Assessment of Continental Northern Pintail (*Anas acuta*) Band-Recovery Data

Final Report

December 2008

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Assessment of Continental Northern Pintail (*Anas acuta*) Band-Recovery Data Part I: Distribution and derivation of the harvest

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Nearly all prairie-nesting dabbling duck species dramatically increased in abundance since the early 1990s except northern pintail (*Anas acuta*), which decreased from an estimated 9.6 million in 1955 to 2 million by 1988 (Hestbeck 1993, Scheaffer 2003) and has remained at relatively low levels since then. By 2002, pintails were represented by a low of 1.8 million birds in the traditional survey area (U.S. Fish and Wildlife Service 2007a) despite recent restrictive harvest regulations. However, by 2007, the estimate of pintails in the traditional survey area had increased to 3.3 million birds, which was statistically unchanged from the 2006 estimate (U. S. Fish and Wildlife Service 2007a). Despite the increase since 2002, the current population estimate remains 20% below the long-term average (1955-2005, average number = 4.1 million) and 41% below the goal of 5.6 million proposed by the North American Waterfowl Management Plan. Although the pintail remains the most abundant duck in the Pacific Flyway, their numbers are only 25% of levels recorded in the 1970s (Fleskes et al. 2002). The continued low abundance of pintails has caused great concern among managers as evidenced by the United States Fish and Wildlife Service declaring pintails a focal species targeted for increased management emphasis and development of a species-specific harvest management strategy (U.S. Fish and Wildlife Service 2007b).

To aid in reaching the 5.6 million pintail population goal set by the North American Waterfowl Management Plan, a comprehensive evaluation of available pintail data is necessary (Podruzny et al. 2002). One portion of this evaluation includes describing the origin of where harvested birds are banded. This may provide value in assessing Flyway boundaries or management units specific to northern pintail (Munro and Kimball 1982). Previous work on the distribution and derivation of harvest has been completed on mallards (*Anas platyrhynchos*) to aid in discrimination of management units, but pintails have a different life history from mallards and mallard distributions may not be appropriate for pintail management (Munro and Kimball 1982, Anderson and Henny 1972). For example, Munro and Kimball (1982) found that the flyway boundaries were indistinct for mallards, which may not be the case for pintails. There has also been work completed recently on DNA analysis to derive harvest locations for goose populations (Inman et al. 2003). Additional effort has also investigated winter distribution patterns of species such as black ducks (Diefenbach et al. 1988) and canvasbacks (Nichols and Haramis 1980).

Anderson and Henny (1972) based their banding reference areas for mallards on a combination of the amount of banding data, the importance of areas to breeding mallards, and political boundaries. The same process needs to be completed for northern pintail not only for descriptive purposes, but to understand patterns in harvest for pintails. Basing hunting regulations upon regions specific to migration corridors for pintails rather than political Flyways could be important to increasing their numbers (Bellrose and Crompton 1970).

Bird banding blocks are defined by the 10’ block of latitude and longitude within which the banding or encounter of a bird location falls (Gustafson et al. 1997). Reference areas are geographic areas used for summarizing banding and band recovery data with similar recovery distribution patterns. There are two ways to examine harvest patterns of northern pintails. One is to determine the harvest distribution, which focuses on a single banding block or groups of related blocks and the multiple locations that the birds are recovered from these banding blocks. The other way is to consider the harvest derivation of birds, which refers to the proportional composition of a specific harvest (e.g., from some specified area of interest) with respect to different source areas such as banding blocks (Nichols and Royle 2005). The combination of these methods will provide a good representation of relationships between northern pintails banding and harvest areas.

To properly manage northern pintail population, it is important to assess the distribution and derivation specific to pintail. Therefore, we described the harvest of pintails to provide geographically homogeneous groups with similar movements based on recovery data. This may provide insight into migration pathways for northern pintail, which could help in their management. Our ultimate goal was to connect important banding and harvest regions for northern pintail for future banding, management, and regulatory activities.

Methods

We obtained banding data for normal, wild birds shot or found dead during hunting season from the United States Geological Survey Bird Banding Laboratory for 1970-2003. All birds were banded during July and August (pre-season). In the banding reports for each shot bird are latitude and longitude data defining the degree block where the bird was banded and recovered. Additionally, codes associated with the state or province and administrative Flyway of banding and recovery location are provided. These codes were used to group states and provinces into delineated regions and 4 administrative Flyways using program SAS (SAS 9.1 2007).

To determine the distribution of pintail harvest, a multiresponse permutation procedure (MRPP) was performed to create either a specific arrangement or assignment of recoveries into specified banding block groupings (Zimmerman et al. 1985). Banding blocks were partitioned into groups based on similarity of recovery distributions (Mielke 1985). To have a sufficient sample size, both direct and indirect recoveries were used in this analysis. This allowed us to derive the harvest for northern pintail based on similarity among banding blocks.

To describe the distribution of harvest, we used the identified regions from the MRPP analysis as well as the existing flyways (Pacific, Central, Mississippi, and Atlantic). We also investigated the harvest recovery location for each state and province in North America based on birds banded in the MRPP regions. We repeated this process using the Pacific, Central, Mississippi, and Atlantic Flyways. We then investigated recovery patterns at a larger geographic scale by describing the recovery distributions for birds banded in the MRPP regions and banding location within these identified regions. This process was repeated using the 4 Flyways. The states and provinces with the greater number of direct recoveries were assessed for each Flyway and MRPP region. We included only those states and provinces with more than 200 direct recoveries.

We were also interested in identifying the banding blocks associated with each of the 4 major wintering areas including California, the playa region of northwest Texas, the Texas Gulf Coast, and Louisiana. Recoveries were assessed from these 4 locations and then assigned to banding blocks based on the greater total number of recoveries as well as the highest percentage of recoveries from each of the wintering locations.

Results

The resulting identified MRPP groupings indicated 12, 6, 5, or 3 regions based on the level of combining similar groupings of banding blocks as the regions were reduced (Figure 1). The most parsimonious grouping resulted in the use of 3 regions for describing pintail derivation subsequently called western, central, and eastern. The 3 regions identified from the MRPP analysis were similar to the administrative Flyway boundaries. Essentially, the western region represented the Pacific Flyway and the eastern region corresponded to the Atlantic Flyway, whereas the central region reflected the combined Central and Mississippi Flyways (Figure 1).

The most recoveries from birds banded among regions was from the western region with 13,418 recoveries (central = 10,959 and eastern = 1,719; Table 1). The greatest numbers of recovered birds were located in Alaska, California, Colorado, North Dakota, Alberta, the Northwest Territories, and Saskatchewan. These areas tend to be toward the western region where the most recoveries occurred (Table 1). Overall, the recovery rate from all regions was 6.7% of banded pintails in North America from 1970-2003.

There was a similar pattern for recoveries in the states and provinces when banded birds were grouped in the Pacific, Central, Mississippi, and Atlantic Flyways (Table 2). The most recoveries were in the Pacific Flyway with 12,989 recoveries whereas there were 5,272 recoveries in the Central Flyway, 5,637 in the Mississippi Flyway, and 1,217 in the Atlantic Flyway. The greater numbers of recovered birds were located in the same states as those found using the MRPP regions except that Manitoba was included (Table 2).

We found that the greatest numbers of direct recoveries were in the regions or Flyways from which pintails were originally banded (Tables 3, 4). The western banded birds were recovered in the Pacific Flyway, the central banded birds were recovered evenly in both the Central (38.4%) and Mississippi Flyways (37.3%), and the eastern banded birds were recovered in the Atlantic region (Table 3). Pintails banded in the Pacific Flyway were found in the western region, birds banded in the Central and Mississippi Flyways were found in the central region, and birds banded in the Atlantic Flyway were found in the eastern region (Table 4). So, as expected, there was a similar recovery pattern found between the 3 regions and the 4 Flyways.

Of the pintails banded in the central MRPP region, 86% were recovered in the central region compared to 38.4% of these birds recovered in the Central Flyway and 37.3% recovered in the Mississippi Flyway (Figure 2). The distribution of recovery indicated a smaller percentage of recovery in the western MRPP region versus the Pacific Flyway, but similar percentages in the eastern region and Atlantic Flyway (Figure 2).

Greater than 75% of birds banded in the western MRPP region were recovered in the western region or Pacific Flyway (Figure 3). There were very few birds recovered in the eastern region or Atlantic Flyway (Figure 3). The opposite was true for birds banded in the eastern MRPP region where most of the recoveries were in the eastern region and Atlantic Flyway

(Figure 4). There was a greater percentage of eastern MRPP birds recovered in the central MRPP region compared to the Mississippi and Central Flyways (Figure 4).

Recovery patterns changed when considering banding locations by Flyway boundaries. Pintails banded in the Pacific Flyway were typically recovered in the western MRPP region (Figure 5). However, there were an equal number of birds recovered in the Pacific and Central Flyways when banded in the Pacific Flyway (Figure 5). Birds banded in the Central Flyway were mostly recovered in the Central Flyway, but were split between the western and central MRPP regions (Figure 6). The majority of birds banded in the Mississippi Flyway were recovered in the central MRPP region, but split between the Mississippi and Central Flyways (Figure 7). Almost all birds banded in the Atlantic Flyway were recovered in the eastern MRPP region and the Atlantic Flyway (Figure 8).

There were relatively few recoveries in the eastern MRPP region compared to the central and western MRPP regions (Figure 9). Many of the states and provinces common to both the central and western MRPP regions with greater than 200 recoveries were similar except for California, Oregon, and Alaska in the western MRPP region and Manitoba, Colorado, Utah, Michigan, North Dakota, and South Dakota in the central MRPP region (Figure 9). Most of the pintails banded in the Atlantic Flyway were harvested in Quebec (Figure 10). The states and provinces with the most recoveries from birds banded in the Central Flyway overlapped with those recovered in the Mississippi and Pacific Flyways (Figure 10).

Assigning banding blocks based on the total number of recoveries in each of the wintering areas resulted in no clear geographic division between those birds recovered in Texas and Louisiana (Figure 11). There were only two banding blocks that had the most recoveries of pintails from the Texas playa wintering area. Pintails recovered in the Louisiana wintering area were primarily birds banded in the Mississippi Flyway (Figure 11). Pintails recovered in California were mostly banded in the western portion of North America (Figure 11). When the banding blocks were assigned based on the percentage of birds recovered in each of the wintering areas, there were more banding blocks assigned to the Texas playas (Figure 12). Even so, there remained considerable geographic overlap between those birds recovered in Texas and Louisiana (Figure 12).

Discussion

Overall, pintails were recovered in the same MRPP region or Flyway as they were banded. The majority of pintails were recovered in the western and central MRPP regions or the Pacific and Central/Mississippi Flyways. Because of the relatively fewer eastern bandings, there were few recoveries in the eastern region or Atlantic Flyway. The Atlantic Flyway was the only Flyway that is reasonably intact based on recovery distributions of pintails. More importantly, it was difficult to discriminate recovery patterns between the Central and Mississippi Flyways. The percentage of recoveries in the central MRPP region was similar to the percentage of recoveries found in the combined Central and Mississippi Flyways. The MRPP analyses combined the central portion of North America based on recovery distributions, which allows for more effective boundaries based on recovery distributions. Overall, 22% of all banded pintails were recovered in the Mississippi Flyway and 22.4% in the Central Flyway and, when combined, these two Flyways resulted in a slightly higher percentage than found in the central region (42%).

Most of the pintail recoveries were from birds banded in Alaska, California, Colorado, North Dakota, Oregon, South Dakota, Alberta, Manitoba, Northwestern Territories, and Saskatchewan. These states and provinces are providing the majority of banding data and most are found in the Pacific and Central Flyways or western and central MRPP regions. The eastern MRPP region is not currently providing sufficient bandings or recoveries for independent analyses and changes may be considered necessary for future pintail analyses. In addition, none of the birds recovered in the four major wintering areas were banded in the eastern region or Atlantic Flyway.

We recommend that future work on development of pintail banding activities focus on the three regions found using the MRPP analysis. These 3 regions described the distribution of pintails as well as the 4 Flyways, but in a more concise and direct manner. Unless the banding effort is increased, we also recommend that the eastern region not be used for future analyses as it does not provide adequate information for northern pintails in North America. Finally, northern pintails should be managed based on being located more western than mallards and focus should be put on these states and provinces when banding to get the optimal information on the pintail population. These recommendations will further help to assess the pintail population in the future as well as provide a mechanism for managing the species separate from mallards.

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. Resource publication 105, U.S. Fish and Wildlife Service, Washington, D. C., 166 pp.

