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Source: *The Journal of Wildlife Management*, Vol. 60, No. 3, (Jul., 1996), pp. 551-559

Published by: Allen Press

Stable URL: <http://www.jstor.org/stable/3802072>

Accessed: 05/08/2008 09:32

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HARVESTING MULTIPLE STOCKS OF DUCKS

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Abstract: This study was conducted to help assess whether recent harvest rates of ducks banded before the hunting season in the United States varied among stocks (i.e., species, age-sex cohort, location of banding) and whether regulatory actions have been successful at shifting harvest pressure among stocks in the desired manner. Direct recovery rates during 1976–91 were used to index harvest rates and were influenced to some degree by location of banding, age class, sex, species, and hunting regulations. However, differences in recovery probability among species were consistent ($P = 0.787$) over 3 periods with different hunting regulations (1976–84, 1985–87, 1988–91), despite regulatory changes designed to affect species differentially. Band-recovery models that excluded the interaction between hunting regulations and sex of ducks were inadequate ($P \leq 0.013$), suggesting sex-specific changes in recovery probabilities with changes in regulations. There was little evidence ($P \leq 0.151$) that regulatory changes affected recovery rates of ducks from 3 banding reference areas differentially. Harvesting duck stocks in an optimal manner requires an ability to harvest selectively, a good understanding of each stock's dynamics, and knowledge of any interdependence in stock sizes.

J. WILDL. MANAGE. 60(3):551–559

Key words: banding, ducks, harvest, hunting, logistic analysis, power, migratory birds, recovery rate, regulations.

Stocks of migratory birds in North America often are exposed to a common sport harvest, in that hunting regulations allow individuals of different species, populations, and age-sex cohorts to be harvested at the same time and place. This practice has been a common approach with ducks, where daily bag limits and the length and timing of hunting seasons are based on the aggregate status of many stocks, particularly those breeding in the important prairie and parkland habitats of southcentral Canada. As understanding of the status and dynamics of individual stocks has improved, managers increasingly have sought to maximize total yield (or at least harvest opportunity) by apportioning harvest pressure among stocks in an optimal way. The traditional tools of this approach have been flyway-specific, species-specific, and occasionally sex-specific daily bag limits and seasons.

Whether these stock-specific regulations have worked as intended is unclear. Harvest rates of migratory bird stocks are the result of a complex interaction of myriad influences, some of which are beyond the control of managers. First, different stocks may vary in their inherent vulnerability, which is a function of spatial and temporal distributions, social behavior, and other factors. For example, species that use maritime habitats are generally less vulnerable to

sport harvest than those using palustrine habitats, and young birds are almost always more vulnerable than adults. Second, harvest rates of various stocks are influenced by hunter preferences, which involve not only selective shooting by hunters, but decisions regarding when and where to hunt. Managers must contend with this background noise in the system when manipulating harvest rates of individual stocks.

Because of the implications for successful harvest management, we were interested in whether recent harvest rates of ducks in North America have been stock-dependent and whether regulatory actions have been successful at shifting harvest pressure among these stocks in the desired manner. Specifically, our intention was to test whether duck harvest rates have been dependent on species, age, sex, or location just before the start of the hunting season. We were also interested in whether recent regulatory changes in the United States have had a demonstrable effect on harvest rates and whether those effects have been stock-dependent. Estimates of harvest rates were not available, so we used the direct recovery rate of ducks banded just before the hunting season as an index to harvest rate. Direct recovery rate is defined as the probability that a bird is shot during the first hunting season following banding and its band

