	1	47	1.31 (\pm 0.07)	2.00	1.00	1.44	1.18
		2	48	2.38 (\pm 0.14)	4.00	1.00	2.66	2.11
		3	40	2.97 (\pm 0.28)	6.00	1.00	3.51	2.43
		4	30	2.71 (\pm 0.16)	4.00	1.14	3.02	2.40
		5	27	2.70 (\pm 0.19)	5.00	1.00	3.07	2.32
		6	23	2.66 (\pm 0.29)	6.00	1.00	3.23	2.08
		7	36	2.90 (\pm 0.19)	7.00	1.00	3.27	2.53
		8	26	3.31 (\pm 0.24)	6.67	1.17	3.77	2.84
		9	25	3.47 (\pm 0.23)	6.00	1.31	3.91	3.03
		10	43	3.88 (\pm 0.18)	6.60	1.24	4.22	3.53
	Hunter Mobility: (# of counties where harvest occurred)	1	54	1.00 (\pm 0.00)	1	1	1.00	1.00
		2	48	1.08 (\pm 0.04)	2	1	1.16	1.00
		3	42	1.19 (\pm 0.07)	3	1	1.33	1.05
		4	33	1.06 (\pm 0.04)	2	1	1.14	0.98
		5	32	1.31 (\pm 0.08)	2	1	1.48	1.15
		6	25	1.64 (\pm 0.16)	3	1	1.96	1.32
		7	40	1.55 (\pm 0.12)	4	1	1.79	1.31
		8	30	1.30 (\pm 0.10)	3	1	1.49	1.11
		9	36	1.72 (\pm 0.17)	6	1	2.06	1.39
		10	76	1.83 (\pm 0.13)	5	1	2.08	1.58

Appendix 2.I (continued)

State	Behavior: (Mean)	Harvest Group	<i>n</i>	Mean (\pm SE)	Max	Min	95% UCL	95% LCL
New Mexico	Species Selectivity: (Percent Mallard)	1	54	42.59 (\pm 6.26)	100.00	0.00	54.86	30.33
		2	49	42.35 (\pm 5.15)	100.00	0.00	52.44	32.26
		3	42	50.63 (\pm 5.28)	100.00	0.00	60.98	40.29
		4	33	41.07 (\pm 5.69)	100.00	0.00	52.23	29.92
		5	32	44.12 (\pm 4.80)	90.00	0.00	53.53	34.71
		6	25	32.09 (\pm 4.73)	76.92	0.00	41.36	22.82
		7	40	44.12 (\pm 4.18)	87.50	0.00	52.31	35.93
		8	30	39.91 (\pm 4.68)	86.96	4.35	49.07	30.74
		9	36	38.76 (\pm 3.89)	90.00	3.57	46.39	31.12
		10	76	46.44 (\pm 3.00)	100.00	0.00	52.31	40.57
	Gender Selectivity: (Percent Female Mallard)	1	27	48.15 (\pm 9.43)	100.00	0.00	66.63	29.67
		2	34	30.15 (\pm 6.16)	100.00	0.00	42.23	18.06
		3	37	35.05 (\pm 5.17)	100.00	0.00	45.19	24.90
		4	25	26.99 (\pm 4.85)	100.00	0.00	36.50	17.48
		5	29	27.03 (\pm 4.22)	75.00	0.00	35.30	18.76
		6	23	35.16 (\pm 7.46)	100.00	0.00	49.79	20.53
		7	36	31.06 (\pm 3.68)	100.00	0.00	38.28	23.84
		8	30	38.51 (\pm 4.30)	100.00	0.00	46.93	30.08
		9	36	28.36 (\pm 3.63)	71.43	0.00	35.47	21.25
		10	75	28.21 (\pm 2.01)	85.71	0.00	32.15	24.27
	Daily Female Mallard Harvest	1	28	0.54 (\pm 0.11)	2	0	0.75	0.32
		2	44	0.55 (\pm 0.11)	2	0	0.75	0.34
		3	75	0.56 (\pm 0.07)	2	0	0.71	0.41
		4	55	0.55 (\pm 0.11)	3	0	0.75	0.34
		5	71	0.56 (\pm 0.08)	2	0	0.72	0.40
		6	59	0.58 (\pm 0.09)	3	0	0.76	0.39
		7	135	0.60 (\pm 0.06)	3	0	0.72	0.48
		8	127	0.71 (\pm 0.07)	2	0	0.84	0.58
		9	187	0.58 (\pm 0.05)	4	0	0.68	0.48
		10	920	0.59 (\pm 0.02)	4	0	0.64	0.55

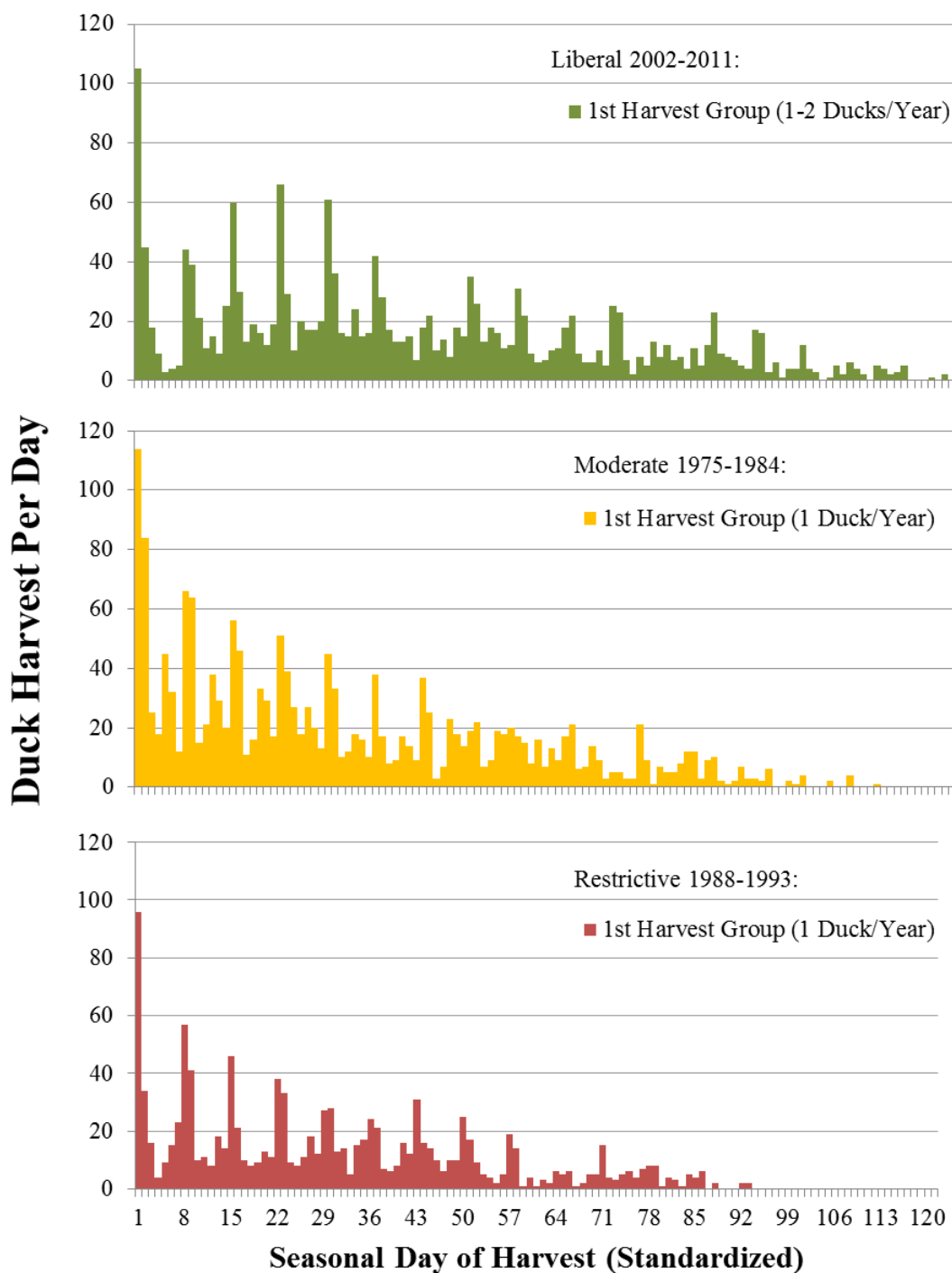
Appendix 2.J: Frequency (Freq) and percent (%) of occurrence of different daily bags in Central Flyway states. Derived from U.S. Fish and Wildlife Service Parts Collection Survey sampled hunters, 2002-2011.

State		Daily Bag					
		1	2	3	4	5	6
ND	Freq	2,031	2,000	1,654	1,334	1,644	1,529
	%	19.93	19.62	16.23	13.09	16.13	15.00
SD	Freq	1,211	1,030	799	666	953	703
	%	22.58	19.21	14.90	12.42	17.77	13.11
NE	Freq	1,379	1,151	780	609	636	522
	%	27.16	22.67	15.36	12.00	12.53	10.28
KS	Freq	1,026	780	665	468	707	419
	%	25.24	19.19	16.36	11.51	17.39	10.31
OK	Freq	1,373	1,186	1,065	800	847	1,081
	%	21.62	18.67	16.77	12.59	13.33	17.02
TX	Freq	2,262	2,228	1,635	1,346	1,700	1,516
	%	21.17	20.85	15.30	12.59	15.91	14.19
MT	Freq	461	342	265	201	302	116
	%	27.33	20.27	15.71	11.91	17.90	6.88
WY	Freq	716	473	352	229	265	122
	%	33.19	21.93	16.32	10.62	12.29	5.66
CO	Freq	884	624	425	324	305	338
	%	30.48	21.52	14.66	11.17	10.52	11.66
NM	Freq	693	540	399	289	322	432
	%	25.91	20.19	14.92	10.80	12.04	16.15
Central Flyway	Freq	12,019	10,350	8,038	6,264	7,681	6,784
	%	23.50	20.24	15.72	12.25	15.02	13.27