Bellrose F. C., Jr. and R. D. Crompton. 1970. Migrational behavior of mallards and black ducks as determined from banding. Illinois Natural History Survey Bulletin 30:167-234.

Diefenbach D. R., J. D. Nichols, and J. E. Hines. 1988. Distribution patterns during winter and fidelity to wintering areas of American black ducks. Canadian Journal of Zoology 66:1506-1513.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. September-March survival of female northern pintails radiotagged in San Joaquin valley, CA. Journal of Wildlife Management 66:901-911.

Gustafson, M. E., J. Hildenbrand and L. Metras. 1997. The North American Bird Banding Manual (Electronic Version). Version 1.0

Hestbeck, J. B. 1993. Overwintering distribution of northesrn pintail populations in North America. Journal of Wildlife Management 57:582-589.

Inman R. L., K. T. Scribner, H. H. Prince, J. A. Warrilow, D. R. Luukkonen, and P. I. Padding. 2003. A novel method for Canada goose harvest derivation using genetic analysis of tail feathers. Wildlife Society Bulletin 31:1126-1131.

Mielke, P. W., Jr. 1985. Geometric concerns pertaining to applications of statistical tests in the atmospheric sciences. Journal of the Atmospheric Sciences 42:1209-1213.

Munro, R. E. and C. F. Kimball. 1982. Population ecology of the mallard: VII. distribution and derivation of the harvest. U. S. Fish and Wildlife Service. Resource Publication 147. 127 pp.

Nichols J. D. and J. A. Royle. 2005. Methods for estimating derivation of harvest based on marked individuals. 11th Annual North American Goose Conference and workshop abstract. January 2-5, Reno, Nevada.

Nichols J. D. and G. M. Haramis. 1980. Sex-specific differences in winter distribution patterns of canvasbacks. Condor 82:406-416.

Podruzny, K. M., J. H. Devries, L. M. Armstrong, and J. J. Rotella. 2002. Long term response of northern pintails to changes in wetland conditions and agriculture in the Canadian Prairie pothole region. Journal of Wildlife Management 66:993-1010.

SAS Institute Inc. (2007). SAS 9.1 for Windows XP. Cary, NC: SAS Institute.

Scheaffer, S. E. 2003. Northern pintail: prospectus for an action group. New York Fish and Wildlife Cooperative Research Unit, Ithaca, NY, USA.

U.S. Fish and Wildlife Service. 2007a. Waterfowl population status. U. S. Department of the Interior, Office of Migratory Bird Management, Laurel, Maryland, USA. 60pp.

U.S. Fish and Wildlife Service. 2007b. Northern Pintail Harvest Strategy. Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Department of Interior, Washington, D.C.

Zimmerman G. M., H. Goetz, and P. W. Mielke, jr. 1985. Use of an improved statistical method for group comparisons to study the effect of prairie fire. Ecology 66:606-611.

Table 1. Region of banding and the state or province of recovery for banded northern pintails 1970-2003.

Harvest Area Of Recovery	Number of birds banded	Western		Central		Eastern	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Alabama	51	0	0	0	2	0	0
Alaska	36389	933	898	151	170	9	4
Arizona	18	1	0	0	0	0	0
Arkansas	0	0	0	0	0	0	0
California	23969	1071	1891	5	40	0	1
Colorado	37841	72	430	506	715	3	12
Conneticut	2	0	0	0	0	0	0
Delaware	425	0	0	0	1	13	20
District of Columbia	0	0	0	0	0	0	0
Florida	1	0	0	0	0	0	0
Georgia	0	0	0	0	0	0	0
Idaho	1583	54	60	1	10	0	1
Illinois	9	0	0	1	0	0	0
Indiana	0	0	0	1	0	0	0
Iowa	304	0	0	16	11	1	2
Kansas	16	0	1	1	1	0	0
Kentucky	9	0	0	0	1	0	0
Louisiana	72	0	0	1	3	0	0
Maine	42	0	0	0	0	2	2
Maryland	425	0	0	0	0	0	0
Massachusetts	200	0	0	0	0	0	0
Mexico	0	0	0	0	0	0	0
Michigan	207	0	0	5	5	9	0

Table 1. *(cont.)*

Harvest Area Of Recovery	Number of birds banded	Western Direct	Western Indirect	Central Direct	Central Indirect	Eastern Direct	Eastern Indirect
Minnesota	7319	3	15	297	230	22	67
Mississippi	0	0	0	0	0	0	0
Missouri	16	0	0	0	0	0	0
Montana	9305	86	179	90	138	4	10
Nebraska	568	2	3	7	18	0	0
Nevada	2077	129	79	3	11	0	0
New Hampshire	2	0	0	0	0	1	0
New Jersey	20	0	0	0	0	0	2
New Mexico	3	0	0	0	0	0	0
New York	693	0	0	11	6	42	24
North Carolina	8	0	0	0	0	0	0
North Dakota	39894	39	141	915	1090	60	102
Ohio	103	0	0	4	0	6	2
Oklahoma	0	0	0	0	0	0	0
Oregon	5714	253	331	5	18	0	1
Pennsylvania	591	0	0	5	7	18	21
Rhode Island	2	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0
South Dakota	11609	4	51	353	265	13	23
Tennessee	1	0	0	0	0	0	0
Texas	3	0	0	0	0	0	0
Utah	5281	92	174	353	265	0	4
Vermont	187	0	0	0	0	8	7

Table 1. (*cont.*)

Harvest Area Of Recovery	Number of birds banded	Western Direct	Western Indirect	Central Direct	Central Indirect	Eastern Direct	Eastern Indirect
Virginia	4	0	0	0	0	0	0
Washington	1126	27	57	1	5	0	1
West Virginia	0	0	0	0	0	0	0
Wisconsin	1716	0	3	63	47	24	31
Wyoming	1002	2	14	6	16	0	0
Alberta	73515	1572	1904	377	718	13	24
British Columbia	519	11	21	8	4	0	0
Manitoba	18011	58	111	526	476	26	45
New Brunswick	826	0	0	4	1	84	37
Newfoundland	710	0	2	1	5	59	26
Northwestern Territories	38624	509	661	389	487	12	28
Nova Scotia	856	0	1	5	3	74	31
Ontario	3788	0	5	133	73	122	106
Prince Edward Island	535	0	0	1	2	50	17
Quebec	3341	0	2	19	8	208	93
Saskatchewan	58177	541	798	767	1024	24	67
Yukon	3138	68	59	23	29	0	1
Mexico	0	0	0	0	0	0	0

Table 2. Region of banding and the state or province of recovery for banded northern pintails 1970-2003.

Harvest Area Of Recovery	Number of birds banded	Atlantic Direct	Atlantic Indirect	Mississippi Direct	Mississippi Indirect	Central Direct	Central Indirect	Pacific Direct	Pacific Indirect
Alabama	51	0	0	0	1	0	1	0	0
Alaska	36389	0	0	54	67	109	93	930	912
Arizona	18	0	0	0	0	0	0	0	0
Arkansas	0	0	0	0	0	0	0	0	0
California	23969	0	1	1	13	4	32	1071	1886
Colorado	37841	1	6	70	173	437	555	73	423
Conneticut	2	0	0	0	0	0	0	0	0
Delaware	425	13	19	0	1	0	1	0	0
District of Columbia	0	0	0	0	0	0	0	0	0
Florida	1	0	0	0	0	0	0	0	0
Georgia	0	0	0	0	0	0	0	0	0
Idaho	1583	0	0	0	3	1	7	54	60
Illinois	9	0	0	1	0	0	0	0	0
Indiana	0	0	0	0	0	0	0	0	0
Iowa	304	0	2	13	10	4	1	0	0
Kansas	16	0	0	0	1	1	0	0	1
Kentucky	9	0	0	0	1	0	0	0	0
Louisiana	72	0	0	1	3	0	0	0	0
Maine	42	2	2	0	0	0	0	0	0
Maryland	425	20	28	2	4	0	0	0	0
Massachusetts	200	11	6	2	2	0	0	0	0
Mexico	0	0	0	0	0	0	0	0	0
Michigan	207	3	6	10	8	1	0	0	0

Table 2 *(cont.)*

Harvest Area Of Recovery	Number of birds banded	Atlantic Direct	Atlantic Indirect	Mississippi Direct	Mississippi Indirect	Central Direct	Central Indirect	Pacific Direct	Pacific Indirect
Minnesota	7319	9	0	273	223	37	37	3	14
Mississippi	0	0	0	0	0	0	0	0	0
Missouri	16	0	0	0	0	0	0	0	0
Montana	9305	0	1	33	56	61	94	86	176
Nebraska	568	0	0	2	3	5	15	2	3
Nevada	2077	0	0	2	4	1	7	129	79
New Hampshire	2	1	0	0	0	0	0	0	0
New Jersey	20	0	2	0	0	0	0	0	0
New Mexico	3	0	0	0	0	0	0	0	0
New York	693	40	24	13	5	0	1	0	0
North Carolina	8	0	0	0	0	0	0	0	0
North Dakota	39894	6	15	490	752	479	436	39	130
Ohio	103	5	1	5	1	0	0	0	0
Oklahoma	0	0	0	0	0	0	0	0	0
Oregon	5714	0	0	0	6	2	16	256	328
Pennsylvania	591	14	19	9	8	0	1	0	0
Rhode Island	2	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0
South Dakota	11609	1	1	182	166	183	125	4	47
Tennessee	1	0	0	0	0	0	0	0	0
Texas	3	0	0	0	0	0	0	0	0
Utah	5281	0	1	6	12	17	34	92	175
Vermont	187	8	7	0	0	0	0	0	0

Table 2. (*cont.*)

Harvest Area Of Recovery	Number of birds banded	Atlantic Direct	Atlantic Indirect	Mississippi Direct	Mississippi Indirect	Central Direct	Central Indirect	Pacific Direct	Pacific Indirect
Virginia	4	0	0	0	0	0	0	0	0
Washington	1126	0	0	0	3	1	0	27	56
West Virginia	0	0	0	0	0	0	0	0	0
Wisconsin	1716	18	19	69	57	0	2	0	3
Wyoming	1002	0	0	0	7	0	10	2	13
Alberta	73515	2	5	142	321	482	457	1336	1863
British Columbia	519	0	0	2	0	1	2	16	23
Manitoba	18011	11	10	380	342	159	171	60	109
New Brunswick	826	82	36	6	2	0	0	0	0
Newfoundland	710	59	26	1	5	0	0	0	2
Northwestern Territories	38624	1	3	160	249	310	287	439	637
Nova Scotia	856	74	31	5	3	0	1	0	0
Ontario	3788	105	92	150	74	0	13	0	5
Prince Edward Island	535	50	17	1	2	0	0	0	0
Quebec	3341	203	92	23	9	1	0	0	2
Saskatchewan	58177	2	11	300	609	508	493	522	776
Yukon	3138	0	1	6	17	18	13	67	58
Mexico	0	0	0	0	0	0	0	0	0

Table 3. Number of birds banded in each region and the corresponding recovery region and flyway for northern pintails banded 1970-2003.

Harvest Area Of Recovery	Number of birds banded	Western		Central		Eastern	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Region							
Western	153329	4211	5474	597	1049	22	37
Central	228277	1316	2412	4071	4594	311	493
Eastern	9174	0	5	58	46	605	326
Flyway							
Pacific	79814	3979	5440	1230	2337	0	4
Central	270557	636	665	2190	2239	2	5
Mississippi	31606	213	446	2124	2725	77	52
Atlantic	8803	2	9	154	198	585	316

Table 4. Number of birds banded in each flyway and the corresponding recovery region and flyway for northern pintails banded 1970-2003.

Harvest Area Of Recovery	Number of birds banded	Atlantic Direct	Atlantic Indirect	Mississippi Direct	Mississippi Indirect	Central Direct	Central Indirect	Pacific Direct	Pacific Indirect
Flyway									
Pacific	8803	0	4	71	125	154	208	2643	3577
Central	270557	13	42	1379	2337	2472	2472	2503	4069
Mississippi	31606	63	131	902	720	201	225	63	131
Atlantic	79814	577	309	62	41	1	4	0	4
Region									
Western	153329	0	5	61	134	2827	4182	2639	3570
Central	228277	49	38	1046	4472	3411	4472	220	331
Eastern	9174	590	315	210	262	129	266	9	13

Figure 1. Results of the 3 region Multi-Response Permutation Procedure analysis for recovered northern pintail banded in North America between 1970 and 2003.