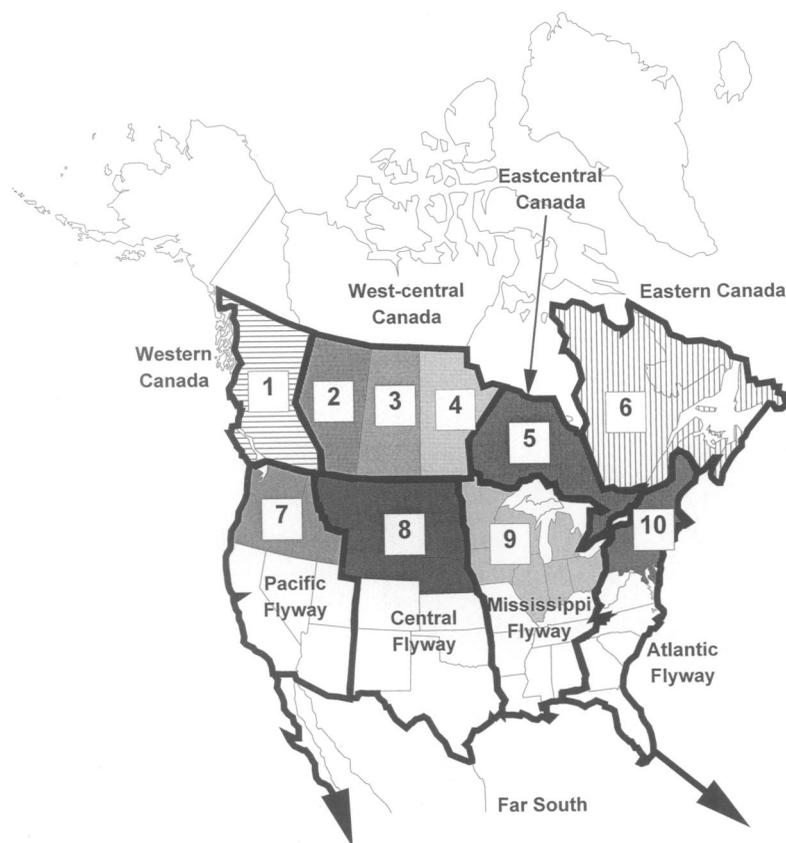


Fig. 1. Banding-reference areas (shaded and numbered) and harvest zones (bold outline and labeled) used to investigate sources of variation in harvest rates of ducks banded pre-season in North America. Ducks banded within reference areas shared migration and wintering areas (i.e., harvest zones) and, thus, were exposed to similar hunting regulations.

reported to the U.S. Bird Banding Laboratory (Laurel, Md.). Therefore, the reliability of recovery rate as an index to harvest rate depends on the assumption that band-reporting rates did not vary among stocks or over time. Unfortunately, little information exists to test this assumption so our results should be interpreted with caution.

We thank R. J. Barker, W. L. Kendall, and J. D. Nichols for advice in designing this study and for assistance with the analyses. J. P. Bladen provided the band-recovery data. W. L. Kendall, J. D. Nichols, and 2 anonymous reviewers provided suggestions for earlier drafts.

METHODS

We compiled records of normal, wild ducks banded pre-season (i.e., Jul-Sep) during 1950-92 in the United States or Canada and all direct recoveries of same during the hunting season (i.e., Sep-Feb). We used the procedure de-

scribed by Anderson and Henny (1972) and Nichols and Hines (1987) to combine banding locations into larger reference areas. Banding reference areas were delineated by visually examining the geographic distribution of recoveries from all ducks (regardless of species, age class, or sex) banded in individual states and provinces. Our intent was to define pre-hunting-season aggregations of ducks that shared migration and wintering areas and, thus, ensure that birds banded within a reference area were exposed to similar hunting regulations. Although our emphasis was on combining banding locations with similar recovery distributions, we also considered political boundaries and the amount of data available for prospective areas. Those states or provinces of banding that had similar distributions of recoveries among 9 broad harvest zones were grouped into 10 banding reference areas (4 in the United States and 6 in Canada) (Fig. 1).

Table 1. Percentage of direct recoveries that occurred in 9 harvest zones from ducks banded in U.S. reference areas, 1950–92. Numbers of recoveries are provided in parentheses. Geographic boundaries of reference areas and harvest zones are provided in Fig. 1.

Harvest zone	Banding reference area			
	PAC (7)	CEN (8)	MIS (9)	ATL (10)
Western Canada	1.91 (281)	0.00 (0)	0.00 (0)	0.00 (0)
Pacific Flyway	96.39 (14,146)	7.15 (1,166)	0.02 (10)	0.00 (0)
Westcentral Canada	0.05 (7)	2.07 (337)	1.03 (640)	0.00 (1)
Central Flyway	0.84 (124)	47.47 (7,737)	3.59 (2,219)	0.08 (26)
Eastcentral Canada	0.01 (1)	0.56 (91)	2.19 (1,355)	5.56 (1,860)
Mississippi Flyway	0.12 (18)	36.76 (5,991)	87.67 (54,266)	5.22 (1,748)
Eastern Canada	0.00 (0)	0.13 (22)	0.14 (88)	4.57 (1,530)
Atlantic Flyway	0.10 (15)	1.54 (251)	4.64 (2,874)	83.97 (28,110)
Far South	0.57 (84)	4.31 (702)	0.72 (443)	0.60 (201)

We confined our analysis to banding reference areas within the United States because we did not want any U.S. regulatory effects to be confounded by independent regulatory changes in Canada (few birds banded in the United States are harvested in Canada). The U.S. reference areas were defined as: (1) Atlantic (ATL), which included the New England states, New York, Pennsylvania, New Jersey, Delaware, and Maryland; (2) Mississippi (MIS), which included Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana, and Ohio; (3) Central (CEN), which included Montana, Wyoming, North and South Dakota, and Nebraska; and (4) Pacific (PAC), which included Washington, Oregon, and Idaho. These reference areas constitute the northernmost portions of flyway administrative units. A large proportion (>80%) of the recoveries from birds banded in the ATL, MIS, and PAC reference areas were located in their respective flyways (Table 1). Recoveries of ducks banded in the CEN reference area were more evenly divided between the Central Flyway (47%) and the Mississippi Flyway (37%).