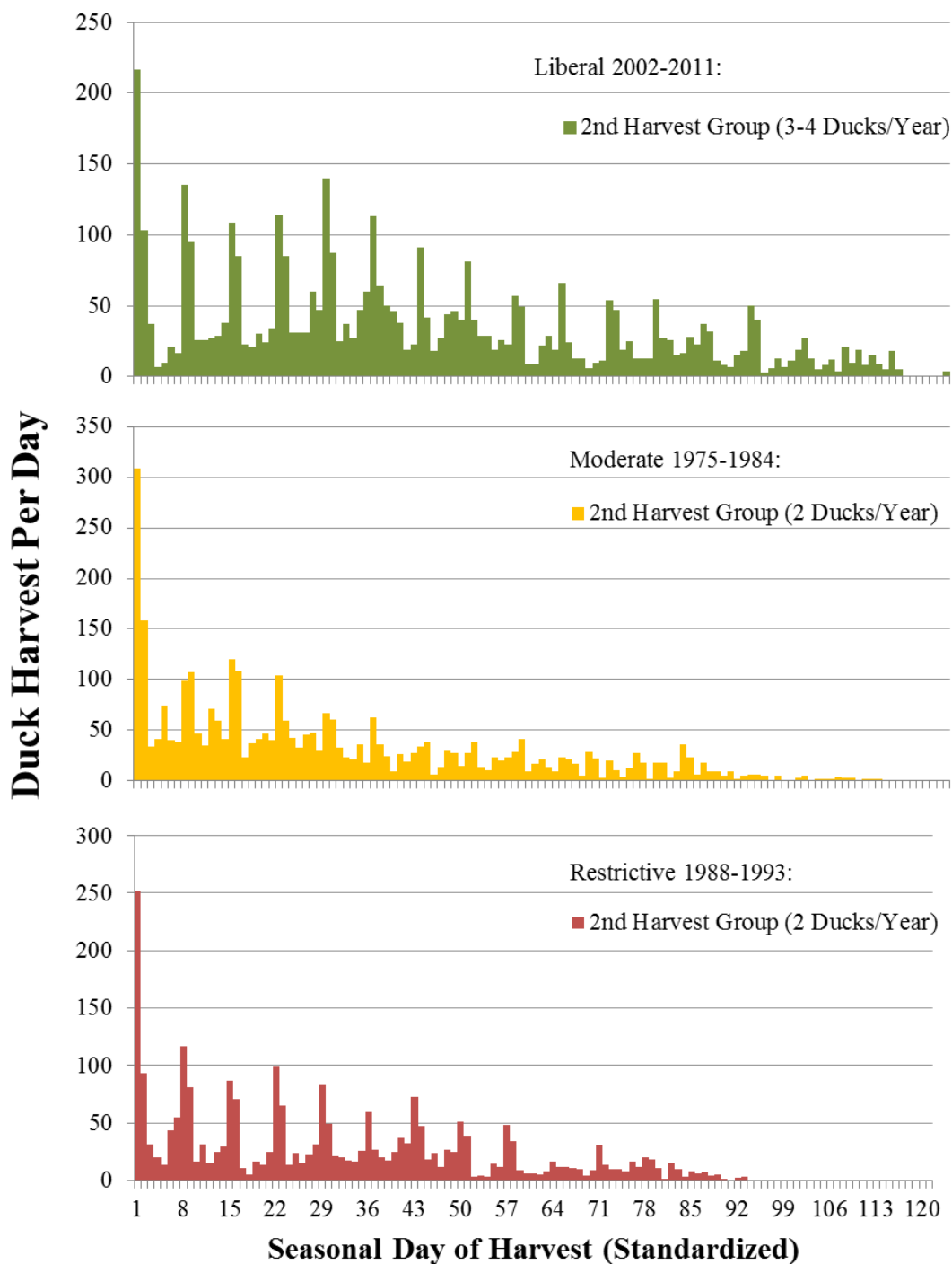
Appendix 2.K: Number of counties an individual duck hunter from the Central Flyway harvested duck in (frequency [Freq] and percent [%] of total sample). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011. Not calculated on an annual basis, thus may show an individual hunter movements for up to 3 years because the PCS samples hunters for up to 3 years.

State		Counties Where Harvest Occurred (for individual hunters)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ND	Freq	1,017	403	104	36	22	10	4	-	1	-	1	-	-	-	-	-
	%	63.64	25.22	6.51	2.25	1.38	0.63	0.25	-	0.06	-	0.06	-	-	-	-	-
SD	Freq	442	179	68	27	12	8	4	1	-	-	2	-	1	-	-	-
	%	59.41	24.06	9.14	3.63	1.61	1.08	0.54	0.13	-	-	0.27	-	0.13	-	-	-
NE	Freq	353	121	42	25	9	5	3	1	-	1	-	-	-	-	-	-
	%	63.04	21.61	7.50	4.46	1.61	0.89	0.54	0.18	-	0.18	-	-	-	-	-	-
KS	Freq	272	123	54	19	8	1	2	2	-	1	-	-	-	-	-	-
	%	56.43	25.52	11.20	3.94	1.66	0.21	0.41	0.41	-	0.21	-	-	-	-	-	-
OK	Freq	341	156	64	35	14	5	5	1	3	-	-	-	-	-	-	-
	%	54.65	25.00	10.26	5.61	2.24	0.80	0.80	0.16	0.48	-	-	-	-	-	-	-
TX	Freq	625	247	126	51	27	10	8	4	2	2	1	1	-	-	-	-
	%	56.61	22.37	11.41	4.62	2.45	0.91	0.72	0.36	0.18	0.18	0.09	0.09	-	-	-	-
MT	Freq	186	53	13	4	3	-	-	-	-	-	-	-	-	-	-	-
	%	71.81	20.46	5.02	1.54	1.16	-	-	-	-	-	-	-	-	-	-	-
WY	Freq	174	46	9	2	1	-	-	-	-	-	-	-	-	-	-	-
	%	75.00	19.83	3.88	0.86	0.43	-	-	-	-	-	-	-	-	-	-	-
CO	Freq	254	98	38	15	9	2	1	-	-	-	-	-	-	-	-	-
	%	60.91	23.50	9.11	3.60	2.16	0.48	0.24	-	-	-	-	-	-	-	-	-
NM	Freq	147	42	20	5	4	2	-	-	-	-	-	-	-	-	-	-
	%	66.82	19.09	9.09	2.27	1.82	0.91	-	-	-	-	-	-	-	-	-	-
Central Flyway	Freq	3,482	1,434	542	242	121	51	29	16	10	3	5	2	3	1	-	1
	%	58.60	24.13	9.12	4.07	2.04	0.86	0.49	0.27	0.17	0.05	0.08	0.03	0.05	0.02	-	0.02

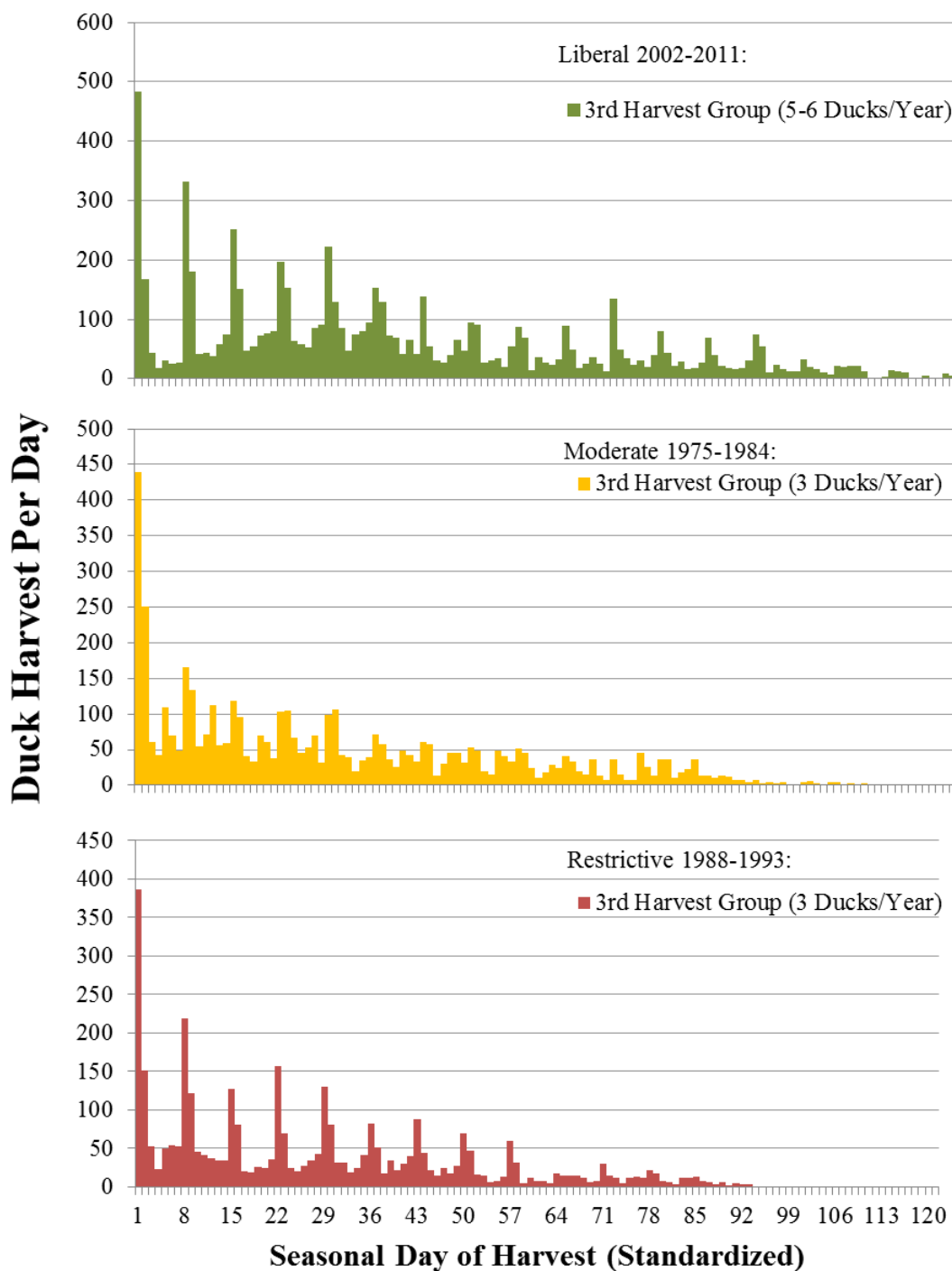
Appendix 2.L: Duck harvest distribution in the Central Flyway for the lowest-ranked harvest group for liberal (2002-2011; 1-2 ducks/hunter/year), moderate (1975-1984; 1 duck/hunter/year), and restrictive (1988-1993; 1 duck/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



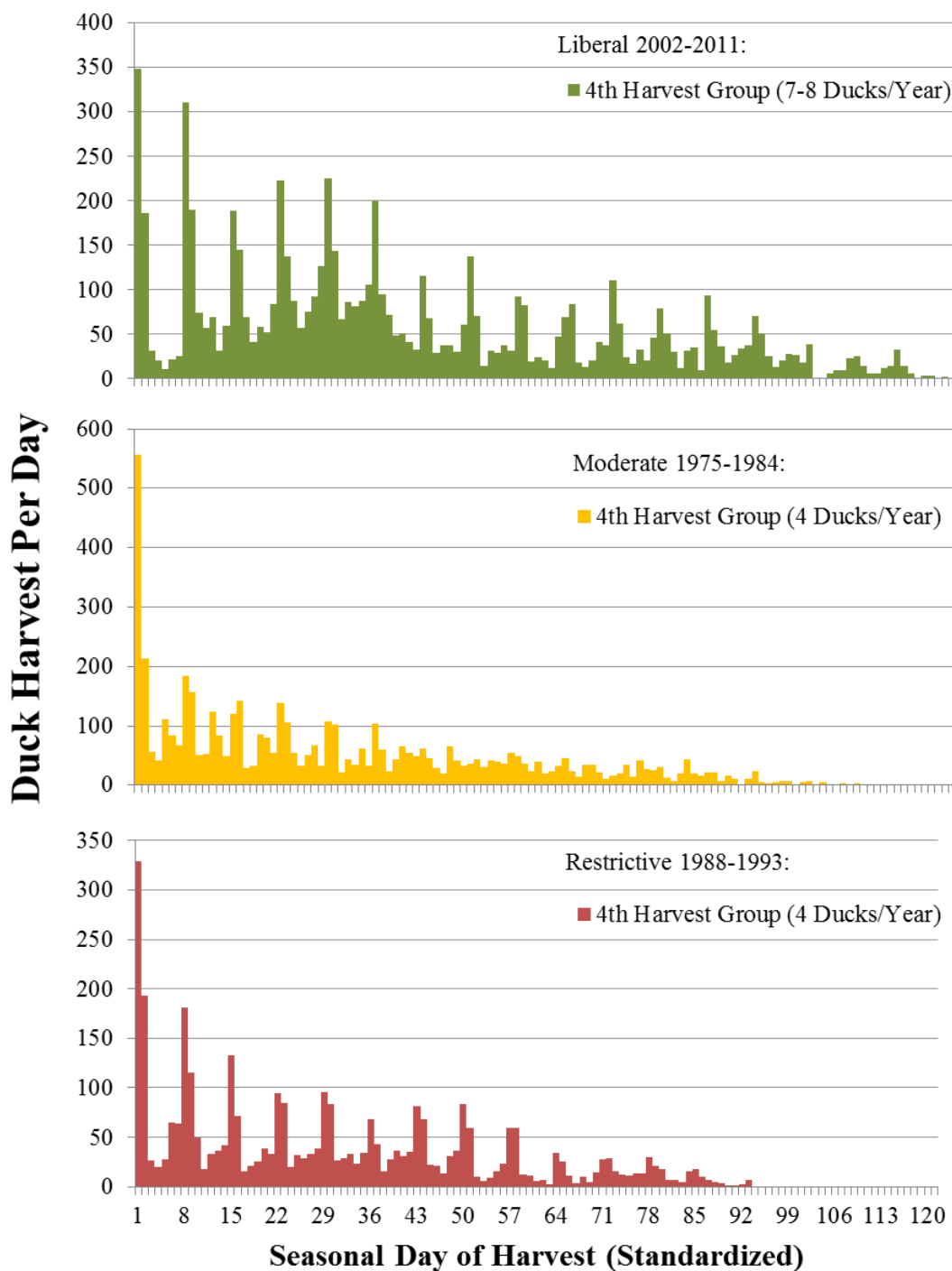
Appendix 2.M: Duck harvest distribution in the Central Flyway for the second harvest group for liberal (2002-2011; 3-4 ducks/hunter/year), moderate (1975-1984; 2 ducks/hunter/year), and restrictive (1988-1993; 2 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