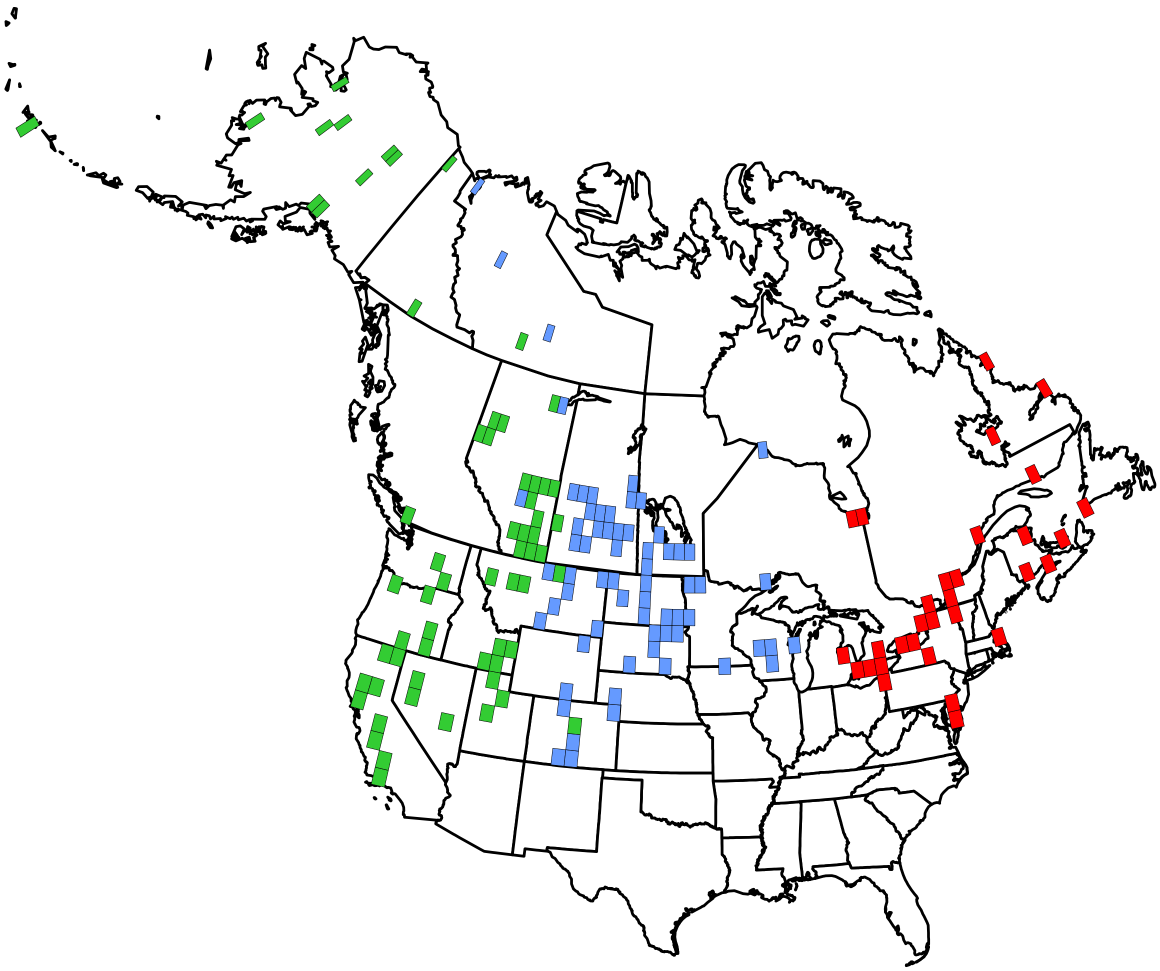
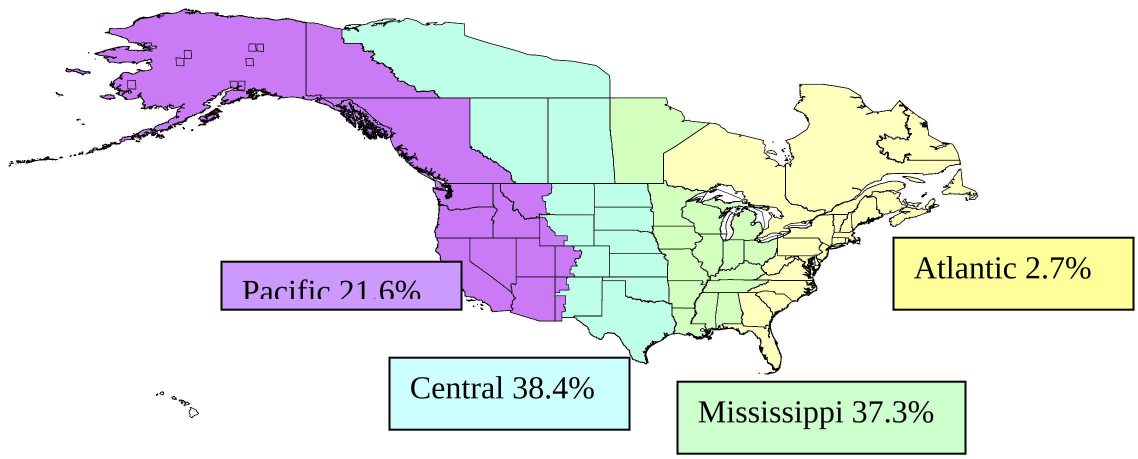


Figure 2. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the central region from 1970-2003.



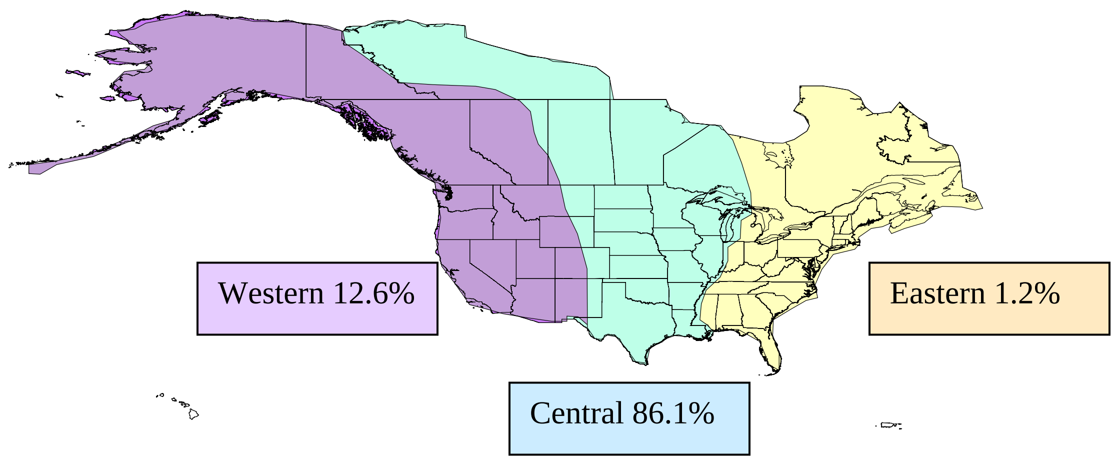


Figure 3. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the western region from 1970-2003.

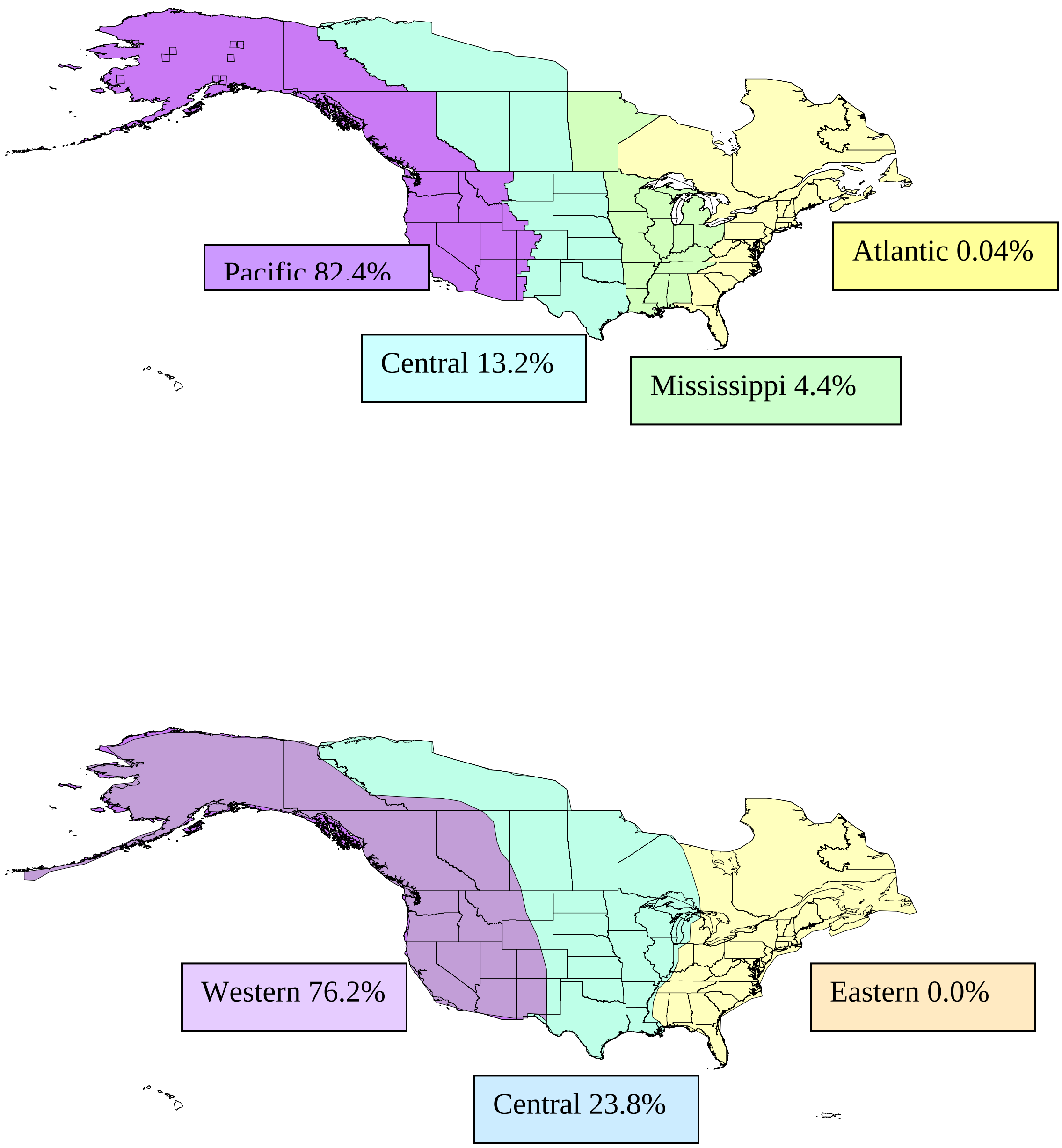
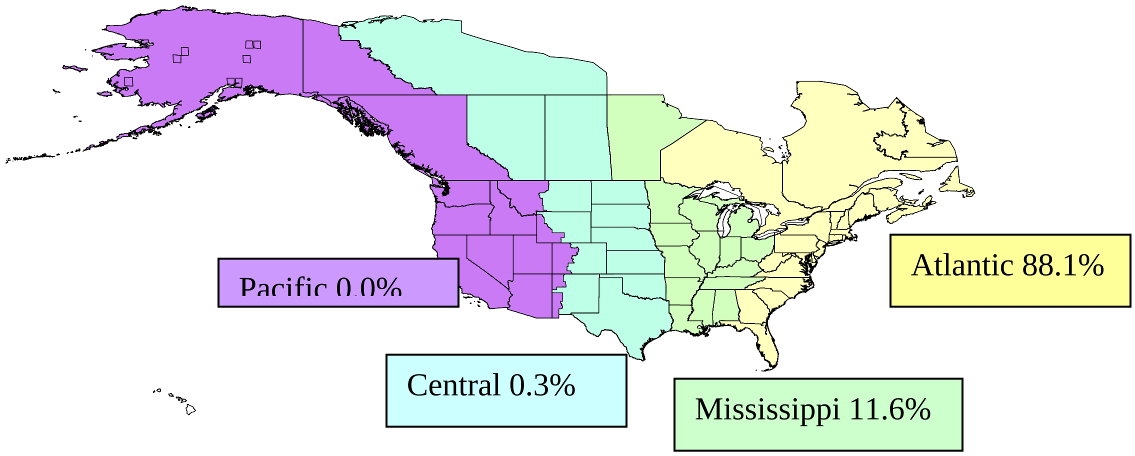


Figure 4. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the eastern region from 1970-2003.