We then restricted our analysis to the years 1976–91, which were characterized by 3 periods of largely stable, but contrasting, hunting regulations. During 1976–84 basic regulations (e.g., season length, bag limits) throughout the United States were relatively liberal, and there was extensive use of special September seasons and bonus bag limits for teal (*Anas discors*, *A. crecca*) and widespread use of the point system (U.S. Fish and Wildl. Serv. 1988). In 1984, 25 of 38 eligible states used the point system, primarily in the Mississippi Flyway and Central Flyway. One purpose of the point system was to allow greater daily harvests of those duck stocks that were considered abundant or lightly harvested,

while reducing harvest pressure on those stocks in need of greater protection. During 1976–84 the point system was characterized by relatively large differences in species-specific bag limits. For example, a hunter in the Mississippi Flyway could legally shoot a maximum of 10 northern pintails (*Anas acuta*), but only 2 wood ducks (*Aix sponsa*), each day. Regulations during this period were designed to minimize harvest pressure on black ducks (*Anas rubripes*), wood ducks, and female mallards (*A. platyrhynchos*), while allowing greater harvests of teal, American wigeon (*A. americana*), gadwall (*A. strepera*), northern pintail, and scaup (*Aythya affinis*, *A. marila*). Duck hunting regulations during 1976–84 were more species-specific than during any other period in U.S. history.

Season lengths and bag limits in the following period (1985–87) were more restrictive, but the use of special seasons and bonus bags for teal continued. The point system continued to be used extensively, but there was much less variability in point values among species. In 1987, 22 of 41 eligible states employed the point system.

During 1988–91, regulations were restricted further and there were no teal seasons or bonus bags offered. The point system was either not offered (1988) or had bag limits similar to the conventional bag limit (1989–91), which specified few differences among stocks in allowable harvest. Throughout the 1976–91 period there were differences in season length and bag limits among flyways, but regulatory changes occurred concurrently in all flyways.

We modeled the logit of the recovery probability as a linear response of banding reference area, species, age class, sex, and regulatory period. This approach was analogous to a 5-way

analysis of variance, except that the predicted recovery probability was bounded between 0 and 1, and the binomial, not the normal, described the distribution of errors. Maximum-likelihood estimates of model parameters were obtained using the CATMOD procedure of SAS software (SAS Inst. Inc. 1989). Banded sample sizes were sufficient to examine the following treatment levels: 3 reference areas (ATL, MIS, CEN), 4 species (mallard, green-winged teal, blue-winged teal, northern pintail), 2 age classes (young-of-the-yr, ad), both sexes, and the 3 regulatory periods. This examination was based on 410,222 bandings and 23,648 recoveries. The fully-parameterized model included an intercept, all main effects, and all possible interactions for a total of 32 effects and 144 parameters.

We explored the ability of reduced models to describe the data using likelihood ratio tests and Akaike's Information Criterion (AIC) (Burnham and Anderson 1992). These reduced models, when compared with the fully-parameterized model, expressed specific hypotheses about the dependency of recovery probability on banding reference area, species, age class, sex, and regulatory period. The no-AREA model excluded from the full model all main and interaction effects involving banding reference area and had 16 effects and 48 parameters. Comparison of the no-AREA model with the full model tested the hypothesis that banding reference area was not a significant source of variability in recovery rates. The no-SPP model excluded from the full model all those effects that included species and had 16 effects and 36 parameters. With this model we were interested in testing whether there were any detectable differences in species' recovery rates over the levels of the other treatments. Similarly, we examined the no-AGE (16 effects, 72 parameters), no-SEX (16 effects, 72 parameters), and no-REG (i.e., regulatory period) (16 effects, 48 parameters) models.