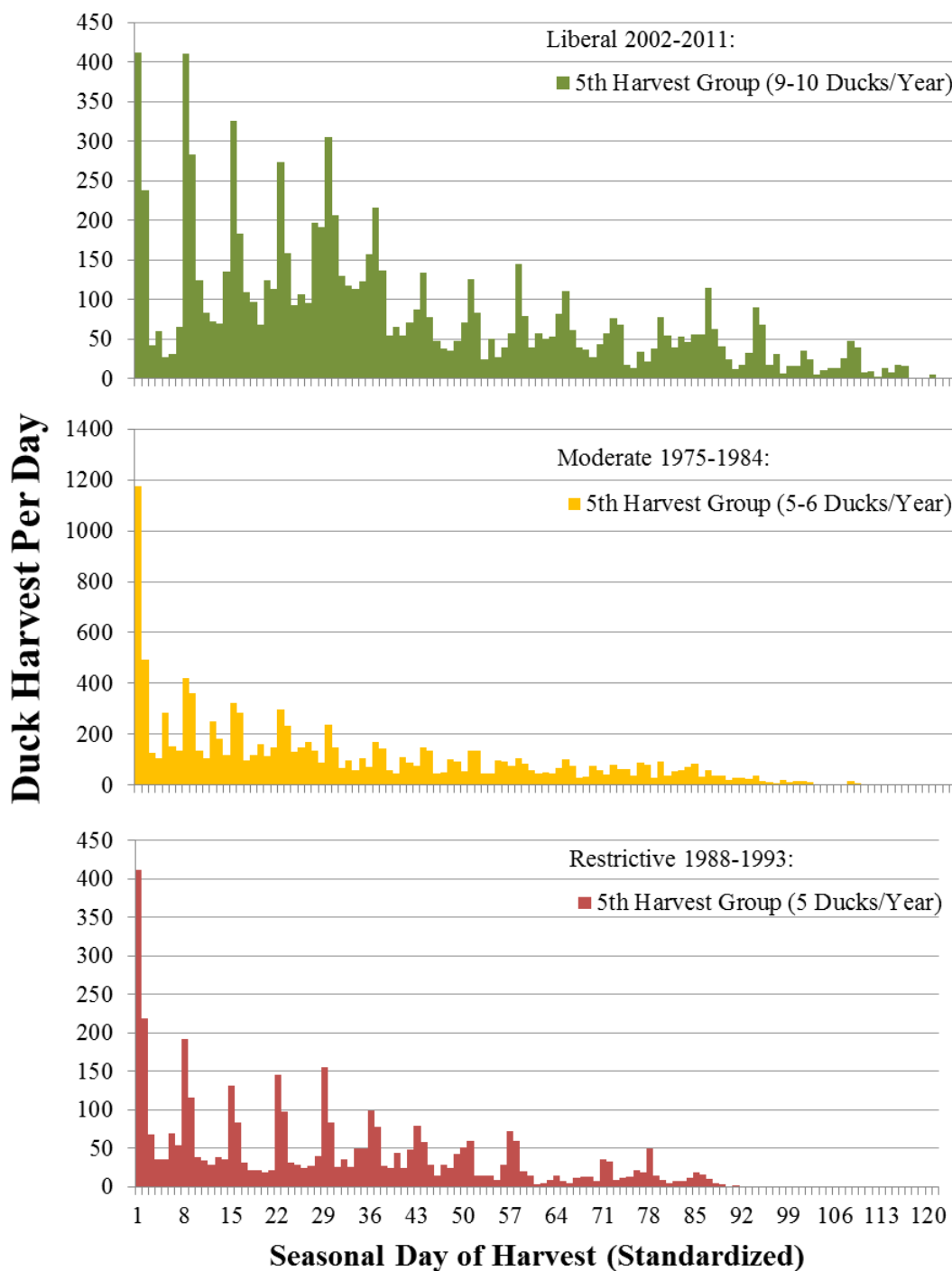
Appendix 2.N: Duck harvest distribution in the Central Flyway for the third harvest group for liberal (2002-2011; 5-6 ducks/hunter/year), moderate (1975-1984; 3 ducks/hunter/year), and restrictive (1988-1993; 3 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



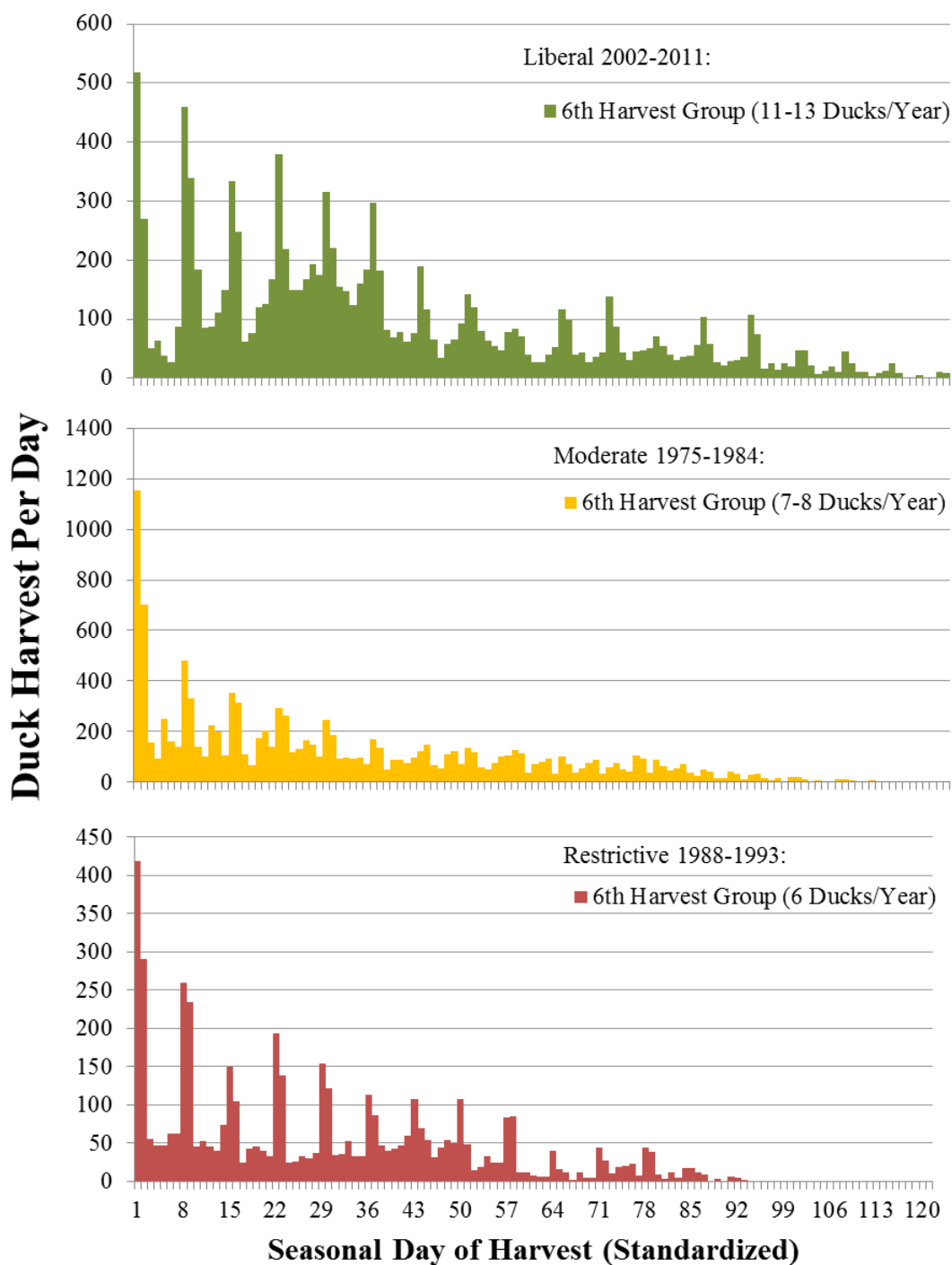
Appendix 2.O: Duck harvest distribution in the Central Flyway for the fourth harvest group for liberal (2002-2011; 7-8 ducks/hunter/year), moderate (1975-1984; 4 ducks/hunter/year), and restrictive (1988-1993; 4 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