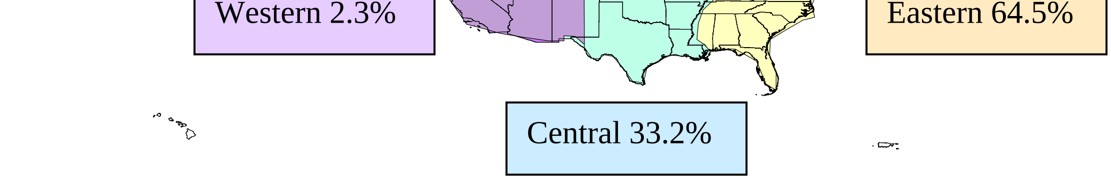
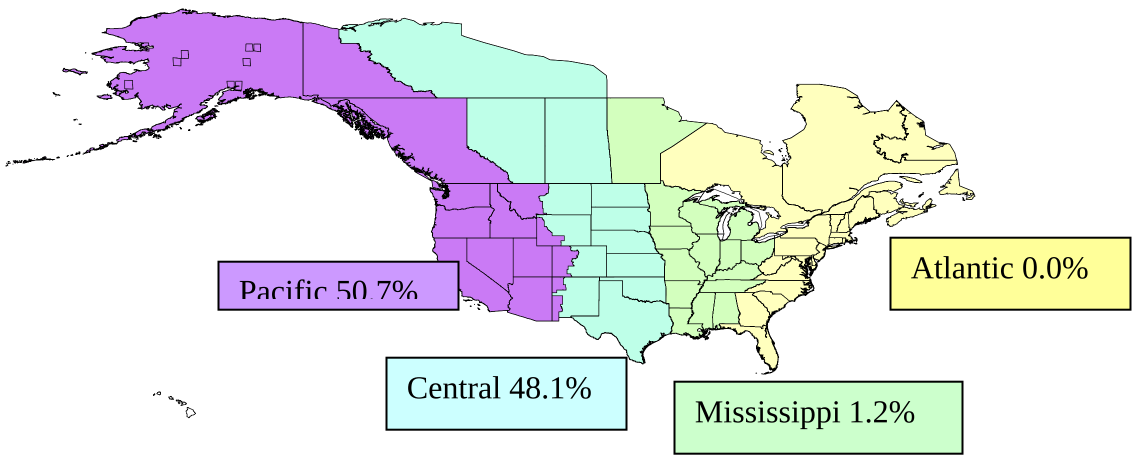


Figure 5. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the Pacific Flyway from 1970-2003.



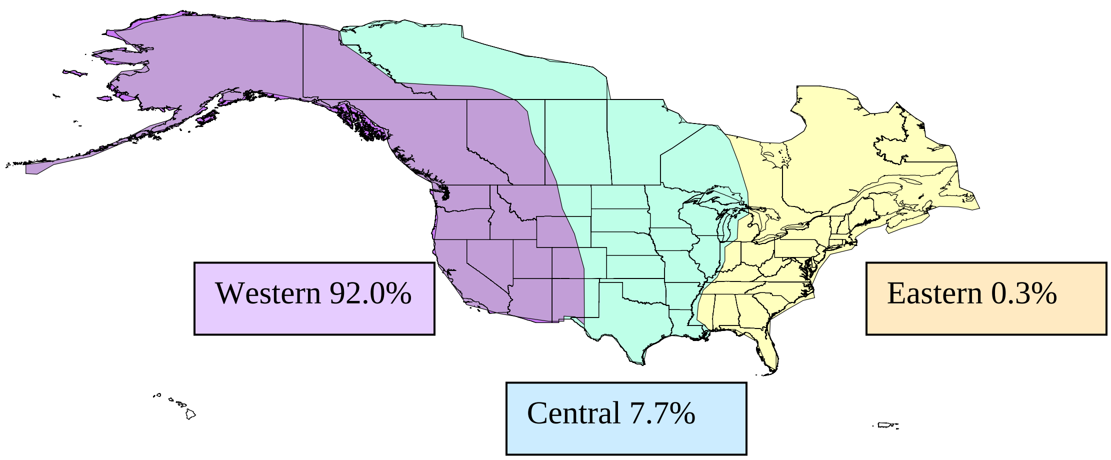
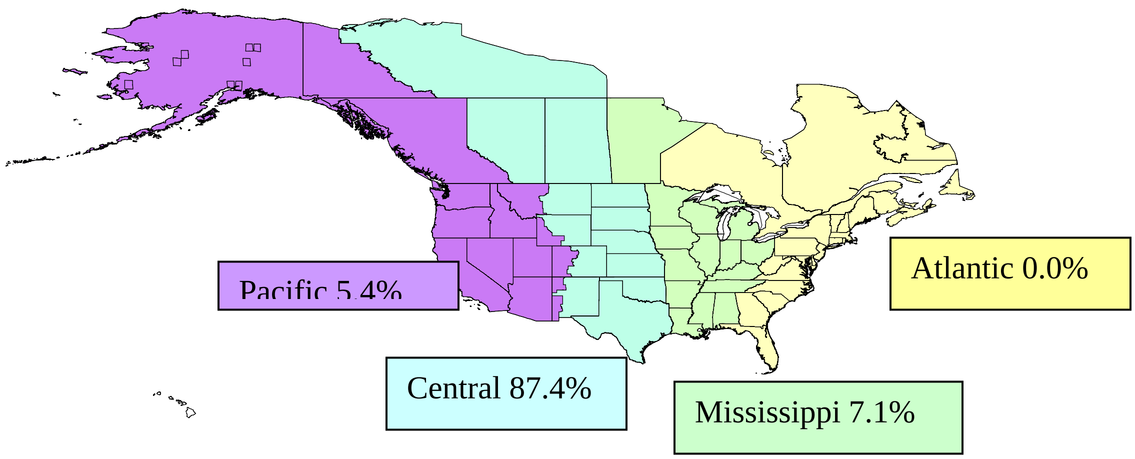


Figure 6. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the Central Flyway from 1970-2003.



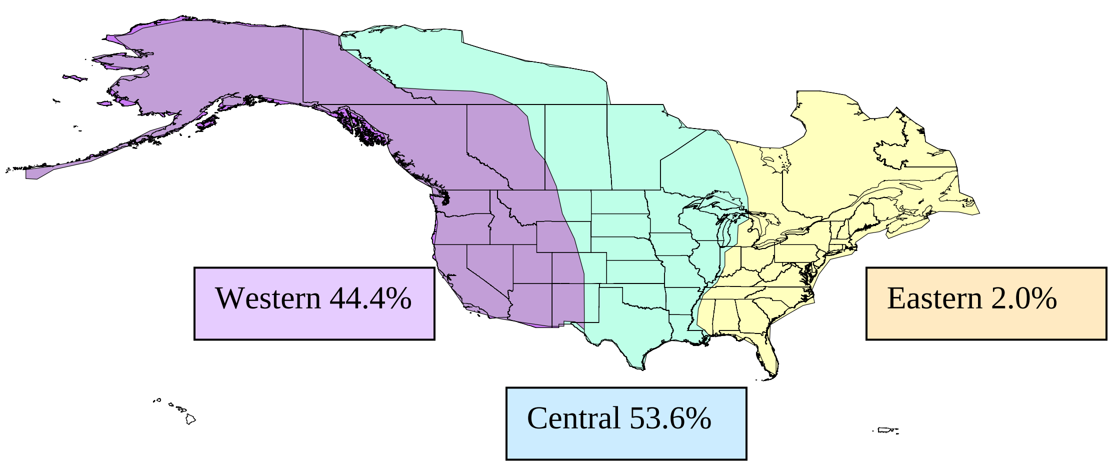
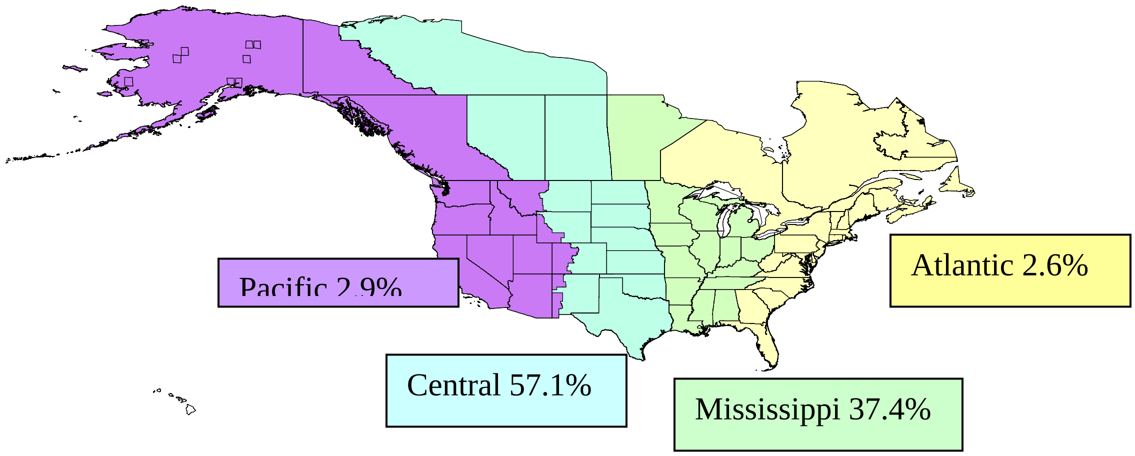


Figure 7. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the Mississippi Flyway from 1970-2003.



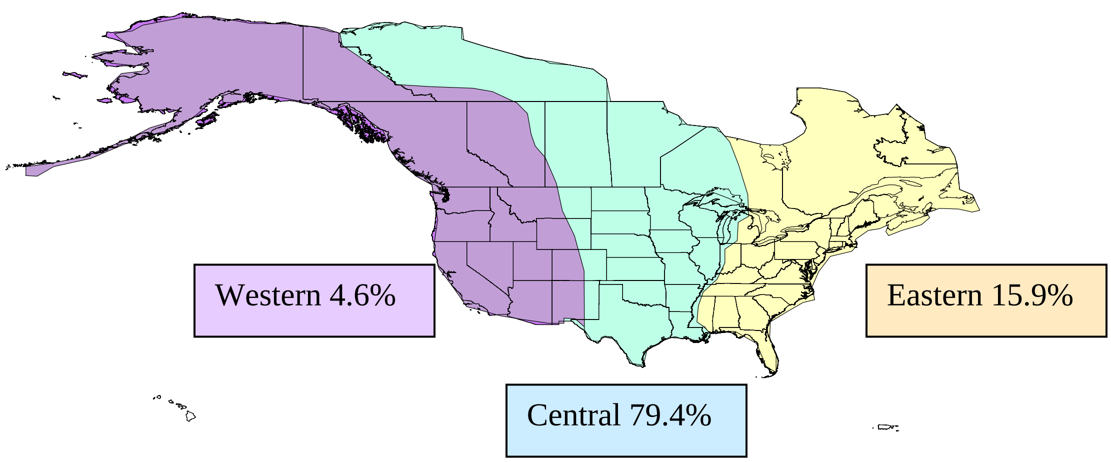


Figure 8. Percentage of northern pintails recovered in each region of the MRPP analysis and Flyway from birds banded in the Atlantic Flyway from 1970-2003.