Because of our interest in the effects of hunting regulations, we also examined a number of models that excluded from the full model certain interaction effects involving regulatory period. The most specific model (no-REG*) included a main effect for regulatory period, but excluded all those interaction effects involving period (17 effects, 50 parameters). Comparison of this model with the full model tested whether changes in recovery probabilities that occurred with changes in regulations were stock-specific

(as defined by reference area, species, age class, and sex). Interaction effects involving regulatory period then were added to this specific model in an hierarchical fashion. Again, likelihood ratio tests and AIC were used to identify important sources of variation in recovery probabilities. Here we were interested in determining how regulatory changes in 1985 and 1988 affected stocks differentially, if at all.

The interaction effect between species and regulatory period was of particular interest because of the implications for species-specific harvest management. Therefore, in the event that we could not detect a differential effect of regulatory change among species, we approximated the power of a future test under similar experimental conditions, for a range of alternatives. We decomposed the interaction effect $SPP \times REG$ into a set of 2×3 tables; in each table, a pair of species was taken at a time for analysis under the 3 categories of REG. We specified alternatives as values of the ratio of relative recovery odds from periods 3 and 1 (these periods were chosen because they had the greatest species-specific differences in regulations):

$$\Omega = r_{B3}/(1 - r_{B3})(r_{A3}/[1 - r_{A3}])^{-1} \cdot (r_{B1}/[1 - r_{B1}] [r_{A1}/\{1 - r_{A1}\}]^{-1})^{-1},$$

where r_{ij} was recovery probability for species i in period j . Because duck recovery probabilities tended to be small (i.e., <0.10),

$$\Omega \cong r_{B3}/r_{A3} (r_{B1}/r_{A1})^{-1};$$

that is, specifying a value of Ω was almost equivalent to specifying a ratio of relative recovery probabilities. Given $\Omega \in (0.5, 2.0)$, fixing r_{i2} at recovery probability values estimated from the null model lacking the $SPP \times REG$ interaction, and obtaining d as the mean of the REG parameter estimates from the null model, we calculated values of r_{ij} as functions of Ω , r_{i2} , and d . We computed power for each such table of alternative r_{ij} at $\alpha = 0.05$ (O'Brien 1986).

Our analysis had several limitations. First, regulatory changes that were and were not stock-specific (i.e., not all regulatory changes were designed to affect stocks differentially) occurred simultaneously and, thus, their effects (if any) were confounded. Second, any regulatory effects also were confounded with any temporal effects (e.g., results could reflect systematic changes in inherent vulnerability of stocks over

Table 2. Direct recovery rates (\hat{f}) of ducks banded preseason (Jul–Sep) in 3 U.S. reference areas. The geographic boundaries of reference areas are provided in Fig. 1.

Area	Age-sex ^a	Species ^b	Regulatory period						
			1976–84		1985–87		1988–91		
			\hat{f}	SE	\hat{f}	SE	\hat{f}	SE	
ATL (10)	AM	MAL	0.069	0.002	0.051	0.006	0.043	0.003	
		GWT	0.038	0.012	0.025	0.018	0.016	0.009	
		BWT	0.016	0.003	0.013	0.004	0.011	0.004	
	AF	PIN	0.026	0.009	0.029	0.029	0.047	0.020	
		MAL	0.061	0.002	0.035	0.005	0.030	0.002	
		GWT	0.029	0.011	0.000	0.000	0.007	0.007	
	YM	BWT	0.021	0.004	0.015	0.008	0.003	0.003	
		PIN	0.073	0.019	0.000	0.000	0.020	0.012	
		MAL	0.089	0.002	0.086	0.005	0.064	0.002	
	YF	GWT	0.092	0.012	0.059	0.024	0.048	0.014	
		BWT	0.024	0.002	0.015	0.004	0.021	0.005	
		PIN	0.043	0.013	0.100	0.100	0.118	0.039	
	MIS (9)	AM	MAL	0.078	0.002	0.064	0.005	0.047	0.002
			GWT	0.060	0.012	0.066	0.029	0.028	0.012
			BWT	0.035	0.003	0.020	0.005	0.017	0.005
AF		PIN	0.054	0.014	0.154	0.104	0.024	0.017	
		MAL	0.073	0.002	0.052	0.003	0.045	0.002	
		GWT	0.063	0.015	0.060	0.029	0.035	0.012	
YM		BWT	0.015	0.003	0.043	0.030	0.000	0.000	
		PIN	0.025	0.005	0.041	0.016	0.016	0.007	
		MAL	0.060	0.002	0.039	0.002	0.030	0.002	
YF		GWT	0.066	0.021	0.051	0.036	0.025	0.018	
		BWT	0.018	0.003	0.000	0.000	0.033	0.019	
		PIN	0.035	0.009	0.017	0.010	0.019	0.008	
CEN (8)		AM	MAL	0.115	0.002	0.089	0.003	0.071	0.003
			GWT	0.073	0.012	0.162	0.061	0.063	0.023
			BWT	0.029	0.003	0.033	0.016	0.017	0.010
	AF	PIN	0.059	0.011	0.051	0.029	0.047	0.021	
		MAL	0.085	0.002	0.058	0.003	0.046	0.002	
		GWT	0.088	0.016	0.138	0.065	0.071	0.035	
	YM	BWT	0.029	0.003	0.032	0.014	0.019	0.009	
		PIN	0.084	0.013	0.038	0.027	0.064	0.022	
		MAL	0.054	0.002	0.041	0.002	0.031	0.002	
	YF	GWT	0.019	0.007	0.022	0.011	0.015	0.011	
		BWT	0.012	0.003	0.008	0.005	0.004	0.003	
		PIN	0.016	0.003	0.009	0.004	0.006	0.002	
	AF	MAL	0.030	0.002	0.021	0.002	0.014	0.001	
		GWT	0.031	0.010	0.016	0.008	0.013	0.013	
		BWT	0.015	0.005	0.004	0.004	0.000	0.000	
YM	PIN	0.014	0.002	0.016	0.004	0.007	0.002		
	MAL	0.063	0.003	0.053	0.004	0.044	0.004		
	GWT	0.015	0.006	0.020	0.007	0.037	0.037		
YF	BWT	0.009	0.003	0.011	0.003	0.000	0.000		
	PIN	0.052	0.007	0.043	0.009	0.018	0.006		
	MAL	0.041	0.003	0.028	0.003	0.018	0.003		
YF	GWT	0.030	0.010	0.015	0.007	0.000	0.000		
	BWT	0.016	0.004	0.011	0.004	0.000	0.000		
	PIN	0.026	0.004	0.016	0.005	0.010	0.004		