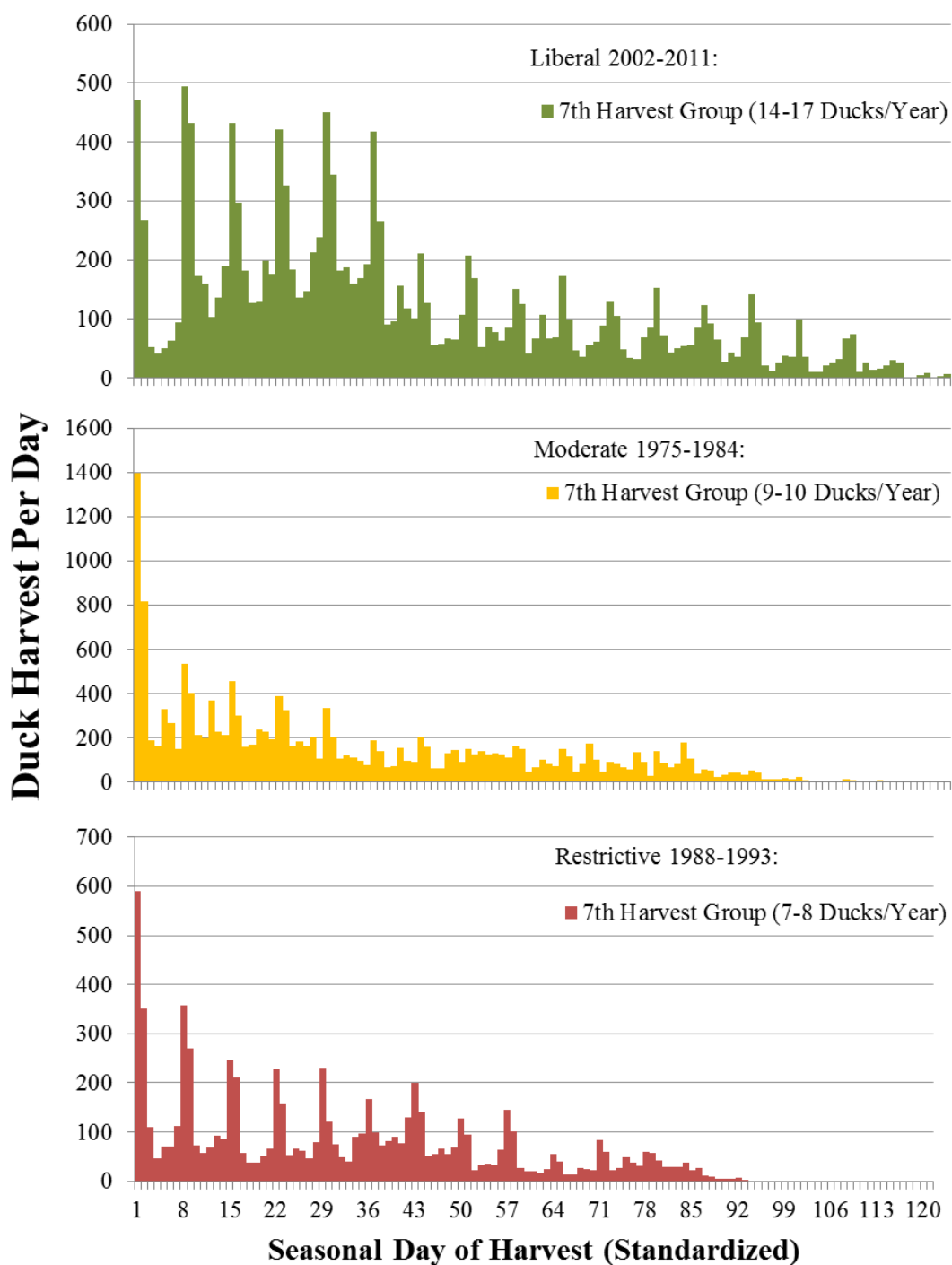
Appendix 2.P: Duck harvest distribution in the Central Flyway for the fifth harvest group for liberal (2002-2011; 9-10 ducks/hunter/year), moderate (1975-1984; 5-6 ducks/hunter/year), and restrictive (1988-1993; 5 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



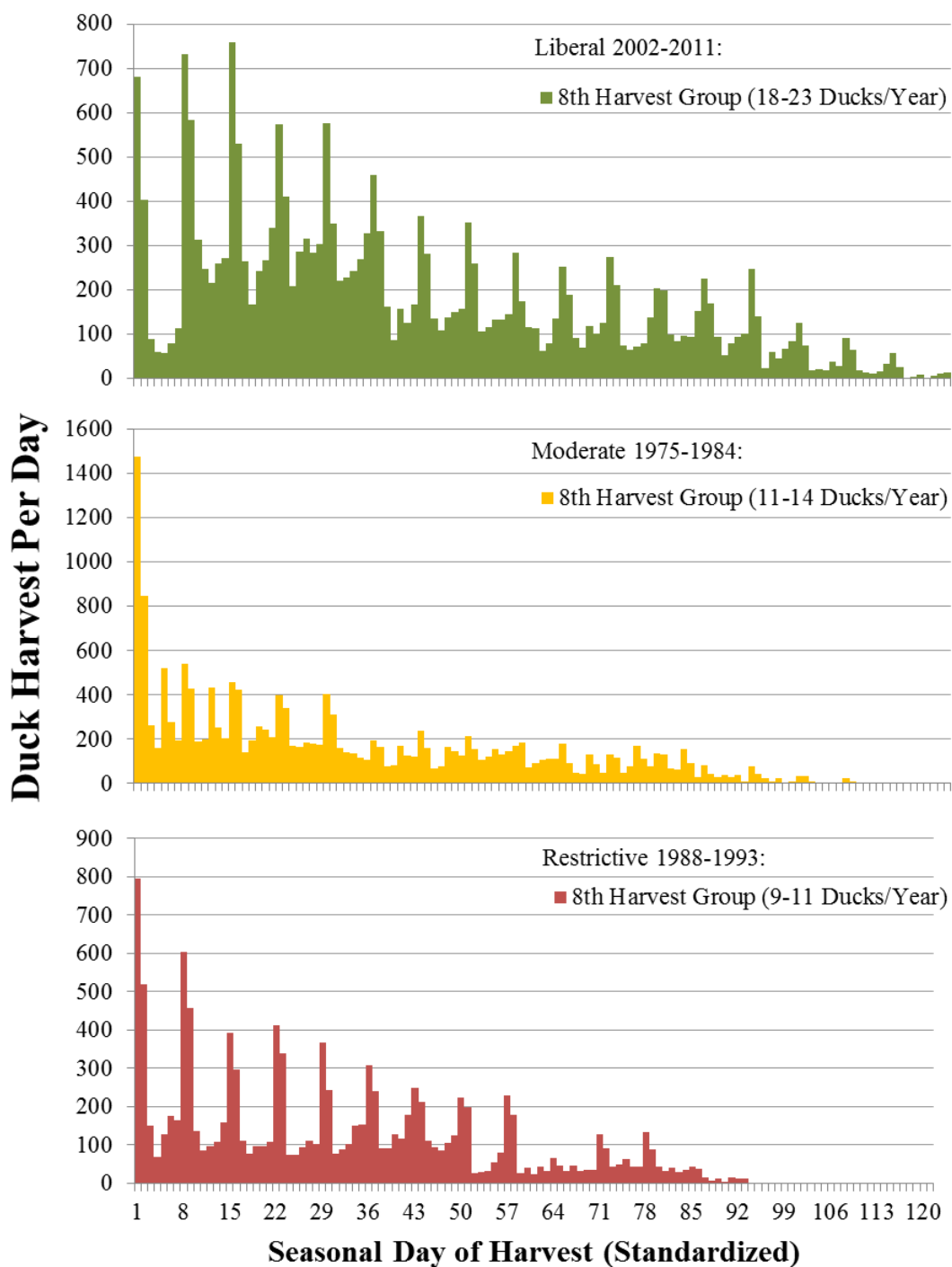
Appendix 2.Q: Duck harvest distribution in the Central Flyway for the sixth harvest group for liberal (2002-2011; 11-13 ducks/hunter/year), moderate (1975-1984; 7-8 ducks/hunter/year), and restrictive (1988-1993; 6 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



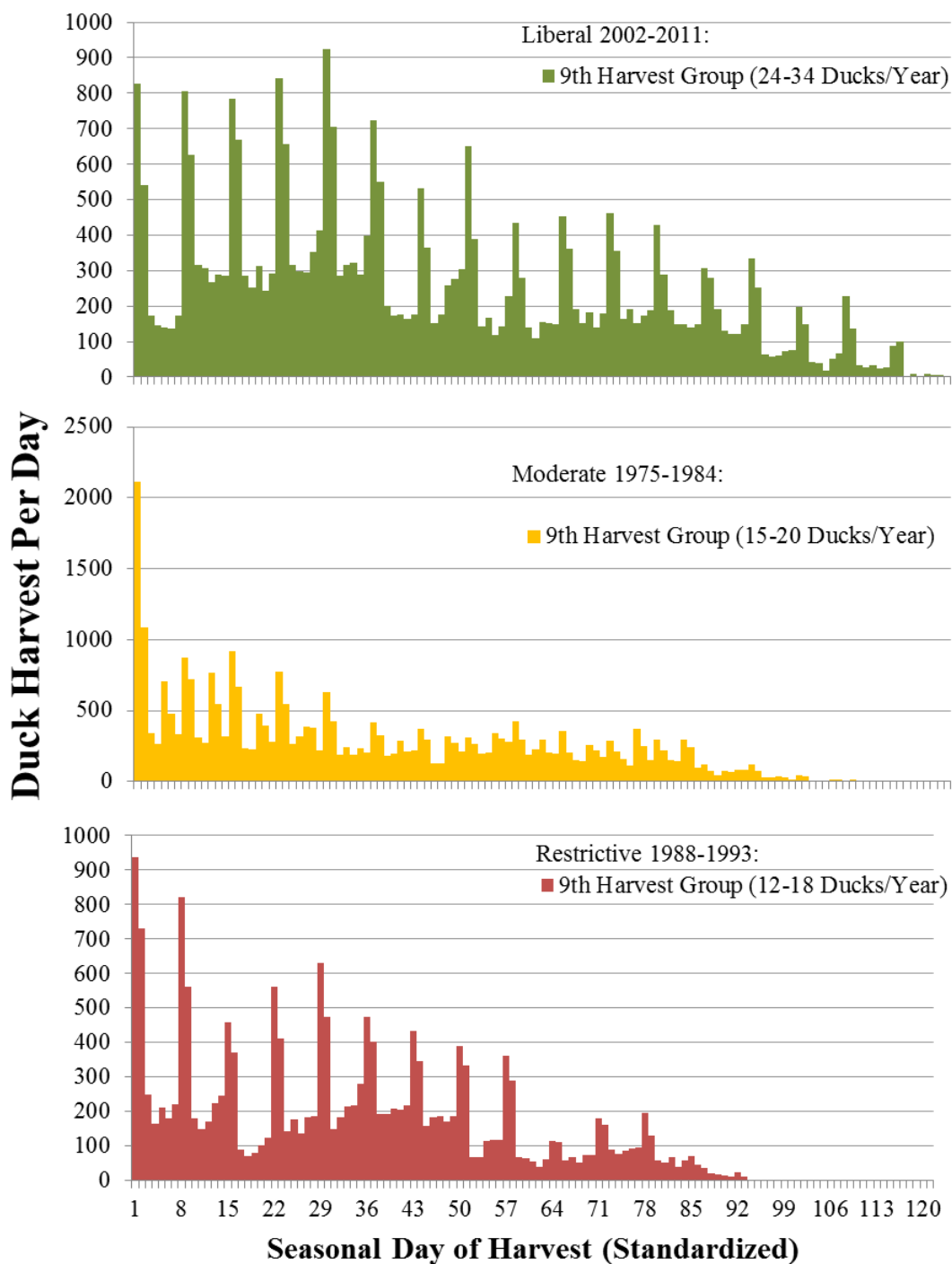
Appendix 2.R: Duck harvest distribution in the Central Flyway for the seventh harvest group for liberal (2002-2011; 14-17 ducks/hunter/year), moderate (1975-1984; 9-10 ducks/hunter/year), and restrictive (1988-1993; 7-8 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