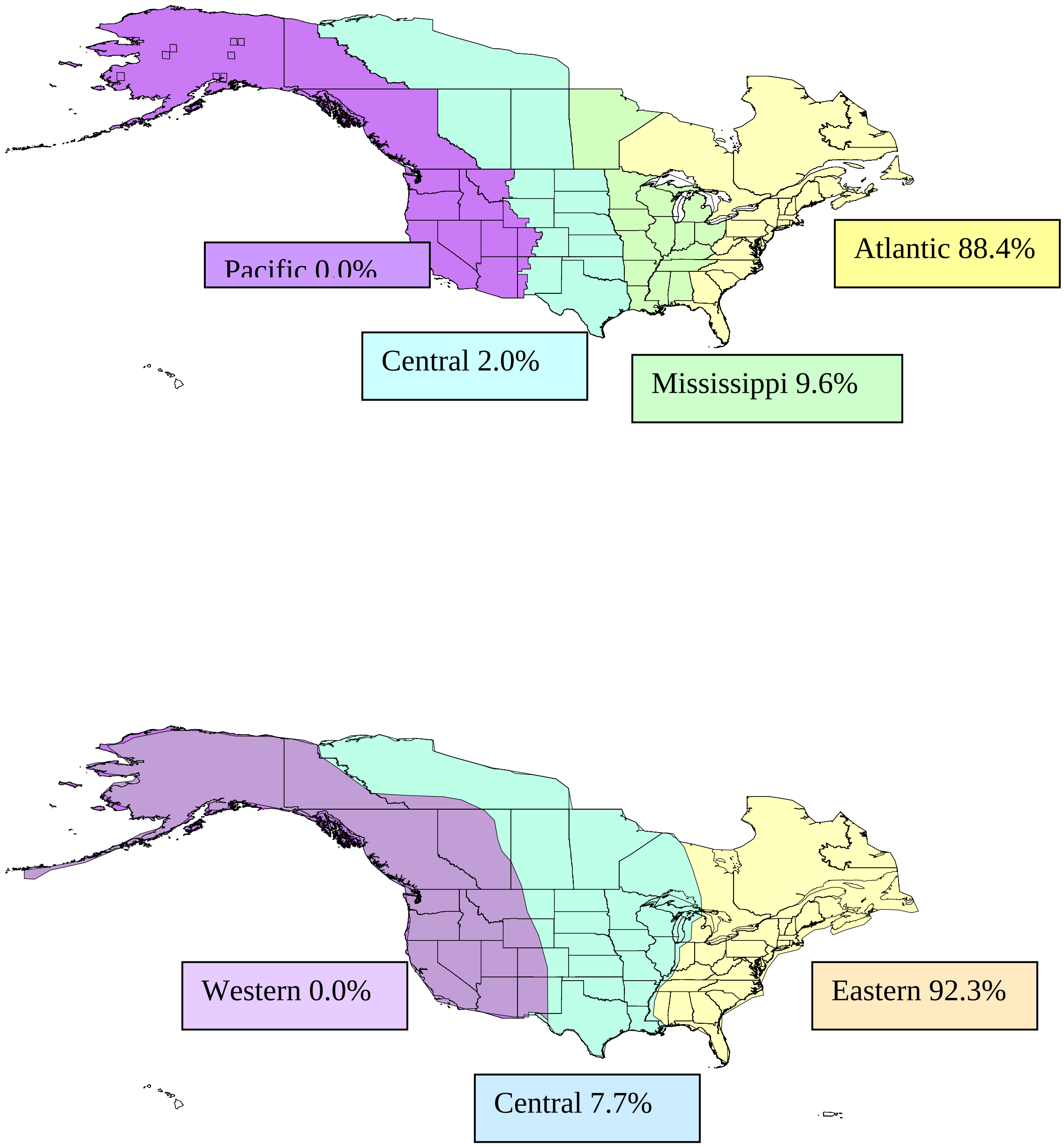
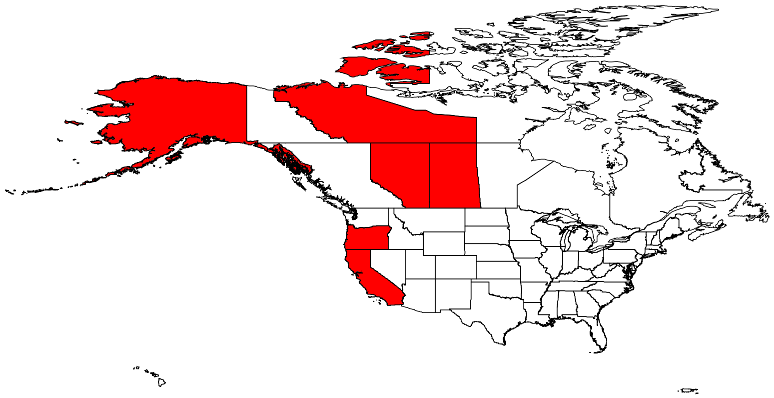
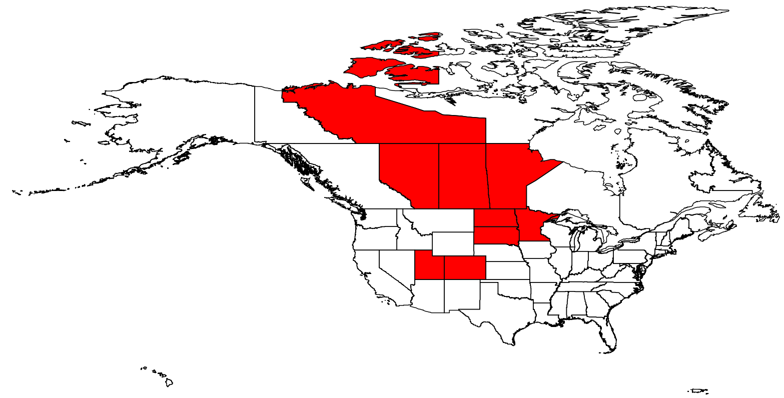


Figure 9 States and provinces with a total number of direct recoveries greater than 200 for northern pintails banded in the western, central, and eastern regions from 1970-2003.



Western Region



Central Region

Eastern Region

Figure 10 States and provinces with a total number of direct recoveries greater than 200 for northern pintails banded in the Pacific, Central, Mississippi, and Atlantic Flyways from 1970-2003.

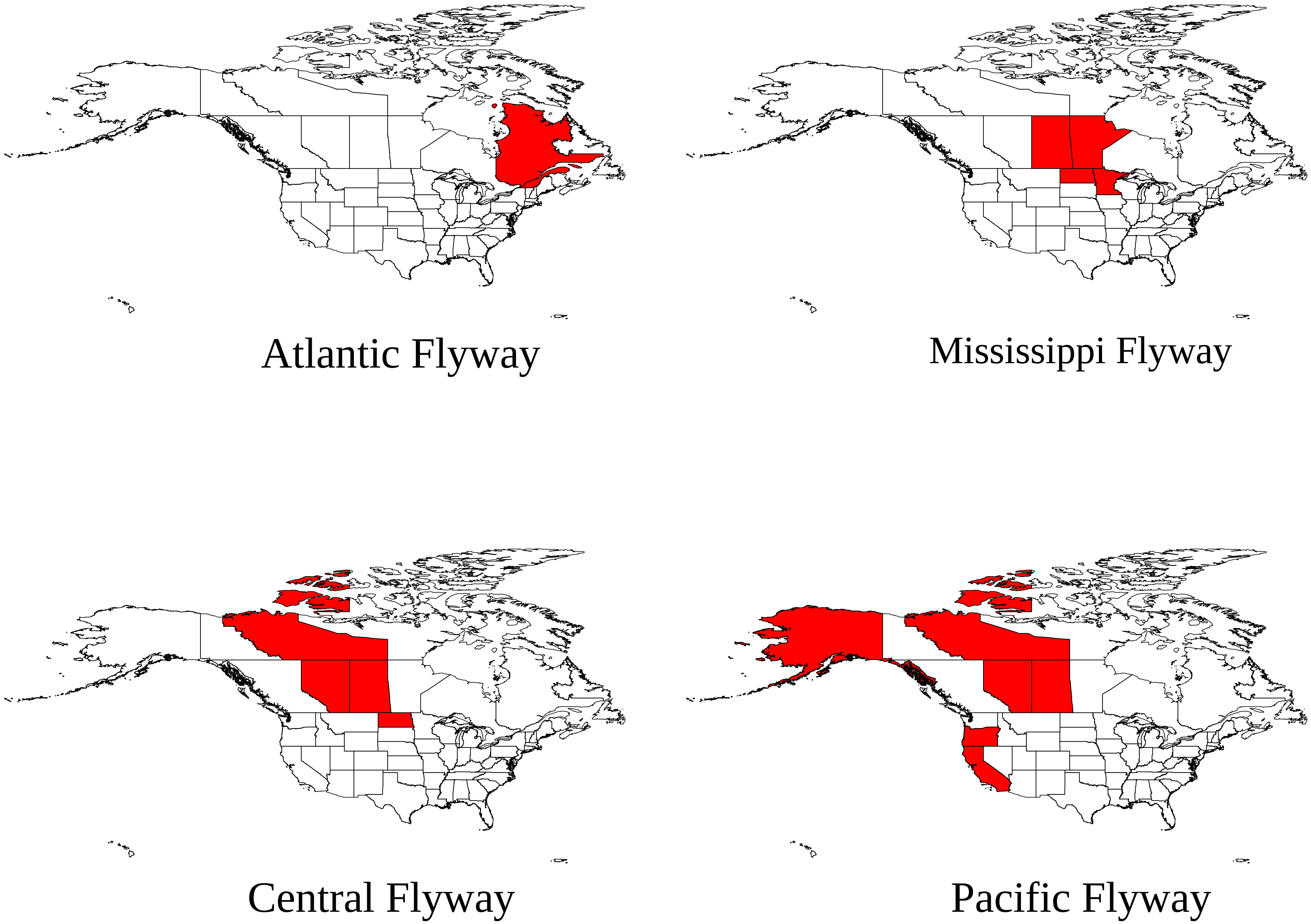


Figure 11 Assignment of bird banding blocks based on the highest total number of recoveries in the wintering areas of California, playa region of Texas, Texas coast, and Louisiana from 1970-2003.

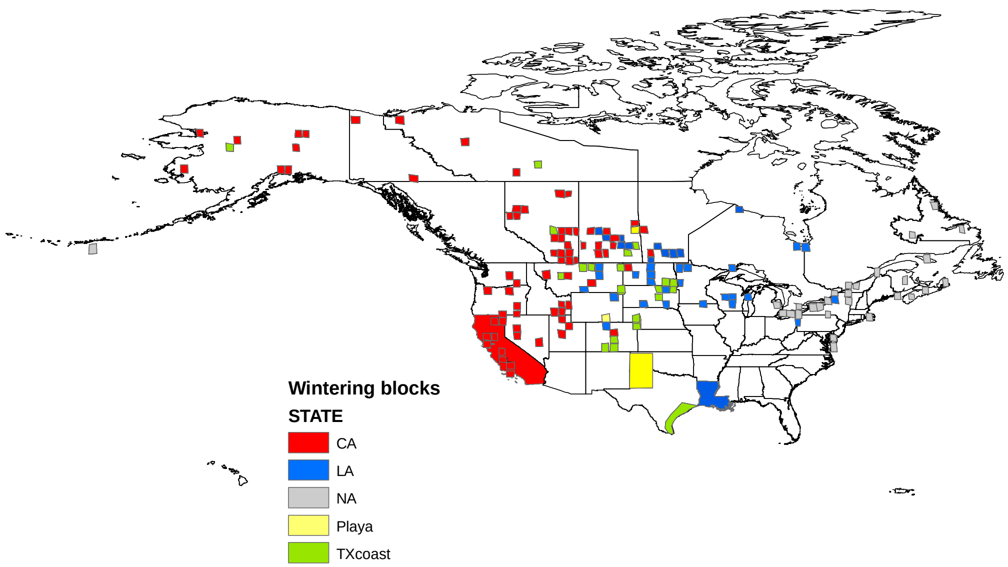
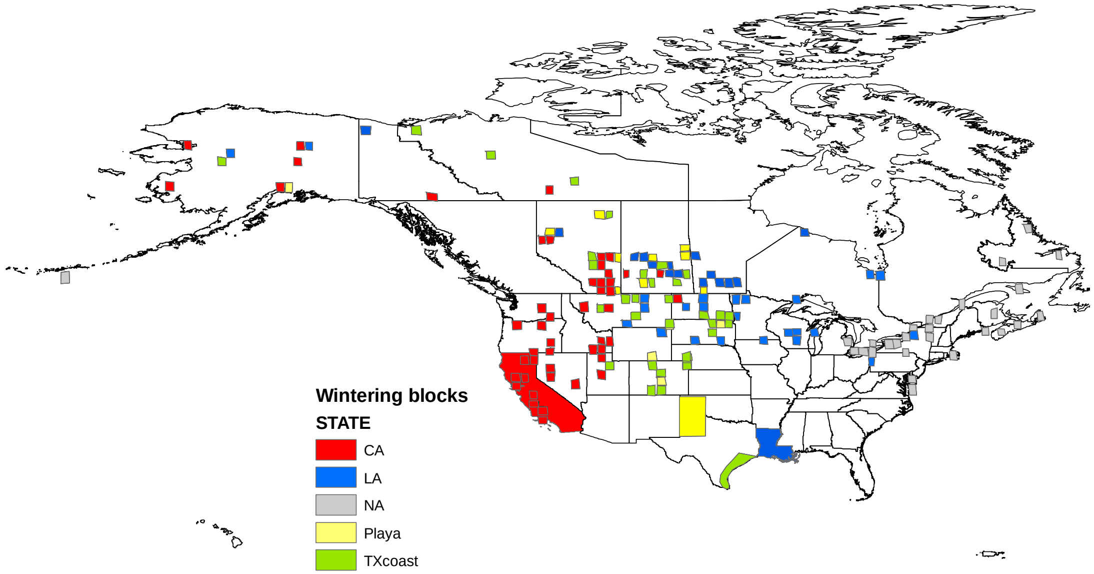


Figure 12 Assignment of bird banding blocks based on the number of birds recovered in the wintering areas of California, playa region of Texas, Texas coast, and Louisiana divided by the total number recovered in that area from 1970-2003.