^a AM = adult male, AF = adult female, YM = young male, YF = young female.
^b MAL = mallard, GWT = green-winged teal, BWT = blue-winged teal, PIN = northern pintail.

time). Finally, inferences regarding variability in harvest rates are dependent on the critical assumption that there were no systematic differences in band-reporting rate over levels of the various treatments.

RESULTS

Banded-sample size varied greatly among the 144 populations (3 reference areas × 4 species × 2 age classes × 2 sexes × 3 regulatory periods)

Table 3. Logit models* for variation in the recovery probability among 144 populations of ducks (defined by reference area, species, age class, sex, and regulatory period) banded pre-season in the United States, 1976–91.

Model	Parameters	AIC	Likelihood-ratio test		
			χ^2	df	P
Full	144	174,658.89			
no-AREA	48	175,648.14	1,181.25	96	<0.001
no-AGE	72	175,403.60	888.71	72	<0.001
no-SEX	72	175,298.47	783.58	72	<0.001
no-SPP	36	176,562.49	2,119.60	108	<0.001
no-REG	48	175,733.35	1,266.46	96	<0.001

* The full model included the main effects of area (AREA), age class (AGE), sex (SEX), species (SPP), and regulatory period (REG), and all possible interactions. The reduced models excluded from the full model the specified main effect and all related interaction effects.

in the fully-parameterized model ($\bar{x} = 2,849$, range = 12–32,200). Among the treatments, the largest sample sizes tended to be for the MIS reference area, for mallards and blue-winged teal, for young males, and for the 1976–84 period.

Recovery rates ranged from 0.00 (SE = 0.00) to 0.162 (SE = 0.061) and tended to be highest for ducks banded in the ATL and MIS reference areas during 1976–84 (Table 2). Mallard and green-winged teal recovery rates usually were higher than those of blue-winged teal and northern pintails. Young usually had higher recovery rates than adults, and recovery rates of males often were higher than those of females. In almost all cases recovery rates declined with successive changes in regulations.

Using likelihood-ratio tests we rejected the no-AREA, no-AGE, no-SEX, no-SPP, and no-REG models ($P < 0.001$), confirming that there

was variation in recovery probabilities depending on banding reference area, age class, sex, species, and regulatory period (Table 3). That these 5 models were less satisfactory than the most general model was also supported by AIC values.