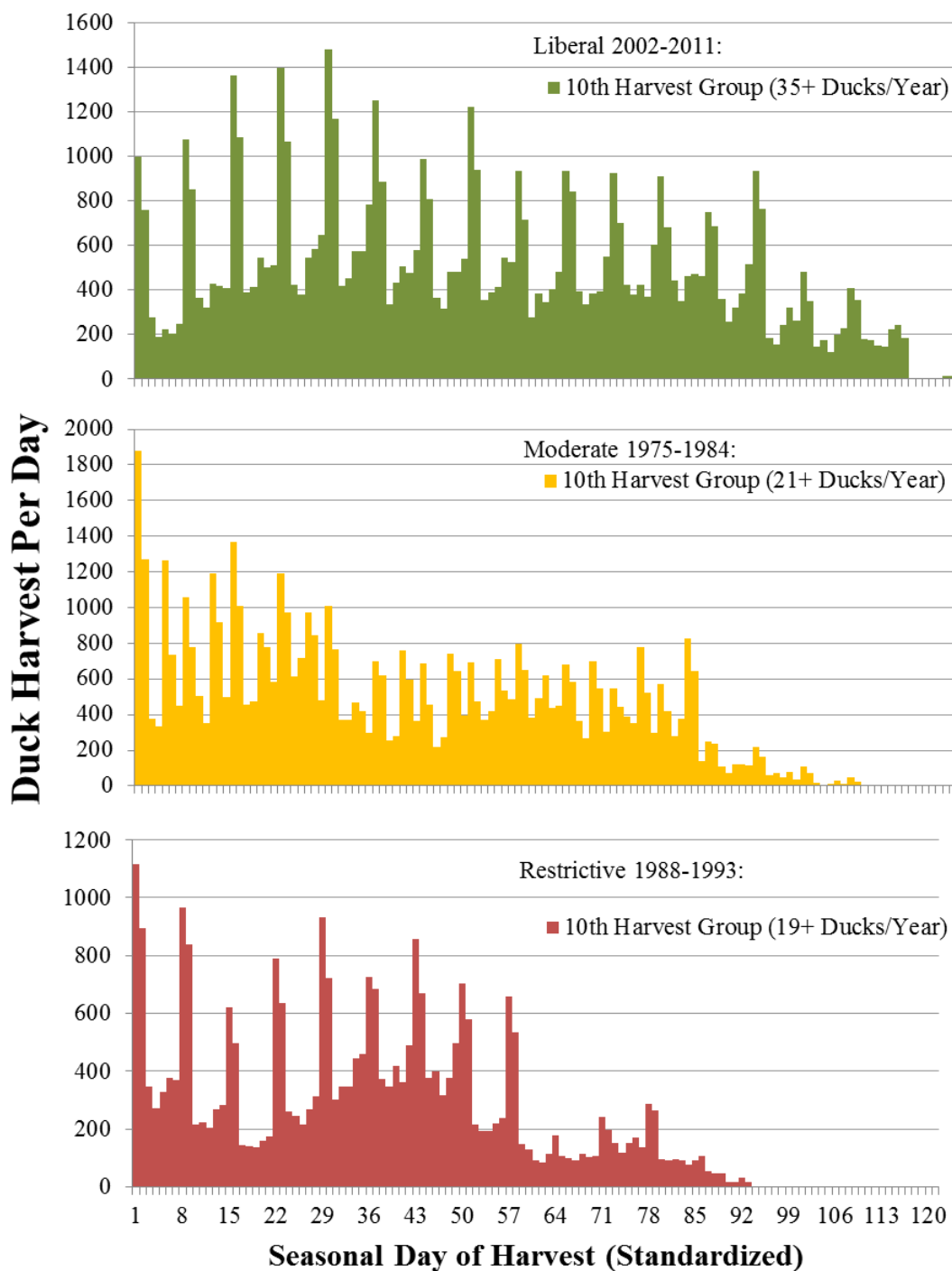
Appendix 2.S: Duck harvest distribution in the Central Flyway for the eighth harvest group for liberal (2002-2011; 18-23 ducks/hunter/year), moderate (1975-1984; 11-14 ducks/hunter/year), and restrictive (1988-1993; 9-11 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



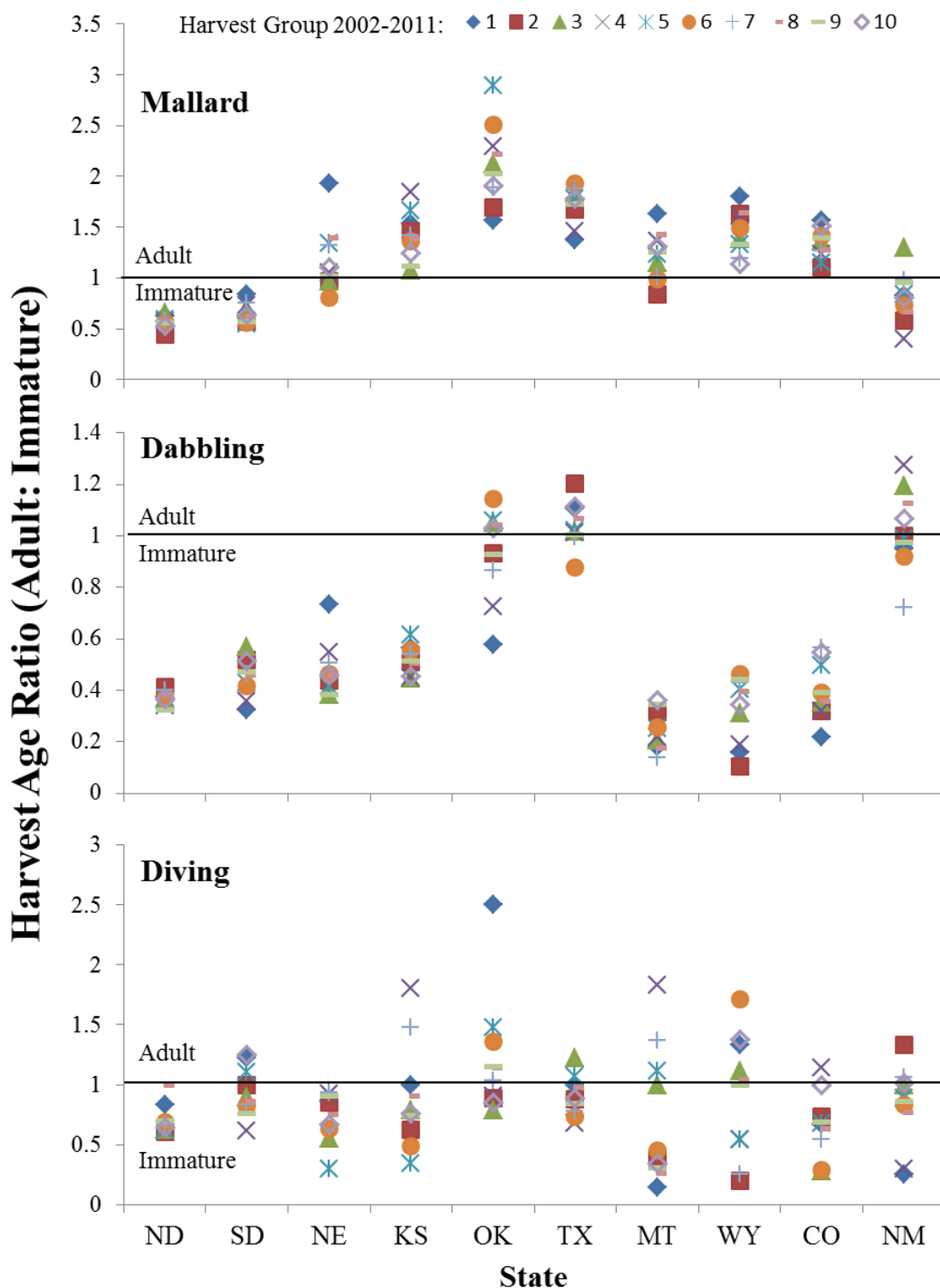
Appendix 2.T: Duck harvest distribution in the Central Flyway for the ninth harvest group for liberal (2002-2011; 24-34 ducks/hunter/year), moderate (1975-1984; 15-20 ducks/hunter/year), and restrictive (1988-1993; 12-18 ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



Appendix 2.U: Duck harvest distribution in the Central Flyway for the highest-ranked harvest group for liberal (2002-2011; 35+ ducks/hunter/year), moderate (1975-1984; 21+ ducks/hunter/year), and restrictive (1988-1993; 19+ ducks/hunter/year) seasons (standardized for all states [Day 1 = start of hunting season for each state]), derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



Appendix 2.V: Age ratios of harvest for mallard (*Anas platyrhynchos*), dabbling ducks (*Anas* spp., *Aix sponsa*), and diving ducks (*Aythya* spp., *Bucephala* spp., *Clangula hyemalis*, *Melanitta* spp., and *Oxyura jamaicensis*) for harvest groups (10% of each regulation period sample, stratified by seasonal harvest) for Central Flyway states, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.



Appendix 2.W: Age ratios from harvest estimates for mallard (*Anas platyrhynchos*), dabbling ducks (*Anas* spp., *Aix sponsa*), and diving ducks (*Aythya* spp., *Bucephala* spp., *Clangula hyemalis*, *Melanitta* spp., *Oxyura jamaicensis*) for harvest groups (10% of each regulation period sample, stratified by seasonal harvest) for Central Flyway states, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
North Dakota	Mallard	1	195	75	120	0.63
		2	432	133	299	0.44
		3	809	319	490	0.65
		4	870	317	553	0.57
		5	1329	493	836	0.59
		6	1458	523	935	0.56
		7	1819	667	1152	0.58
		8	2530	919	1611	0.57
		9	2742	979	1763	0.56
		10	2293	796	1497	0.53
	Dabbling	1	114	31	83	0.37
		2	353	103	250	0.41
		3	750	201	549	0.37
		4	831	211	620	0.34
		5	1135	307	828	0.37
		6	1582	427	1155	0.37
		7	1793	511	1282	0.40
		8	2544	704	1840	0.38
		9	3025	738	2287	0.32
		10	3000	801	2199	0.36
	Diving	1	44	20	24	0.83
		2	95	36	59	0.61
		3	234	90	144	0.63
		4	266	102	164	0.62
		5	429	165	264	0.63
		6	424	173	251	0.69
		7	649	257	392	0.66
		8	856	427	429	1.00
		9	903	371	532	0.70
		10	803	315	488	0.65

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
South Dakota	Mallard	1	121	55	66	0.83
		2	225	82	143	0.57
		3	394	162	232	0.70
		4	306	129	177	0.73
		5	555	197	358	0.55
		6	660	238	422	0.56
		7	853	367	486	0.76
		8	1148	443	705	0.63
		9	1147	418	729	0.57
		10	2457	957	1500	0.64
	Dabbling	1	82	20	62	0.32
		2	208	71	137	0.52
		3	419	152	267	0.57
		4	367	97	270	0.36
		5	498	150	348	0.43
		6	709	208	501	0.42
		7	816	259	557	0.46
		8	1044	329	715	0.46
		9	1301	416	885	0.47
		10	2473	840	1633	0.51
	Diving	1	20	11	9	1.22
		2	44	22	22	1.00
		3	72	34	38	0.89
		4	79	30	49	0.61
		5	78	41	37	1.11
		6	124	56	68	0.82
		7	167	76	91	0.84
		8	195	90	105	0.86
		9	244	105	139	0.76
		10	583	324	259	1.25