Assessment of Continental Northern Pintail (*Anas acuta*) Band-Recovery Data Part II: Survival and recovery rate by hunting period and region

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Nearly all prairie-nesting dabbling duck species dramatically increased in abundance since the early 1990s except northern pintail (*Anas acuta*), which decreased from an estimated 9.6 million in 1955 to 2 million by 1988 (Hestbeck 1993, Scheaffer 2003) and has remained at relatively low levels since then. By 2002, pintails were represented by a low of 1.8 million birds in the traditional survey area (U.S. Fish and Wildlife Service 2004) despite recent restrictive harvest regulations. However, by 2007, the estimate of pintails in the traditional survey area had increased to 3.3 million birds, which was statistically unchanged from the 2006 estimate (U. S. Fish and Wildlife Service 2007a). Despite the increase since 2002, the current population estimate remains 20% below the long-term average (1955-2005, average number = 4.1 million) and 41% below the goal of 5.6 million proposed by the North American Waterfowl Management Plan. Although the pintail remains the most abundant duck in the Pacific Flyway, their numbers are only 25% of levels recorded in the 1970s (Fleskes et al. 2002). The continued low abundance of pintails has caused great concern among managers as evidenced by the United States Fish and Wildlife Service declaring pintails a focal species targeted for increased management emphasis and development of a species-specific harvest management strategy (U.S. Fish and Wildlife Service 2007b).

To aid in reaching the 5.6 million pintail population goal set by the North American Waterfowl Management Plan, a comprehensive evaluation of available pintail data is necessary (Podruzny et al. 2002). One portion of this evaluation includes testing models to estimate survival and recovery rates of the pintail population. Banding data provide a unique opportunity to investigate variation in life history traits such as survival and recovery rates (Krementz et al. 2003) and these critical parameters are needed to harvest a population in an optimal fashion (White 1983). The recovery rate is necessary for estimating the harvest rate, which is the primary consideration during development of regulations for harvest of pintail and other waterfowl (Munro and Kimball 1982). Many sources of variation affect survival and recovery rate estimates including annual changes in available habitat or severe weather events (Guyn and Clark 1999). Determining variables that are related to this variation will provide accurate and more precise measures of survival and recovery rates. It would also provide a means of comparison among models with different variables. Previous studies investigating survival and recovery rates for pintails focused on annual estimates using relatively simple interactive models, but other factors may be influencing these rates (Scheaffer et al. 1999, Runge and Boomer 2005). Increasing model complexity with specific explanatory variables may better explain patterns in the annual survival and recovery rates for northern pintails. For example, previous studies have found substantial temporal and regional variation in annual survival of pintails (e.g., Guyn and Clark 1999, Nicolai et al. 2005).

It has been shown that long-term trends in the estimated pintail breeding population size vary regionally (Miller and Duncan 1999); further, studies on other waterfowl species support the concept that spatial variation is an important factor in survival analyses (Pollock and Raveling 1982, Sedinger and Rexstad 1994). Many of the current studies on pintail survival and recovery rates focused on specific regions (Nicolai et al. 2005), but comparing data across geographic regions may provide different results. For example, whereas the number of pintails in Alaska has remained relatively constant, the estimated numbers in the Prairie Pothole Region of Canada continue to be below the long-term average (Nicolai et al. 2005). In addition, waterfowl survival rates within geographic strata have shown an effect of location (Nichols and Hines 1987) and the current survival and recovery rates available for pintail do not take regional differences into account (Runge and Boomer 2005, Sheaffer 1999). There is an apparent lack of information as to whether survival and recovery rates vary geographically for northern pintails and if regional distribution of pintails is a significant factor influencing the variability of previous estimates.

Temporal variation may also contribute to observed patterns of annual estimates of survival and recovery rates. The 95% confidence intervals of current survival and recovery estimates are relatively large, making it difficult to evaluate changes in annual survival over time (Runge and Boomer 2005). Previous work has suggested that there was little evidence of declines in annual survival estimates, but did find evidence for long-term patterns (Hestbeck 1993). Rogers et al. (1979) utilized hunting regulations on mallard (*Anas platyrhynchos*) by classifying years into liberal and restrictive periods to investigate long-term trends. Determining the effect of harvest on pintail populations depends on models that describe the relationship between regulatory decisions (i.e., bag limits and season length) and population parameters of interest (Conroy et al. 2005). The relationship between hunting frameworks and annual survival is not clear for pintails and should be assessed (Miller et al. 1995). Currently, there are major gaps in the analysis of band-recovery data for pintails over time and combining years using harvest regulations may provide better insight into the survival and recovery rates of pintails.

One consideration for identifying patterns of survival and recovery rates is the apparent movement of the average northern pintail breeding population north by 2.4° latitude (Runge and Boomer 2005). It has been recognized that during dry periods in the prairie pothole region, pintails settle farther north most likely in response to habitat conditions (Smith 1970, Runge and Boomer 2005). This may have an effect on survival and recovery estimates because a study found that average latitude of the breeding population was an important predictor of subsequent recruitment (Sheaffer 1999). Runge and Boomer (2005) found that correcting for average latitude of the pintail breeding population accounts for some of the variation of the apparent change in pintail dynamics since the mid 1970s. Overflight and non-overflight years may provide another temporal influence to account for differences in survival and recovery rates as a possible indicator of habitat conditions.

The northern pintail is declining, but the reasons for this are not clear. The most current harvest model for pintails does not incorporate any regional or periodic differences that could better explain the variation in survival (Runge and Boomer 2005). Our goal for this study was to investigate whether additional parameters may better model the variability of survival and recovery rate estimates. We utilized the most current band-recovery data to determine survival and recovery rates for northern pintail with the added parameters of temporal periods and region. Our principal variables of interest included identified breeding regions, overflight versus non-overflight years, bag limits, and season lengths. We tested for differences in survival between these variables as well as by age and sex.

Methods:

We obtained banding data for normal, wild shot birds from the United States Geological Survey Bird Banding Laboratory for 1970-2003. All birds were banded during July-September (pre-season). Records were grouped according to age and sex. We used the Brownie approach in Program MARK (White and Burnham 1999) to test 46 *a priori* models to estimate survival and recovery rates. Survival probability is the probability that a banded bird in year *t* survives to the banding period in year *t*+1. The recovery probability is the probability that a banded bird was shot, recovered, and reported during the hunting season in year *t*. When reporting trends and averages, we removed survival estimates of 1970 and 2002 and 1970 and 2003 recovery rates due to unreliable estimates that are typically produced at the beginning and end of banding periods (e.g., survival estimates of 1.0). Inclusion of these estimates would bias the resulting averages and trends.

To account for spatial variation, we first geographically stratified the sampling region into homogeneous units and pooled data from sites within each stratum (Royle and Dubovsky 2001). We accomplished this using a Multi-Response Permutation Procedure (MRPP) to identify banding blocks with dissimilar recovery distributions based on a cluster analysis (J. Dubovsky, pers. comm.). The purpose of a MRPP analysis is to discriminate patterns of geographic similarity between recovery locations and banding reference areas. Similar distributions are then assigned a region based on statistical inference rather than political boundaries. Our data resulted in a maximum of 12 identifiable banding regions based on similar recovery locations which we reduced further to 6, 5, and 3 regions (Figure 1) in subsequent survival rate analyses. Limited recovery data resulted in a lack of convergence during survival analyses when using the 12, 6, and 5 region delineation, which prevented their use (Figure 1). Therefore, we used the 3 region delineation, which was referenced as western, central, and eastern regions to test for any spatial effects in the model set (Figure 1).

We included estimates of annual survival in our model set, but we were also interested in whether pintail survival differed between other temporal periods of interest. Therefore, we grouped years into temporal periods based on bag limits, season lengths, and overflight versus non-overflight years. Hunting frameworks from the Central Flyway were used to group years by bag limit and season length temporal periods, but because the framework patterns were similar among flyways, these groupings were relevant for all tested regions. Each was divided into 3 temporal periods based on relative liberal, moderate, and restrictive regulations (Figures 2 and 3). However, these temporal periods were not related to similar, categorical distinctions included in Adaptive Harvest Management. The periods for season length were similar to those used by Sheaffer et al. (1999). The overflight period was divided into 2 periods using the average latitude to divide the periods (Figure 4).

We developed a candidate model set *a priori* based on the sources of variation of interest; these included age, sex, temporal period, region, and band type. We included band type for the estimation of recovery rate only, using the period before and after the implementation of the internet and 1-800 number options for reporting bands. This may provide insight into whether the increased reporting rate and new reporting methods influence estimates of survival and recovery rates. We considered both interactive and additive effects resulting in 46 models tested. We discriminated among models and selected the best approximating model using Akaike's Information Criterion (AIC; Burnham and Anderson 1998). AIC provides an estimate of the expected, relative distance between the fitted and the unknown process that actually generated the observed data (Burnham and Anderson 1998). This is a generalized approach and can be used with both nested and non-nested models (Williams et al. 2002).

We utilized program CONTRAST (Sauer and Williams 1989) to compare between survival and recovery rates for age and sex classes using their associated variances. We also used program CONTRAST to compare our survival estimates with those estimates used by Runge and Boomer (2002). Runge and Boomer (2002) used an age and sex interactive model for annual estimates of survival and recovery rates. We used linear regression to test the significance of slopes for each age, sex, and region class for annual trends.

Results

A total of 352,252 banding and 24,370 recovery records were used for this analysis (Figure 5). The 3 regions identified from the MRPP analysis and used in our modeling were consistent with the administrative Flyway boundaries. Essentially, the western region represented the Pacific Flyway and the eastern region corresponded to the Atlantic Flyway, whereas the central region reflected the combined Central and Mississippi Flyways. Of these, 53% of birds were banded in the western region, 44% in the central region, and 3% in the eastern region (Table 1). Overall, the percentage of birds recovered and reported across all age and sex classes from 1970-2003 was 6.9%. Pintail banding and recoveries were greatest in the western region, while banding efforts and recoveries in the eastern region were the lowest for all age and sex classes (Table 1).

The best approximating model indicated that survival varied with age, sex, and region with additive time and interactive time effects (Table 2). The recovery rate was fully interactive with age, sex, region, and year. The AICc weight was 0.998, indicating this was the most supported model within the model set (Table 2). The next highest ranked model had a weight of 0.002 and a ΔAIC of 12.31 and included an age and sex interaction, an additive region effect, and an interactive effect of overflight, bag limit, and season length, but was not considered a viable model compared to top-ranked model (Table 2). The inclusion of annual variation for the temporal component indicates that variation in annual survival rates explained more variation than survival rates over grouped temporal periods. Band type and other tested temporal periods had no effect on the variation in recovery rates. The top ten models had both interactive and additive effects for determining survival rates whereas simpler models with fewer parameters were poor at explaining variation.

Using the estimates from the top model, the average annual survival estimate for adult females was 0.660 in the central region, 0.656 in the western region, and 0.576 in the eastern region (Appendix A). A similar pattern was found for immature females with 0.565 in the central region, 0.552 in the western region, and 0.490 in the eastern region (Appendix A). Adult and immature males had greater average annual survival rates than females in the central region (0.760 adult; 0.699 immature), western region (0.751 adult; 0.694 immature), and eastern region (0.725 adult; 0.571 immature) (Appendix B). Annual recovery rate estimates were greatest for all age and sex classes in the eastern region (adult male = 0.032; adult females = 0.038; immature males = 0.070; immature females = 0.062) (Appendices C and D). The standard error associated with both annual survival and recovery rate estimates was also greater in the eastern region for all age and sex classes (Appendices A-D).

There was no difference between the average survival estimates for all age and sex classes ($\chi^2 = 3.03$, df = 3, $p = 0.39$). In addition, there were no differences among regions for adult females ($\chi^2 = 0.255$, df = 2, $p = 0.88$), immature females ($\chi^2 = 0.291$, df = 2, $p = 0.86$), adult males ($\chi^2 = 0.062$, df = 2, $p = 0.97$), or immature males ($\chi^2 = 1.027$, df = 2, $p = 0.60$). For all age and sex classes, the eastern region had the lowest survival rate point estimates whereas the central and western region estimates were similar (Figure 6). Across age and sex classes, immature females had the lowest annual survival estimates whereas adult males had the greatest (Figure 6). Recovery rates were greater for all age and sex classes in the eastern region and most pronounced for males (Figure 7). There was a relatively large standard error associated with recovery rates from the eastern region, reflecting a much lower annual number of banded and recovered birds.