The reduced model that included the main effect of regulatory period, but that excluded all interactions involving period (no-REG*), did not explain the data as well as the full model ($P = 0.001$, Table 4). This result suggested that there were some stock-specific changes in recovery probabilities associated with changes in hunting regulations. However, the AIC for the no-REG* model was less than that for the most general model, suggesting that from an estimation viewpoint some bias might be accepted to improve precision. No 3-, 4-, or 5-way interactions involving regulatory period were necessary to explain the data ($\chi^2 = 85.89$, 80 df, P

Table 4. Logit models for variation in the recovery probability among 144 populations of ducks (defined by reference area, species, age class, sex, and regulatory period) banded pre-season in the United States, 1976–91. This table compares the full model without any regulatory-period interactions (no-REG*) and all models containing first-order regulatory-period interactions with each other (using AIC) and with the fully-parameterized model (using likelihood-ratio tests).

Model	Parameters	AIC	Likelihood-ratio test		
			χ^2	df	P
no-REG*	50	174,615.46	144.57	94	0.001
AREA × REG	54	174,608.49	129.61	90	0.004
AGE × REG	52	174,608.66	133.78	92	0.003
SEX × REG	52	174,589.76	114.88	92	0.054
SPP × REG	56	174,623.82	140.93	88	<0.001
AREA × REG, AGE × REG	56	174,602.97	120.08	88	0.013
SEX × REG, AGE × REG	54	174,582.72	103.83	90	0.151
SEX × REG, AREA × REG	56	174,580.79	97.91	88	0.220
SPP × REG, AGE × REG	58	174,616.92	130.04	86	0.002
SPP × REG, AREA × REG	60	174,617.37	126.49	84	0.002
SPP × REG, SEX × REG	58	174,596.02	111.13	86	0.036
AREA × REG, AGE × REG, SEX × REG	58	174,575.95	89.06	86	0.389
AREA × REG, AGE × REG, SPP × REG	62	174,611.91	117.03	82	0.007
AGE × REG, SEX × REG, SPP × REG	60	174,590.87	99.99	84	0.112
AREA × REG, SEX × REG, SPP × REG	62	174,589.50	94.62	82	0.161
AREA × REG, AGE × REG, SEX × REG, SPP × REG	64	174,584.78	85.89	80	0.306

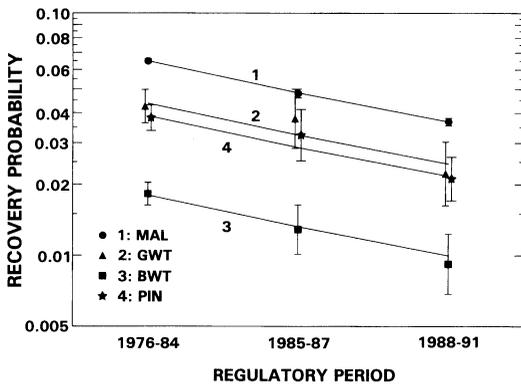


Fig. 2. Estimated recovery probabilities of ducks banded in 3 U.S. reference areas during hunting seasons in 1976–91. Estimates were obtained from logit models that included (symbols, 95% CI) and lacked (lines) the interaction between species and regulations period.

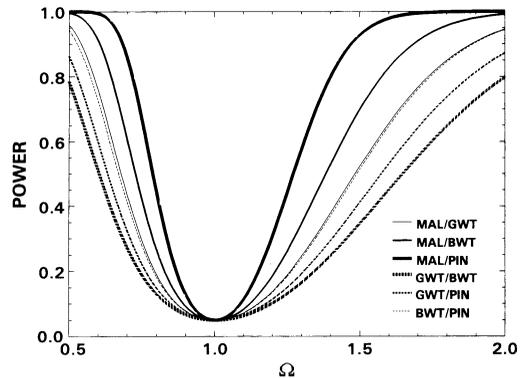


Fig. 3. Approximate power for test of interaction between species and regulations period for ducks banded in 3 U.S. reference areas and hunted in 1976–91. Size of the interaction (Ω) for a species pair is expressed approximately as the ratio of relative recovery probability for regulatory periods 1 (1976–84) and 3 (1988–91).

= 0.306), so we examined the 15 models with first-order interactions (Table 4).

The model that included only AREA \times REG, AGE \times REG, and SEX \times REG interactions fit the data ($P = 0.389$) and had the smallest AIC, suggesting area and cohort-specific changes in recovery probabilities with changes in regulations. Addition of the SPP \times REG interaction to this model did not improve its explanatory power ($\chi^2 = 3.17$, 6 df, $P = 0.787$). Thus, changes in regulations apparently did not affect species differentially. Elimination of the AGE \times REG interaction was not warranted ($\chi^2 = 8.84$, 2 df, $P = 0.012$), although the model without it fit the data ($P = 0.220$) and had the second lowest AIC. This result is suggestive of only a minor age-specific regulatory effect. Models that excluded the SEX \times REG interaction always failed to explain the data satisfactorily ($P \leq 0.013$), suggesting sex-specific changes in recovery probabilities coincident with changes in regulations. Models that excluded the AREA \times REG interaction also tended to perform poorly ($P \leq 0.151$), thus providing evidence that changes in recovery probabilities were area-specific.