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Nebraska	Mallard	1	120	79	41	1.93
		2	236	116	120	0.97
		3	265	130	135	0.96
		4	355	182	173	1.05
		5	365	209	156	1.34
		6	528	235	293	0.80
		7	502	286	216	1.32
		8	1234	719	515	1.40
		9	1239	626	613	1.02
		10	3268	1713	1555	1.10
	Dabbling	1	52	22	30	0.73
		2	145	44	101	0.44
		3	220	61	159	0.38
		4	255	90	165	0.55
		5	238	70	168	0.42
		6	347	110	237	0.46
		7	363	122	241	0.51
		8	906	285	621	0.46
		9	1133	313	820	0.38
		10	2265	712	1553	0.46
	Diving	1	13	6	7	0.86
		2	24	11	13	0.85
		3	14	5	9	0.56
		4	25	12	13	0.92
		5	35	8	27	0.30
		6	31	12	19	0.63
		7	54	26	28	0.93
		8	91	39	52	0.75
		9	126	60	66	0.91
		10	214	86	128	0.67

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Kansas	Mallard	1	81	49	32	1.53
		2	177	105	72	1.46
		3	238	123	115	1.07
		4	225	146	79	1.85
		5	333	208	125	1.66
		6	295	170	125	1.36
		7	452	265	187	1.42
		8	816	473	343	1.38
		9	948	499	449	1.11
		10	2567	1424	1143	1.25
	Dabbling	1	61	22	39	0.56
		2	148	50	98	0.51
		3	263	81	182	0.45
		4	184	57	127	0.45
		5	297	113	184	0.61
		6	311	111	200	0.56
		7	422	148	274	0.54
		8	675	227	448	0.51
		9	1025	348	677	0.51
		10	2268	709	1559	0.45
	Diving	1	12	6	6	1.00
		2	26	10	16	0.63
		3	50	22	28	0.79
		4	14	9	5	1.80
		5	39	10	29	0.34
		6	46	15	31	0.48
		7	62	37	25	1.48
		8	116	55	61	0.90
		9	122	52	70	0.74
		10	341	147	194	0.76

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Oklahoma	Mallard	1	41	25	16	1.56
		2	159	100	59	1.69
		3	287	195	92	2.12
		4	280	195	85	2.29
		5	300	223	77	2.90
		6	445	318	127	2.50
		7	695	454	241	1.88
		8	918	633	285	2.22
		9	2249	1506	743	2.03
		10	4234	2779	1455	1.91
	Dabbling	1	52	19	33	0.58
		2	141	68	73	0.93
		3	289	148	141	1.05
		4	238	100	138	0.72
		5	274	141	133	1.06
		6	407	217	190	1.14
		7	616	286	330	0.87
		8	972	496	476	1.04
		9	2407	1159	1248	0.93
		10	4473	2267	2206	1.03
	Diving	1	7	5	2	2.50
		2	34	16	18	0.89
		3	25	11	14	0.79
		4	40	19	21	0.90
		5	57	34	23	1.48
		6	113	65	48	1.35
		7	69	35	34	1.03
		8	229	122	107	1.14
		9	382	204	178	1.15
		10	625	288	337	0.85

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Texas	Mallard	1	38	22	16	1.38
		2	107	67	40	1.68
		3	133	86	47	1.83
		4	138	82	56	1.46
		5	186	119	67	1.78
		6	161	106	55	1.93
		7	328	214	114	1.88
		8	411	261	150	1.74
		9	794	503	291	1.73
		10	2474	1585	889	1.78
	Dabbling	1	202	106	96	1.10
		2	447	244	203	1.20
		3	817	412	405	1.02
		4	795	400	395	1.01
		5	1047	529	518	1.02
		6	1034	483	551	0.88
		7	1612	805	807	1.00
		8	2642	1363	1279	1.07
		9	4848	2430	2418	1.00
		10	12181	6419	5762	1.11
	Diving	1	36	18	18	1.00
		2	77	36	41	0.88
		3	138	76	62	1.23
		4	178	72	106	0.68
		5	236	122	114	1.07
		6	262	111	151	0.74
		7	307	134	173	0.77
		8	495	245	250	0.98
		9	712	326	386	0.84
		10	1960	920	1040	0.88

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Montana	Mallard	1	71	44	27	1.63
		2	162	74	88	0.84
		3	185	99	86	1.15
		4	229	132	97	1.36
		5	235	130	105	1.24
		6	231	115	116	0.99
		7	173	87	86	1.01
		8	379	223	156	1.43
		9	523	291	232	1.25
		10	1310	743	567	1.31
	Dabbling	1	26	4	22	0.18
		2	54	13	41	0.32
		3	70	12	58	0.21
		4	62	11	51	0.22
		5	135	27	108	0.25
		6	128	26	102	0.25
		7	83	10	73	0.14
		8	146	22	124	0.18
		9	188	48	140	0.34
		10	306	81	225	0.36
	Diving	1	8	1	7	0.14
		2	11	3	8	0.38
		3	18	9	9	1.00
		4	17	11	6	1.83
		5	19	10	9	1.11
		6	29	9	20	0.45
		7	26	15	11	1.36
		8	29	6	23	0.26
		9	30	7	23	0.30
		10	94	24	70	0.34

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Wyoming	Mallard	1	42	27	15	1.80
		2	79	49	30	1.63
		3	129	75	54	1.39
		4	180	111	69	1.61
		5	261	149	112	1.33
		6	234	140	94	1.49
		7	235	128	107	1.20
		8	464	288	176	1.64
		9	643	367	276	1.33
		10	1182	628	554	1.13
	Dabbling	1	22	3	19	0.16
		2	32	3	29	0.10
		3	127	30	97	0.31
		4	89	14	75	0.19
		5	115	33	82	0.40
		6	177	56	121	0.46
		7	133	40	93	0.43
		8	276	78	198	0.39
		9	362	111	251	0.44
		10	455	117	338	0.35
	Diving	1	7	4	3	1.33
		2	6	1	5	0.20
		3	19	10	9	1.11
		4	37	13	24	0.54
		5	17	6	11	0.55
		6	19	12	7	1.71
		7	40	8	32	0.25
		8	51	26	25	1.04
		9	120	60	60	1.00
		10	102	59	43	1.37

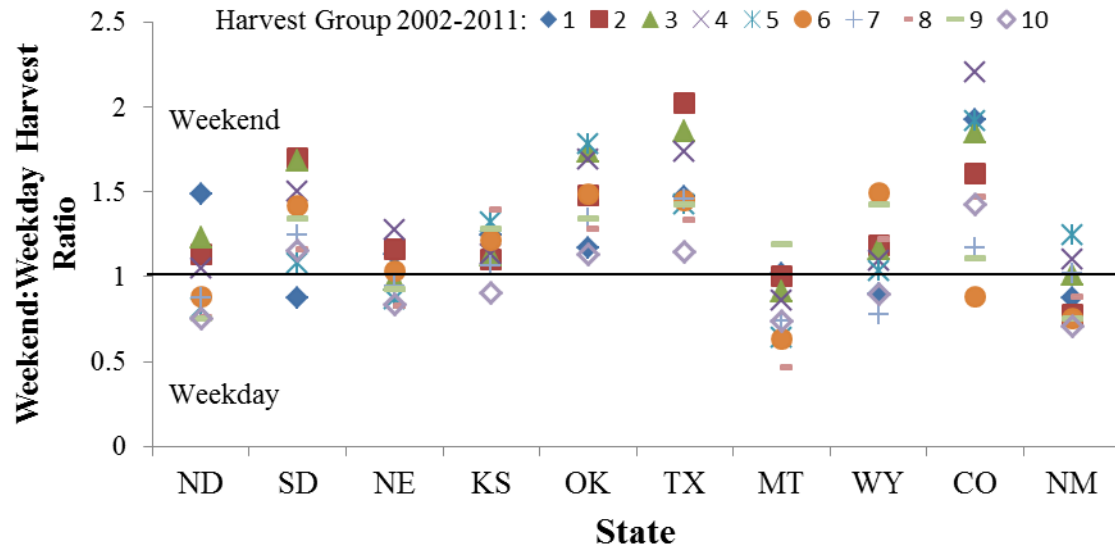
Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
Colorado	Mallard	1	95	58	37	1.57
		2	181	95	86	1.10
		3	277	160	117	1.37
		4	259	143	116	1.23
		5	309	165	144	1.15
		6	319	187	132	1.42
		7	381	213	168	1.27
		8	655	367	288	1.27
		9	681	397	284	1.40
		10	1071	645	426	1.51
	Dabbling	1	56	10	46	0.22
		2	124	30	94	0.32
		3	203	53	150	0.35
		4	177	43	134	0.32
		5	250	83	167	0.50
		6	259	73	186	0.39
		7	382	138	244	0.57
		8	525	138	387	0.36
		9	706	198	508	0.39
		10	824	292	532	0.55
	Diving	1	10	4	6	0.67
		2	33	14	19	0.74
		3	32	7	25	0.28
		4	15	8	7	1.14
		5	37	15	22	0.68
		6	36	8	28	0.29
		7	57	20	37	0.54
		8	72	28	44	0.64
		9	96	39	57	0.68
		10	126	63	63	1.00

Appendix 2.W (continued)

State	Duck Species Group	Harvest Group	<i>n</i>	Adult Harvest (PCS)	Immature Harvest (PCS)	Adult: Immature
New Mexico	Mallard	1	31	14	17	0.82
		2	71	26	45	0.58
		3	117	66	51	1.29
		4	101	29	72	0.40
		5	129	59	70	0.84
		6	90	38	52	0.73
		7	259	128	131	0.98
		8	245	98	147	0.67
		9	376	184	192	0.96
		10	2335	1040	1295	0.80
	Dabbling	1	39	19	20	0.95
		2	90	45	45	1.00
		3	101	55	46	1.20
		4	132	74	58	1.28
		5	137	68	69	0.99
		6	163	78	85	0.92
		7	289	121	168	0.72
		8	306	162	144	1.13
		9	541	267	274	0.97
		10	2525	1303	1222	1.07
	Diving	1	5	1	4	0.25
		2	7	4	3	1.33
		3	16	8	8	1.00
		4	13	3	10	0.30
		5	17	8	9	0.89
		6	22	10	12	0.83
		7	35	18	17	1.06
		8	39	17	22	0.77
		9	52	24	28	0.86
		10	145	73	72	1.01

Appendix 2.X: Weekend:weekday ratio of duck harvest estimates for harvest groups (10% of each regulation period sample, stratified by seasonal harvest) for Central Flyway states, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.



Appendix 2.Y: Weekend:weekday ratio of duck harvest estimates for harvest groups (10% of each regulation period sample, stratified by seasonal harvest) for Central Flyway states, derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.