Our model results produced similar average survival estimates compared to the estimates from Runge and Boomer's (2005) model (Figure 8). There were no statistical differences between the results for adult males ($\chi^2 = 1.294$, $p = 0.26$), immature males ($\chi^2 = 0.103$, $p = 0.75$), adult females ($\chi^2 = 0.011$, $p = 0.92$), or immature females ($\chi^2 = 0.609$, $p = 0.44$). Our estimates were also similar to other long-term studies on northern pintail survival completed in the last few years as well (Table 3). The male survival estimates were similar among all studies; however, our survival estimate for immature females was lower than other continental studies but greater than estimates in Alaska (Table 3).

The top model included an additive time effect, an age*time effect, and a region*time effect. We investigated these trend lines to determine any patterns to explain variation in the survival estimates. There was no increase or decrease in survival rates over time for the combined age and sex classes ($r^2 = 0.025$, $p = 0.40$; Figure 9). There was not any discernible pattern associated with annual survival rates, which may explain the inability of defined temporal periods to describe patterns in survival rates. Adding the age component to the time model indicated that annual survival of adult pintails appeared to increase from 1970-2002 whereas survival of immature pintails slightly decreased (Figure 10). Slope parameter estimates were not significantly different from 0, indicating no relationship between age and time (adult: $r^2 = 0.053$, $p = 0.21$; immature: $r^2 = 0.0008$, $p = 0.88$). The small divergence between the two lines may explain the presence of the age and time interaction in the best model for survival rates. The region and time component indicate little change in annual survival rates for any of the 3 regions over time (central: $r^2 = 0.007$, $p = 0.66$; eastern: $r^2 = 0.033$, $p = 0.33$; western: $r^2 = 0.006$, $p = 0.67$; Figure 11).

The inclusion of an age*time and region*time interaction may be driven by individual age and sex classes, so we investigated the regression trend lines of all regions for each age and sex class. The pattern of trends for survival rates in all 3 regions for all age and sex classes indicate that adult females and males appear to have increased whereas immature females and males have stayed the same (Figure 12). However, none of the slopes were found to differ from

0 for any age and sex class for all regions (Table 4). Trends in recovery rates also indicated little difference among the 3 regions (Figure 13). Recovery rates in the western region significantly decreased for adult females, which was the only significant slope for the recovery rate trend lines (Table 4). Adult females were the only cohort with a generally decreasing trend in long-term recovery rates across all regions.

Results from the second ranked model provided insight into the lack of a temporal effect for annual survival estimates. There was no difference among liberal, moderate, and restrictive periods using either bag limits or season lengths (bag limits: $\chi^2 = 2.148$, df = 2, $p = 0.34$; season length: $\chi^2 = 1.306$, df = 2, $p = 0.52$). The overall average annual survival rate for the overflight period was 0.639 and for the non-overflight period was 0.634; the difference was not statistically significant ($\chi^2 = 0.015$, df = 1, $p = 0.90$).

Discussion

The best model for estimation of survival and recovery rates of northern pintails included an age, sex, and region interactive component with additive time effects. This suggests a regional effect, but not a temporal effect for northern pintail survival rates. Despite these model components, the average annual survival rates did not differ for any age and sex class among the three regions. There was a large discrepancy between banding effort and recoveries among regions, which could be driving this regional effect. With only 3% of the banded birds in the Eastern region, we estimated an annual average recovery rate of 11.8% compared to 6% in the central region and 7.3% in the western region. Considering there were less than 20 recoveries reported annually in all age and sex classes in the eastern region, and at least 40 in the other two regions, the unequal amount of data likely influenced the resulting annual survival estimates and associated measures of variation. This pattern follows the current distribution of harvest in the

Atlantic Flyway (U.S. Fish and Wildlife 2007b), but it may be driving the inclusion of region in the top model. That is, it does not appear the survival rates differ between the remaining 2 regions once the eastern region is removed from consideration.

The lack of temporal patterns for survival rates in the top model was a bit surprising, but other studies have also found little temporal variation in annual survival probabilities (Gould and Nichols 1998, Franklin et al. 2002). Current models in place for northern pintails use a breeding population survey correction to develop harvest and hunting regulations (Runge and Boomer 2005, U.S. Fish and Wildlife 2007b). Those data indicate that northern pintails are moving farther north during dry years, but our models suggest that this movement has no apparent overall effect on female pintail survival. However, annual recruitment is reduced by the movement further north as females delay or fail to initiate nesting. Apparently, any mortality resulting from the increased energetic cost related to overflights are offset by the lack of mortality typically related to the stress of reproduction. In addition, hunting regulations such as bag limits and season length provided little insight into the variation of pintail survival. There may be another variable not investigated that is influencing the survival rates, but our data does not support any temporal effect.

The top model had an AIC_c weight of 0.998, making it the overwhelming best approximating model. Unfortunately, the more complex models we incorporated into our study may create a complication for future banding studies of pintails. There was an age*time and a region*time interaction effect, which complicates classifying groups for analysis. For example, use of the best model requires calculation of a survival rate for each age, sex, and region class, then a separate time parameter, then a time effect for both males and females, and finally a time effect for each of the 3 regions. If one was doing a 5-year study to address the effect of regulations, this would mean calculating 38 survival terms. Complicating the issue is the fact that none of the point survival estimates or trend lines were statistically significantly different among age, sex, and region, which seems to contradict the results of the top model. However, effects were evident in separating the top model from the remainder of tested models despite non-statistically different findings. In addition, the traditional models used for pintail management have typically been based on age and sex classes. These simpler models were not competitive to the top ranked models of the 46-model set, which may cause some concern as to what is influencing changes in pintail abundance. However, the resulting average survival estimates for all age and sex classes were similar to other studies conducted with simple age and sex interactions (Runge and Boomer 2002, Sheaffer et al. 1999, Lake et al. 2006). This could suggest changes in the pintail population are primarily a result of declining recruitment, rather than changes in annual survival.

Overall, there were few significant trends and patterns in the northern pintail data. Runge and Boomer (2002) found that recovery rates were decreasing during the 1970s and 1980s on a continental scale, but we did not find a similar pattern at the regional scale. In all 3 regions, only adult females had consistently decreasing recovery rates. The current management emphasis on female pintails may be protecting this group from harvest pressure compared to other age and sex classes.

References

Anderson, D. R., K. P. Burnham, and G. C. White. 1998. Comparison of Akaike information criterion and consistent Akaike information criterion for model selection and statistical inference from capture-recapture studies. Journal of Applied statistics 25:263-282.

Conroy, M. J., C. J. Fonnesbeck, and N. L. Zimpfer. 2005. Modeling regional waterfowl harvest rates using markov chain monte carlo. Journal of Wildlife Management 69:77-90.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. September-March survival of female Northern Pintails radiotagged in San Joaquin valley, CA. Journal of Wildlife Management 66:901-911.

Franklin, A. B., D. R. Anderson, and K. P. Burnham. 2002. Estimation of long-term trends and variation in avian survival probabilities using random effects models. Journal of applied statistics 29:267-287.

Gould, W. R., and J. D. Nichols. 1998. Estimation of temporal variability of survival in animal populations. Ecology 79:2531-2538.

Guyn, K. L. and R. G. Clark. 1999. Factors affecting survival of northern pintail ducklings in Alberta. The Condor 101:369377.

Hestbeck, J. B. 1993a. Overwintering distribution of northern pintail populations in North America. Journal of Wildlife Management 57:582-589.

Hestbeck, J. B. 1993b. Survival of northern pintails banded during winter in North America, 1950-88. Journal of Wildlife Management 57:590-597.

Krementz, D. G., J. E. Hines, and D. R. Luukkonem. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management 67:398-407.

Lake, B. C., J. Walker, and M. S. Lindberg. 2006. Survival of ducks banded in the boreal forest of Alaska. Journal of Wildlife Management 70:443-449.

Miller, M. R., and D. C. Duncan. 1999. The northern pintail in North America: status and conservation needs of a struggling population. Wildlife Society Bulletin 27:788-800.

Miller, M. R. J. P. Fleskes, D. L. Orthmeyer, W. E. Newton, and D. S. Gilmer. 1995. Survival of adult female northern pintails in Sacremento Valley, California. Journal of Wildlife Management 59:478-486.

Munro, R. E. and C. F. Kimball. 1982. Population ecology of the mallard: VII. distribution and derivation of the harvest. U. S. Fish and Wildlife Service. Resource Publication 147. 127 pp.

Nichols, J. D., and J. E. Hines. 1987. Population ecology of the mallard: VIII. Winter distribution patterns and survival rates of winter-banded mallards. United States Fish and Wildlife Service. Resource Publication 162. 154 pp.

Nicolai, C. A., P. L. Flint, and M. L. Wege. 2005. Annual survival and site fidelity of northern pintails banded on the Yukon-Kuskokwim Delta, Alaska. Journal of Wildlife Management 69:1202-1210.

Podruzny, K. M., J. H. Devries, L. M. Armstrong, and J. J. Rotella. 2002. Long term response of northern pintails to changes in wetland conditions and agriculture in the Canadian Prairie pothole region. Journal of Wildlife Management 66:993-1010.

Pollock, K. H., and D. G. Raveling. 1982. Assumptions of modern band-recovery models, with emphasis on heterogeneous survival rates. Journal of Wildlife Management 46: 88-98.

Rogers, J. P., J. D. Nichols, F. W. Martin, C. F. Kimball, and R. S. Pospahala. 1979. An examination of harvest and survival rates of ducks in relation to hunting. Transactions of the North American Wildlife and Natural Resources Conference 44:114-126.

Royle, J. A., and J. A. Dubovsky. 2001. Modeling spatial variation in waterfowl band-recovery data. Journal of Wildlife Management 65:726-737.

Runge, M. C., and G. S. Boomer. 2005. Population dynamics and harvest management of the continental northern pintail population. Unpublished report, Migratory Bird Management Office, Biological Resources Division, U. S. Fish and Wildlife Service and U. S. Geological Survey. pp. 42.

Sauer, J. R., and B. K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. Journal of Wildlife Management 53:137-142.

Scheaffer, S. E. 2003. Northern pintail: prospectus for an action group. New York fisheries and Wildlife Cooperative Research Unit, Ithaca, NY, USA.

Scheaffer, S. E., M. C. Runge, and R. A. Malecki. 1999. Models for adaptive management of northern pintails. New York Cooperative Fish and Wildlife Research Unit, Ithaca, NY, USA. 75pp.

Sedinger, J. S. and E. A. Rexstad. 1994. Do restrictive harvest regulations result in higher survival rates in mallards? A comment. Journal of wildlife Management 58:571-577.

Smith, R. I. 1970. Response of pintail breeding population to drought. Journal of Wildlife management 34:381-396.

U.S. Fish and Wildlife Service. 2007a. Waterfowl population status. U. S. Department of the Interior, Office of Migratory Bird Management, Laurel, Maryland, USA. 60pp.

U.S. Fish and Wildlife Service. 2007b. Northern Pintail Harvest Strategy. Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Department of Interior, Washington, D.C.

White, G. C. l983. Numerical estimation of survival rates from band-recovery and biotelemetry data. Journal of Wildlife Management 47:716-728.T

White, G. C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement: 120-138.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and Management of Animal populations: modeling, estimation, and decision making. Academic Press, London, England.

Table 1. The mean and total number of continental bandings and recoveries in the central, eastern, and western regions for adult male, adult female, immature male, and immature female northern pintails, 1970-2003.

Region	Age/sex group	Mean number/year		Total	
		Banded	Recovered	Banded	Recovered
Central					
	Adult females	1283	45	43617	1534
	Adult Males	1272	87	43248	2950
	Immature Females	1048	60	35643	2025
	Immature Males	920	82	31286	2779
Eastern					
	Adult females	77	6	2615	197
	Adult Males	42	5	1442	157
	Immature Females	120	14	4069	477
	Immature Males	115	17	3904	587
Western					
	Adult females	1153	42	39210	1442
	Adult Males	1666	148	56644	5047
	Immature Females	1335	76	45389	2575
	Immature Males	1329	135	45185	4600

Table 2. Model set results from program MARK used to analyze banding recoveries of northern pintail banded in Canada and U.S., 1970-2003. Variables of interest were used to estimate survival and recovery rates by age (a), sex (s), region (r), band type (bt), year (t), and temporal classification of years based on bag limit (bl), season length (sl), and relative latitude of breeding population (of).