We used the model described above with the smallest AIC to estimate recovery probabilities for mallards, green-winged teal, blue-winged teal, and northern pintails during the 3 regulatory periods (Fig. 2). These estimates agreed well with recovery probabilities estimated from the full model, which of course included the SPP \times REG interaction. The estimated power to detect an interaction between regulatory period and species was $\geq 75\%$ for a halving or

doubling of the ratio of recovery probabilities for all possible 2-way species comparisons (Fig. 3). Power was highest for comparisons of mallards to other species because mallard recovery probabilities could be estimated with high precision. This result was encouraging because green-winged teal, blue-winged teal, and northern pintails experienced much greater changes in harvest regulations between periods 1 and 3 than did mallards. Thus, we expected the largest change in the ratios of recovery probabilities between the 2 periods when comparing mallards and these other species.

DISCUSSION

Our analysis suggests that recovery probabilities of ducks banded in the northern United States during 1976–91 were influenced to some degree by location of banding, age class, sex, and species. Changes in hunting regulations in 1985 and 1988 also appeared to affect recovery probabilities, but not always in the expected manner. Differences in recovery probability among species appeared to be consistent over the 3 periods, in spite of regulatory changes designed to affect species differentially. We were surprised by this result given the magnitude of species-specific differences in hunting regulations between period 1 (1976–84) and period 3 (1988–91) and our estimates of power. During the earlier period, 25 of 38 eligible states were using the point system, which permitted a maximum daily bag of 10 pintails or teal, compared to a maximum bag of 4–5 mallards. All states

that were eligible in the Atlantic Flyway, Mississippi Flyway, and Central Flyway ($n = 29$) held special September seasons for teal or had bonus bag limits for teal during the regular duck season. In 1988, the point system was eliminated and the maximum daily bag limit for any species was 3. In the Mississippi Flyway and the Central Flyway the daily limit of pintails was reduced to 1. There were no special seasons or bonus bags for teal offered. Our finding that such dramatic changes in hunting regulations did not elicit measurable species-specific responses implies that the ability to manipulate harvest rates of various species is severely limited.

Also surprising was our finding that regulatory changes affected some stocks differentially, even when it was not the intent of harvest managers. The interaction between regulations and sex was important in explaining variation in recovery rates, but only mallard hunting regulations were sex-specific during the study period. Our analysis also provided some evidence that changes in recovery probabilities associated with changes in regulations were area- and age-specific, although this was not a stated goal of harvest management.

Whether these inferences can be extended to harvest rates is unknown because few studies of band-reporting rates have been conducted. Conroy and Blandin (1984) summarized most of these studies and found little evidence of temporal, geographic, or taxonomic variability in reporting rates. More recent information suggests that there was some geographic variability in band-reporting rates for mallards (Nichols et al. 1995), but the differences were not profound. The same study also provided some evidence that band-reporting rates for female mallards were lower than for males. Regardless of any differences in reporting rate among duck stocks, our inferences regarding stock-specific regulatory effects would be valid if there were no systematic changes in band-reporting rates concurrent with changes in regulations. Although we believe such changes were unlikely, we acknowledge the possibility. For example, reduction in the bag limit for a certain species might affect the hunter's willingness to report a band encounter for that species.

The ability to harvest optimally various stocks of migratory birds (or any other natural resource) requires an ability to harvest selectively

and a good understanding of each stock's dynamics. The ability to harvest selectively in turn depends on the inherent vulnerability of various stocks, hunter behavior and preferences, and the ability to effect changes in stock-specific harvest rates by manipulating hunting regulations. Few, if any, studies have addressed the effectiveness of stock-specific hunting regulations in a convincing manner. Nichols and Johnson (1989) summarized efforts to understand the effects of various duck harvest-management strategies and concluded that all studies suffered from a lack of replication and control. Moreover, most investigators examined regulatory effects on a particular stock, rather than addressing the question of whether changes in stock-specific regulations shifted harvest pressure among stocks in the desired way. The exception has been studies of the effectiveness of the point system in redistributing harvest pressure toward male mallards and away from females. However, conclusions remain equivocal (Rexstad and Anderson 1988, Rexstad et al. 1991, Ringelman 1991) and strong inferences regarding regulatory effects must await carefully designed manipulative experiments.