State	Harvest Group	<i>n</i>	Weekday Harvest (PCS)	Weekend Harvest (PCS)	Weekend: Weekday
North Dakota	1	361	145	216	1.49
	2	904	424	480	1.13
	3	1833	822	1011	1.23
	4	2003	976	1027	1.05
	5	2948	1622	1326	0.82
	6	3550	1887	1663	0.88
	7	4356	2319	2037	0.88
	8	6037	3429	2608	0.76
	9	6751	3849	2902	0.75
	10	6193	3534	2659	0.75
South Dakota	1	236	126	110	0.87
	2	489	181	308	1.70
	3	899	335	564	1.68
	4	767	307	460	1.50
	5	1160	557	603	1.08
	6	1521	629	892	1.42
	7	1881	837	1044	1.25
	8	2456	1136	1320	1.16
	9	2767	1179	1588	1.35
	10	5625	2614	3011	1.15
Nebraska	1	192	90	102	1.13
	2	422	195	227	1.16
	3	517	261	256	0.98
	4	648	285	363	1.27
	5	666	356	310	0.87
	6	930	458	472	1.03
	7	943	485	458	0.94
	8	2267	1239	1028	0.83
	9	2538	1318	1220	0.93
	10	5839	3181	2658	0.84

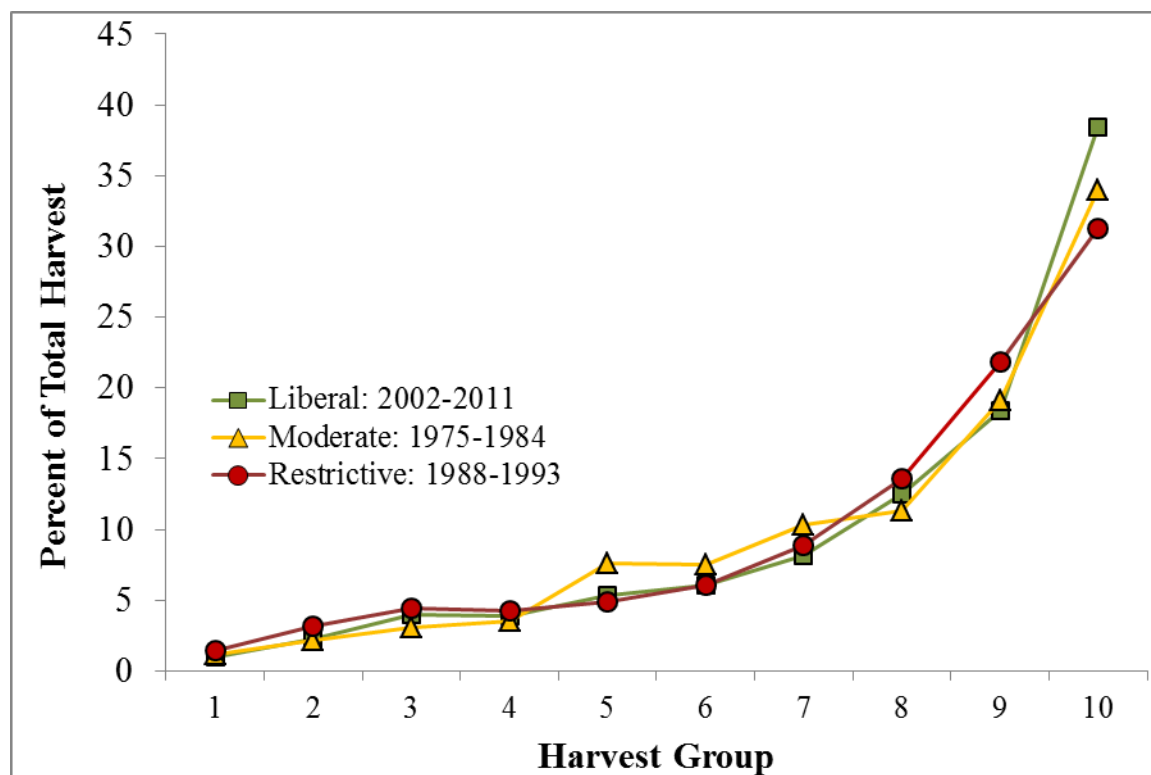
Appendix 2.Y (continued)

State	Harvest Group	<i>n</i>	Weekday Harvest (PCS)	Weekend Harvest (PCS)	Weekend: Weekday
Kansas	1	155	69	86	1.25
	2	355	169	186	1.10
	3	560	264	296	1.12
	4	424	199	225	1.13
	5	678	292	386	1.32
	6	661	298	363	1.22
	7	950	460	490	1.07
	8	1617	675	942	1.40
	9	2114	925	1189	1.29
	10	5219	2744	2475	0.90
Oklahoma	1	104	48	56	1.17
	2	337	136	201	1.48
	3	608	222	386	1.74
	4	560	208	352	1.69
	5	648	233	415	1.78
	6	982	395	587	1.49
	7	1391	594	797	1.34
	8	2154	943	1211	1.28
	9	5149	2200	2949	1.34
	10	9452	4435	5017	1.13
Texas	1	284	115	169	1.47
	2	650	215	435	2.02
	3	1129	395	734	1.86
	4	1140	417	723	1.73
	5	1495	616	879	1.43
	6	1487	607	880	1.45
	7	2289	932	1357	1.46
	8	3629	1552	2077	1.34
	9	6445	2654	3791	1.43
	10	16999	7915	9084	1.15

Appendix 2.Y (continued)

State	Harvest Group	<i>n</i>	Weekday Harvest (PCS)	Weekend Harvest (PCS)	Weekend: Weekday
Montana	1	107	53	54	1.02
	2	228	114	114	1.00
	3	287	150	137	0.91
	4	312	168	144	0.86
	5	393	240	153	0.64
	6	393	241	152	0.63
	7	290	167	123	0.74
	8	561	383	178	0.46
	9	753	343	410	1.20
	10	1731	995	736	0.74
Wyoming	1	72	38	34	0.89
	2	118	54	64	1.19
	3	277	128	149	1.16
	4	312	149	163	1.09
	5	402	198	204	1.03
	6	441	177	264	1.49
	7	413	232	181	0.78
	8	804	362	442	1.22
	9	1155	476	679	1.43
	10	1786	942	844	0.90
Colorado	1	164	56	108	1.93
	2	349	134	215	1.60
	3	519	182	337	1.85
	4	458	143	315	2.20
	5	607	208	399	1.92
	6	629	334	295	0.88
	7	843	388	455	1.17
	8	1281	518	763	1.47
	9	1503	712	791	1.11
	10	2054	847	1207	1.43
New Mexico	1	75	40	35	0.88
	2	172	97	75	0.77
	3	235	117	118	1.01
	4	248	118	130	1.10
	5	299	133	166	1.25
	6	282	161	121	0.75
	7	591	293	298	1.02
	8	600	319	281	0.88
	9	985	561	424	0.76
	10	5054	2957	2097	0.71

Appendix 2.Z: Harvest group (10% of each regulation period sample, stratified by seasonal harvest) contribution to the annual total duck harvest in the Central Flyway during liberal (2002-2011), moderate (1975-1984), and restrictive (1988-1993) harvest regulation periods. Derived from U.S. Fish and Wildlife Service Parts Collection Survey data.



Appendix 3:

Appendix 3.A: Example calculations for the harvest reduction model for target species, based on U.S. Fish and Wildlife Service Parts Collection Survey, 2002-2011.

$$R_H = \sum_{b=l+1}^n h_b - [(l/b) \times h_b]$$

where:
 R_H = predicted daily bag limit change harvest reduction.
 h_b = total harvest of all daily bags of size b .
 b = species-specific bag size taken by a hunter in one day (e.g., 1-6).
 l = hypothetical limit.
 n = maximum limit for target species.

Example 1:

Objective: Reduce pintail limit from 2 ducks daily to one duck daily using 2011 as the reference year.

187,587 = Total estimated pintail harvest in 2011.
 0.8858 = Percent of pintail harvest with 1 in bag.
 0.1141 = Percent of pintail harvest with 2 in bag.
 166,165 = Pintail harvest with 1 duck in bag.
 21,404 = Pintail harvest with 2 ducks in bag.

$$R_H = 21404 - [(1/2) \times 21404]$$

$$R_H = \mathbf{10,702}$$

Example 2:

Objective: Reduce gadwall limit from 6 ducks daily to 3 ducks daily using 2011 as the reference year.

555,983 = Total estimated gadwall harvest in 2011.
 0.5475 = Percent of gadwall harvest with 1 in bag.
 0.2461 = Percent of gadwall harvest with 2 in bag.
 0.1179 = Percent of gadwall harvest with 3 in bag.
 0.0514 = Percent of gadwall harvest with 4 in bag.
 0.0273 = Percent of gadwall harvest with 5 in bag.
 0.0097 = Percent of gadwall harvest with 6 in bag.
 304,401 = Gadwall harvest with 1 duck in bag.
 136,827 = Gadwall harvest with 2 ducks in bag.
 65,550 = Gadwall harvest with 3 ducks in bag.
 28,578 = Gadwall harvest with 4 ducks in bag.
 15,178 = Gadwall harvest with 5 ducks in bag.
 5,393 = Gadwall harvest with 6 ducks in bag.

$$R_H = \{28578 - [(3/4) \times 28578]\} + \{15178 - [(3/5) \times 15178]\} + 5393 - [(3/6) \times 5393]$$

$$R_H = 7145 + 6071 + 2696$$

$$R_H = \mathbf{15,912}$$

** Assumes hunter who harvest over the proposed new limit will at least harvest the same number of duck up to that hypothetical limit. For example, a hunter who normally would have harvested 4, 5, or 6 gadwall will only harvest 3 gadwall under the new limit.*

Appendix 3.B: Example calculations for the harvest redistribution model for non-target species, based on results derived from the harvest reduction model and conditional probability matrix.

$$H_N = R_H \times \frac{P(B|A)}{\sum_{i=1}^n P(B_i|A)}$$

where:

H_N = Extra harvest for a given non-target species

R_H = predicted limit change harvest reduction for target species

B = non-target species

A = target species

n = total number of non-target species.

Example 1:

Question: How many extra mallards could be harvested assuming harvest remains constant for 2011 using the harvest reduction calculated from the pintail example in Appendix 3.A?

$$H_{\text{MALL}} = 10702 \times \{0.4744/[0.4744+0.2437+0.1154+0.2003+0.2815+0.1266+0.0195+0.0945+0.0214+0.0374+0.0436+0.0322]\} \text{ *Probabilities from Table 3.1}$$

$$H_{\text{MALL}} = 10702 \times \{0.4744/1.6905\}$$

$$H_{\text{MALL}} = 10702 \times \{0.2806\}$$

$$\mathbf{H_{MALL} = 3,003}$$

Example 2:

Question: How many extra blue winged teal could be harvested assuming harvest remains constant for 2011 using the harvest reduction calculated from the gadwall example in Appendix 3.A?

$$H_{\text{BWTE}} = 15912 \times \{0.0951/[0.4123+0.2023+0.0951+0.2088+0.1180+0.0891+0.0342+0.0625+0.0192+0.0420+0.0739+0.0364]\} \text{ *Probabilities from Table 3.1}$$

$$H_{\text{BWTE}} = 15912 \times \{0.0951/1.3938\}$$

$$H_{\text{BWTE}} = 15912 \times \{0.0682\}$$

$$\mathbf{H_{BWTE} = 1,086}$$

Appendix 3.C: Distribution of sizes of species-specific daily bags for the Central Flyway, 2002-2011. Derived from U.S. Fish and Wildlife Service Parts Collection Survey.