Ultimately, the ability to control stock-specific harvest rates will be of little consequence if the effects of harvest on the status of migratory bird stocks are poorly understood. The prevailing view in duck harvest management has been to use mallard harvest rates as the standard by which to judge the appropriateness of harvest rates for other duck species. Sufficient understanding of population dynamics to determine optimal harvest rates might be attained through adaptive resource management, which recognizes the importance of learning to meet management objectives (Walters and Holling 1990, Johnson et al. 1993).

Finally, the prevailing view in stock-specific harvest management has been to treat each stock as an independent entity. There has been little explicit recognition that waterfowl stocks are components of a larger community, where phenomena like competition may result in stock sizes that are interdependent. Nudds (1992) believes that the reason lies not only with the predisposition among managers to treat each stock as an "annual crop," but also with the difficulties in understanding levels of biological hierarchy above the organism or population level. Whatever the reason(s), attempts to maximize the

harvest of particular stocks may interfere with each other if there are significant interactions between those stocks (May et al. 1979).

LITERATURE CITED

- ANDERSON, D. R., AND C. J. HENNY. 1972. Population ecology of the mallard. I. A review of previous studies and the distribution and migration from breeding areas. U.S. Fish and Wildl. Serv. Resour. Publ. 105. 166pp.
- BURNHAM, K. P., AND D. R. ANDERSON. 1992. Data-based selection of an appropriate biological model: the key to modern data analysis. Pages 16–30 in D. R. McCullough and R. H. Barrett, eds. *Wildlife 2001: populations*. Elsevier Appl. Sci., New York, N.Y.
- CONROY, M. J., AND W. W. BLANDIN. 1984. Geographic and temporal differences in band reporting rates for American black ducks. *J. Wildl. Manage.* 48:23–36.
- JOHNSON, F. A., B. K. WILLIAMS, J. D. NICHOLS, J. E. HINES, W. L. KENDALL, G. W. SMITH, AND D. F. CAITHAMER. 1993. Developing an adaptive management strategy for harvesting waterfowl in North America. *Trans. North Am. Wildl. Nat. Resour. Conf.* 58:565–583.
- MAY, R. M., J. R. BEDDINGTON, C. W. CLARK, S. J. HOLT, AND R. M. LAWS. 1979. Management of multispecies fisheries. *Science* 205:267–276.
- NICHOLS, J. D., AND J. E. HINES. 1987. Population ecology of the mallard. VIII. Winter distribution patterns and survival rates of winter-banded mallards. U.S. Fish and Wildl. Serv. Resour. Publ. 162. 154pp.
- , AND F. A. JOHNSON. 1989. Evaluation and experimentation with duck management strategies. *Trans. North Am. Wildl. Nat. Resour. Conf.* 54:566–593.
- , R. E. REYNOLDS, R. J. BLOHM, R. E. TROST, J. E. HINES, AND J. P. BLADEN. 1995. Geographic variation in band reporting rates for mallards based on reward banding. *J. Wildl. Manage.* 59:697–708.
- NUDDS, T. D. 1992. Patterns in breeding waterfowl communities. Pages 540–567 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., *Ecology and management of breeding waterfowl*. Univ. Minn. Press, Minneapolis.
- O'BRIEN, R. G. 1986. Using the SAS system to perform power analyses for log-linear models. Pages 778–784 in *Proc. Eleventh Annual SAS Users Group Conf.* SAS Institute, Inc., Cary, N.C.
- REXSTAD, E. A., AND D. R. ANDERSON. 1988. Effect of the point system on redistributing hunting pressure on mallards. *J. Wildl. Manage.* 52:89–94.
- , ———, AND K. P. BURNHAM. 1991. Lack of sex-selectivity in harvest of mallards under the point system. *J. Wildl. Manage.* 55:586–592.
- RINGELMAN, J. K. 1991. Differential harvest of male and female mallards under conventional and point system regulations. *Wildl. Soc. Bull.* 19:258–267.
- SAS INSTITUTE INC. 1989. *SAS/STAT user's guide*. Version 6. SAS Inst. Inc., Cary, N.C. 943 pp.
- U.S. FISH AND WILDLIFE SERVICE. 1988. *Supplemental Environmental Impact Statement: issuance of annual regulations permitting the sport harvest of migratory birds*. U.S. Dep. Inter., Washington, D.C. 340 pp.
- WALTERS, C. J., AND C. S. HOLLING. 1990. Large-scale management experiments and learning by doing. *Ecology* 71:2060–2068.

Received 6 June 1994.

Accepted 22 January 1996.

Associate Editor: Conroy.