State	Proportion of daily bags with b number of ducks for a given species												
	REDH			SCAUP			NOPI			WODU			
	1	2	n	1	≥ 2	n	1	2	n	1	2	3	n
North Dakota	0.79	0.21	1158	0.60	0.40	1010	0.91	0.09	1155	0.77	0.22	0.01	117
South Dakota	0.77	0.23	345	0.55	0.45	276	0.89	0.26	548	0.71	0.27	0.02	262
Nebraska	0.76	0.24	165	0.85	0.15	91	0.93	0.07	296	0.74	0.23	0.03	279
Kansas	0.78	0.22	168	0.79	0.21	66	0.94	0.06	283	0.77	0.21	0.02	154
Oklahoma	0.76	0.24	182	0.76	0.24	126	0.85	0.15	418	0.65	0.32	0.03	348
Texas	0.53	0.47	857	0.67	0.33	635	0.85	0.15	1521	0.55	0.39	0.05	1091
Montana	0.76	0.24	67	0.86	0.14	37	0.93	0.07	82	0.67	0.29	0.04	73
Wyoming	0.87	0.13	38	0.63	0.38	24	0.99	0.01	79	0.81	0.17	0.02	47
Colorado	0.73	0.27	99	0.81	0.19	54	0.94	0.06	142	0.81	0.15	0.04	140
New Mexico	0.81	0.19	53	0.92	0.08	25	0.87	0.13	293	0.77	0.20	0.03	115

REDH = redhead (*Aythya americana*); SCAUP = lesser and greater scaup combined (*A. affinis* and *A. marila*); NOPI = northern pintail (*Anas acuta*); WODU = wood duck (*Aix sponsa*).

Appendix 3.D: Creating a duck guild based on co-occurrence data.

Introduction

Multi-stock management may rely heavily on the successful creation of duck guilds (Johnson et al. 2002). The Hunter's Choice (HC) experiment during 2006-2008 in the Central Flyway employed ducks guilds which allowed hunters to select between a single female mallard (*Anas platyrhynchos*), pintail (NOPI, *A. acuta*), canvasback (*Aythya valisineria*), or mottled duck (*Anas fulvigula*) for a hunter's daily bag (Gammonley et al. 2010). The intention of the experiment was to reduce the harvest of female mallards, pintails, canvasbacks, and mottled ducks by buffering (i.e. reduce the harvest of all other duck stocks in an aggregate) their harvest with each other, expecting the more common stocks to provide the greatest buffering effects (Gammonley et al. 2010). However, based on my co-occurrence data (Chapter 3), other combinations of ducks may have more effectively achieved this goal. For example, green-winged teal (AGWT, *A. crecca*) are more commonly harvested with pintail than canvasback and female mallard. Thus, green-winged teal may reduce the harvest of pintail to a greater extent than female mallard, canvasback, and mottled duck combined. As such, my objective was (1) to use my co-occurrence data to create a duck guild and predict the reduction in pintail harvest, and (2) to compare the predicted harvest reduction for pintail to those from the HC experiment.

Methods

I created a model to predict the effects of harvest changes on duck species stemmed from creation of duck guilds, similar to the HC experiment in the Central

Flyway (Gammonley et al. 2010). The HC experiment combined female mallard, canvasback, pintail, and mottled duck into a guild in which hunters were allowed to harvest only one of those ducks daily (Gammonley et al. 2010). For my model, I also assumed that hunters would have a choice to harvest only one duck per HC guild per day. I ran a hypothetical scenario, where I subjectively combined pintail and green-winged teal into an HC guild. I created this guild by using the co-occurrence data as a guide (Table 3.1 [in Chapter 3]). For example, species that have large probabilities of co-occurring with each other, as well as having a large number of bags in which they occur, anecdotally resulted in the largest harvest reduction estimates.

To predict the reduction in harvest from HC guild implementation, I replicated the matrix onto a smaller scale which included only HC guild species (i.e., pintail and green-winged teal) for simplicity.

Probability of Harvesting:	Conditional on Harvesting:		
	Species	NOPI	AGWT
	NOPI	0.1142	0.1152
	AGWT	0.2437	0.4055
# of bags containing conditional species:		4,817	10,189

I multiplied the new matrix probabilities, $P(B|A)$, by the number of bags where species A occurs, which results in a new matrix seeded with the total number of bags where both species A and B occur for all guild species.

# of Bags containing species:		
Species	NOPI	AGWT
NOPI	550	1,174
AGWT	1,174	4,132

The PCS harvest reduction for HC guild species was defined as the sum of each row in the new matrix. In other words, I defined the PCS harvest reduction for HC guild species $[R]$ as the sum of the probabilities for a particular target species $[A]$ in the HC guild given some other species in the HC guild $[G]$, multiplied by the number of bags where the other HC guild conditional species $[N]$ occurs.

$$R = \sum_{i=1}^n P(A|G_i) * N_i$$

where:

n = number of species in hunter choice guild.

To calculate the PCS percent harvest reduction, I divided the PCS harvest reduction by the total PCS harvest for any species of interest for the sampling period 2002-2011.

Species	PCS Harvest Reduction	Actual PCS Harvest ¹	PCS % Harvest Reduction
NOPI	1,724	5,402	0.3191
AGWT	5,306	17,199	0.3085

¹ Total for years 2002-2011.

Finally, I predicted the harvest reductions for a particular known harvest estimate (e.g., harvest in 2011). I multiplied the PCS percent reduction for a given species of interest by the total estimated harvest for that species (Kruse 2013), for a given year of interest to predict the reduction in harvest.

Species	2011 Harvest ¹	Current Limit ¹	Proposed Limited	PCS % Harvest Reduction	Predicted Harvest Reduction
NOPI	187,587	2	1 choice	0.3191	59,862
AGWT	309,642	6		0.3085	95,518

¹ Kruse 2013

I replicated the harvest redistribution model in Chapter 3 to predict how the reduced effort (i.e., harvest) on one species may translate into the increased effort on another species. I used the same harvest redistribution model, except I did not include any HC guild species probabilities when calculating the relative probability of co-occurrence (Table 1). HC guild species were not included because harvest reduction models already accounted for the predicted harvest changes of HC guild species.

Results

When pintails were grouped with green-winged teal in a HC guild, my model predicted a harvest reduction of 32% for pintails (59,862 ducks) and 31% for green-winged teal (95,518 ducks), based on 2011 known harvest estimates (Table 2). In this scenario, the redistribution of harvest from the reductions of pintail and green-winged teal harvest predicted wigeon harvest to increase the most (11.70% or 19,387 extra ducks) and canvasback harvest to increase the least (4.40% or 1,849 extra ducks) (Table 3).

Discussion

My results reinforce findings in the HC experiment (Gammonley et al. 2010), in that HC guilds can successfully reduce the harvest of certain species (e.g., pintails, ~42%

harvest reduction from the HC experiment guild [pintail, canvasback, mottled duck, female mallard] and 32% harvest reduction using my HC guild [pintail and green-winged teal]). Although, my HC guild might not reduce harvest to the same extent as the HC experiment, my model only included two species. If more species were included in my model, then predicted reductions in harvest also would increase.

However, the redistribution of harvest to non-target species and reduction in harvest of other HC guild species from such actions may not be desirable. My harvest reduction results only consider the species pair interaction. Thus, the total effects (e.g., daily limit reduction, hunter participation) of essentially reducing green-winged teal daily limits from 6 to 1 were not fully realized.

Additional studies, similar to the HC experiment in the Central Flyway (Gammonley et al. 2010), are needed to expand and develop techniques applicable to multi-stock management. Studies that address the potential impacts of multi-stock management techniques on hunters within the system also are needed. Implementation of regulatory alternatives (e.g., HC guilds) should anticipate and evaluate the effects on both duck stocks and hunters.

Literature Cited

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- Johnson, F.A., M.C. Runge, and J.R. Serie. 2002. The problem of scale in adaptive harvest management: alternatives for recognizing stock-specific variation in harvest potential. U.S. Department of the Interior, Washington, D.C., USA.
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Table 1: Example of harvest redistribution calculations based on a hunter's choice guild (Gammonley et al. 2010) and on U.S. Fish and Wildlife Service Parts Collection Survey, 2002-2011.

$$H_N = R_H * \frac{P(B|A)}{\sum_{i=1}^n P(B_i|A)}$$

where:
 H_N = Extra harvest for a given non-target species
 R_H = predicted limit change harvest reduction for target species.
 B = non-target species
 A = target species
 n = total number of non-target species.

Example 1:

Question: How many extra canvasbacks could be harvested from the harvest reduction calculated for northern pintails in Table 1, using 2011 as the reference year?

$$H_{(CANV | NOPI)} = 59862 \times \{0.0214/[0.4774+0.1154+0.2003+0.2815+0.1266+0.0195+0.0945+0.0214+0.0374+0.0436+0.0322]\}$$

**Probabilities from Table 3.1, do not include any hunters choice guilds species probabilities*

$$H_{(CANV | NOPI)} = 59862 \times \{0.0214/1.4498\}$$

$$H_{(CANV | NOPI)} = 59862 \times \{0.0148\}$$

$$H_{(CANV | NOPI)} = \mathbf{885}$$

$$H_{(CANV | AGWT)} = 95518 \times \{0.0137/[0.3824+0.1493+0.1578+0.3022+0.1295+0.0430+0.0507+0.0137+0.0338+0.0570+0.0386]\}$$

**Probabilities from Table 3.1, do not include any hunters choice guilds species probabilities*

$$H_{(CANV | AGWT)} = 95518 \times \{0.0137/1.3580\}$$

$$H_{(CANV | AGWT)} = 95518 \times \{0.0101\}$$

$$H_{(CANV | AGWT)} = \mathbf{964}$$

$$\text{Total potential canvasback harvest} = H_{(CANV | NOPI)} + H_{(CANV | AGWT)}$$

$$\text{Total potential canvasback harvest} = 885 + 964$$

$$\mathbf{\text{Total potential canvasback harvest} = 1,849}$$

Table 2: Predicted reduction in harvest from a hypothetical Hunter's Choice guild of northern pintail (*Anas acuta*; NOPI) and American green-winged teal (*A. crecca*; AGWT). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, 2002-2011.

Species	2011 Harvest ¹	Current Limit ¹	Proposed Limited	PCS % Harvest Reduction	Predicted Harvest Reduction
NOPI	187,587	2	1 choice	0.3191	59,862
AGWT	309,642	6		0.3085	95,518

¹ Kruse 2013

Table 3: Predicted harvest increases for mallard (*Anas platyrhynchos*), blue-winged teal (*A. discors*), American wigeon (*A. americana*), gadwall (*A. strepera*), northern shoveler (*A. clypeata*), wood duck (*Aix sponsa*), redhead (*Aythya americana*), canvasback (*A. valisineria*), scaup [lesser and greater combined] (*A. affinis* and *A. marila*), ring-necked duck (*A. collaris*), and other ducks (all others harvested in sampling frame not already specified) from the predicted harvest decreases from a hypothetical Hunter's Choice guild implementation combining northern pintails (*Anas acuta*) and American green-winged teal (*A. crecca*). Derived from U.S. Fish and Wildlife Service Parts Collection Survey data, and the probabilities of co-occurrence contained in Chapter 3, 2002-2011.

Species	Predicted redistribution of harvest from predicted harvest reductions for:		Total Predicted Harvest Increase	% Increase in Harvest ¹
	Pintail	Green-winged Teal		
Mallard	19,629	26,897	46,526	6.10
Green-winged Teal	-	-	-	-
Blue-winged Teal	4,775	10,501	15,276	10.47
Wigeon	8,288	11,099	19,387	11.70
Gadwall	11,647	21,256	32,903	5.92
Shoveler	5,238	9,109	14,347	8.21
Pintail	-	-	-	-
Wood Duck	807	3,025	3,831	8.41
Redhead	3,910	3,566	7,476	6.08
Canvasback	885	964	1,849	4.40
Scaup [lesser and greater]	1,547	2,377	3,925	8.35
Ring-necked Duck	1,804	4,009	5,813	6.72
Other	1,332	2,715	4,047	4.48

¹ References known 2011 harvest estimates, Kruse 2013