Survival	Recovery	AICc	ΔAIC	AICc weights	Model likelihood	No. of parameters	Deviance
a*s*r+t+a*t+r*t	a*s*r*t	257706.80	0.00	0.998	1.000	548	5435.84
a*s+r+bl*sl*of	a*s*r*t	257719.11	12.31	0.002	0.002	438	5668.77
a*s*r+t+a*t+s*t+r*t+a*r*t+a*r*t	a*s*r*t	257748.01	41.21	0.000	0.000	707	5157.91
a*s*r+t+a*t+s*t+r*t+a*s*t	a*s*r*t	257758.25	51.45	0.000	0.000	612	5358.87
a*s*r+t+a*t+s*t+r*t+s*r*t	a*s*r*t	257806.02	99.22	0.000	0.000	644	5342.41
a*s*r+t+a*t+s*t	a*s*r*t	257807.37	100.57	0.000	0.000	516	5600.60
a*s*r+a*t+s*t+r*t+a*s*t+s*r*t	a*s*r*t	257812.98	106.18	0.000	0.000	676	5285.13
a*s*r+a*t+s*t+r*t+a*s*t+a*r*t	a*s*r*t	257846.61	139.81	0.000	0.000	676	5318.76
a*s*r+a*t+s*t+r*t+a*s*t+a*r*t+s*r*t	a*s*r*t	257869.95	163.15	0.000	0.000	740	5213.58
a*s*r*of *bl*sl	a*s*r*t	257874.68	167.88	0.000	0.000	665	5368.91
a*s*r+t+a*t+s*t+r*t	a*s*r*t	257875.94	169.14	0.000	0.000	580	5540.77
a*s*r*of	a*s*r+t	257894.80	188.00	0.000	0.000	81	6559.51
a*s*t	a*s*r*t	257908.39	201.59	0.000	0.000	540	5653.48
a*s*r*t	a*s*r*t	257926.70	219.90	0.000	0.000	804	5141.77
a*s*r*t	a*s*r+t	258025.72	318.92	0.000	0.000	441	5969.36
a*s*r*t	a*s*bt*r+t	258030.73	323.93	0.000	0.000	453	5950.31
a*s*r*t	a*s*bt+r+t	258049.01	342.21	0.000	0.000	438	5998.67
a*s*r*t	a*s+r+t	258139.12	432.32	0.000	0.000	435	6094.79
a*s*r*t	a*s+bt+r+t	258196.05	489.25	0.000	0.000	436	6149.72
a*s*r*t	a*s+bt+t+r	258218.46	511.66	0.000	0.000	469	6105.96
a*s*r*bl	a*s*r*t	258228.71	521.91	0.000	0.000	444	6166.34
a*s*r*t	a*s+bt+r+of+sl+bl	258400.87	694.07	0.000	0.000	409	6408.67
a*s*r+t+s*t+r*t	a*s*r*t	258477.03	770.23	0.000	0.000	548	6206.07
a*s*r*t	a*s*r*bt*of	258502.37	795.57	0.000	0.000	456	6415.94
a*s*r*sl	a*s*r*t	258561.94	855.14	0.000	0.000	444	6499.57
a*s*r*t	a*s+bt+t	258609.43	902.63	0.000	0.000	434	6567.11
a*s+r*t	a*s*r*t	258689.41	982.61	0.000	0.000	510	6494.68
a*s*r+t+s*t	a*s*r*t	258711.29	1004.49	0.000	0.000	484	6568.71
a*s*r+t+a*t	a*s*r*t	258718.62	1011.82	0.000	0.000	484	6576.04

Table 2 (*cont.*)

a*s*r+t+a*t+s*t+r*t+a*r*t	a*s*r*t	258822.80	1116.00	0.000	0.000	644	6359.19
a*s*r*t	a*s*r*bt*sl	258977.64	1270.84	0.000	0.000	456	6891.21
a*s*r+t	a*s*r*t	259108.86	1402.06	0.000	0.000	452	7030.44
a*s*r*t	a*s*r*bt*bl	259309.30	1602.50	0.000	0.000	456	7222.87
a*s*r+t+r*t	a*s*r*t	259459.88	1753.08	0.000	0.000	516	7253.11
a*s+r*bl*sl*of	a*s*r*t	259515.78	1808.98	0.000	0.000	484	7373.20
a*s*r*t	a*s*bt+r	259565.26	1858.46	0.000	0.000	405	7581.08
a*s*of+r	a*s*r*t	260097.66	2390.85	0.000	0.000	420	8083.40
a*s*r*t	a*s*bt*r	260146.05	2439.25	0.000	0.000	417	8137.81
a*s*r*of	a*s*r*t	260327.03	2620.23	0.000	0.000	444	8264.66
a*s+r+sl	a*s*r*t	261094.27	3387.47	0.000	0.000	416	9088.03
a*s+r+t	a*s*r*t	261668.45	3961.65	0.000	0.000	446	9602.07
a*s*r+of	a*s*r*t	263923.68	6216.87	0.000	0.000	420	11909.42
a*s+r+bl	a*s*r*t	264140.85	6434.05	0.000	0.000	416	12134.61
a*s*r	a*s*r*t	265670.96	7964.15	0.000	0.000	420	13656.70
a*s+r+of	a*s*r*t	266729.19	9022.39	0.000	0.000	416	14722.95

Table 3. Comparison of average annual survival estimates, standard errors, and range of survival rates of northern pintails banded pre-season from studies completed in the past 10 years across the continent and regionally in Alaska.

Authors	Years of study	Location	Age/sex Class	Survival estimate	SE	Range
Rice et al.	1970-2003	Continental				
	(this study)		Adult males	0.745	0.087	48.1 - 100
			Immature males	0.655	0.079	32.0 - 100
			Adult females	0.630	0.105	33.4 - 100
			Immature females	0.536	0.085	24.1 - 100
Runge and Boomer	1960-2002	Continental				
			Adult males	0.747	0.071	59.2 - 98.4
			Immature males	0.692	0.083	41.9 - 99.2
			Adult females	0.645	0.097	42.8 - 89.5
			Immature females	0.645	0.110	39.2 - 100
Scheaffer et al.	1960-1995	Continental				
			Adult males	0.764	0.004	73.5 - 80.7
			Immature males	0.671	0.019	67.7 - 81.1
			Adult females	0.649	0.008	61.9 - 67.1
			Immature females	0.615	0.027	53.8 - 77.9
Lake et al.	1989-1999	Alaska				
			Adult males	0.760	0.030	42.0 - 80.0
			Immature males	0.650	0.040	47.0 - 77.0
			Adult females	0.700	0.040	42.0 - 86.0
			Immature females	0.420	0.040	10.0 - 61.0

Table 4. Slope, *t*-statistic, *p*-value, and the regression coefficient for changes in survival and recovery rates for each age/sex class for each region from 1971-2001.

		Survival rate				Recovery rate			
Age/Sex Class	Region	Slope	*t*	*p*-value	r^2	Slope	*t*	*p*-value	r^2
Adult Female	Central	0.003	0.905	0.373	0.027	0.000	0.152	0.880	0.001
	Eastern	0.005	1.307	0.202	0.056	− 0.001	− 1.726	0.094	0.093
	Western	0.003	0.951	0.350	0.030	− 0.004	− 4.361	0.001	0.396
Immature female	Central	− 0.001	− 0.213	0.833	0.002	0.0001	0.639	0.528	0.014
	Eastern	0.002	0.539	0.594	0.010	− 0.0006	− 1.396	0.173	0.063
	Western	− 0.001	− 0.227	0.822	0.002	− 0.0001	− 0.492	0.627	0.008
Adult Male	Central	0.002	0.835	0.411	0.023	0.0003	1.983	0.057	0.119
	Eastern	0.004	1.251	0.221	0.051	− 0.0002	− 0.547	0.588	0.010
	Western	0.002	0.908	0.371	0.028	− 0.0002	− 1.338	0.191	0.058
Immature male	Central	− 0.000	0.146	0.885	0.0007	0.0004	1.664	0.107	0.087
	Eastern	0.002	0.573	0.571	0.011	0.0006	1.360	0.184	0.060
	Western	0.000	− 0.109	0.914	0.0004	− 0.000	− 0.133	0.895	0.001

Figure 1. Results of the 12, 6, 5, and 3 region groupings from the Multi-Response Permutation Procedure (MRPP) analysis for northern pintail in North America between 1970 and 2003. Different colors indicate different recovery distribution patterns resulting in grouped banding locations forming the indicated regions.

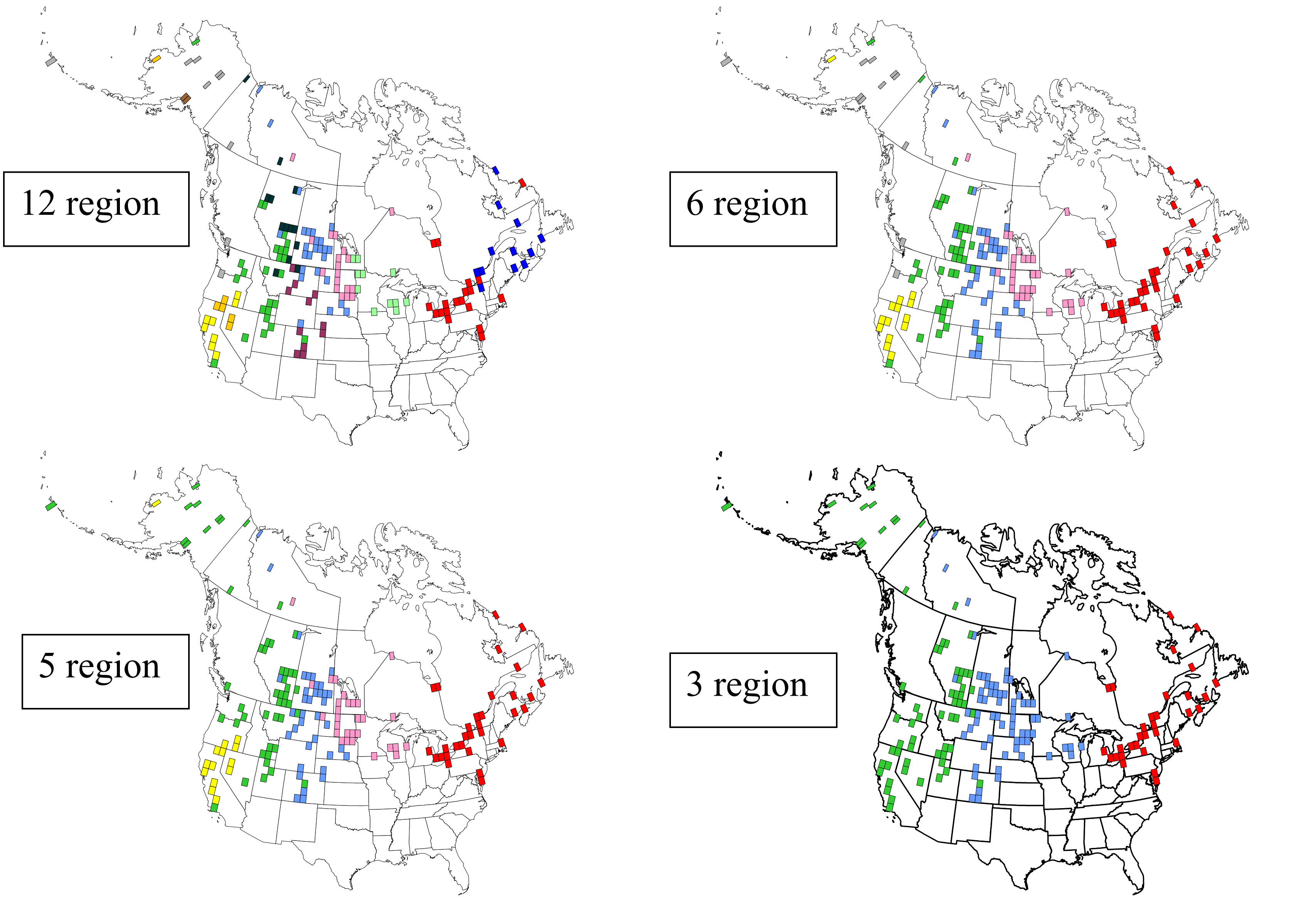


Figure 2. Grouping of years based on hunting season length (the number of hunting days) used to model temporal periods for continental northern pintail survival and recovery rates, 1970-2003.

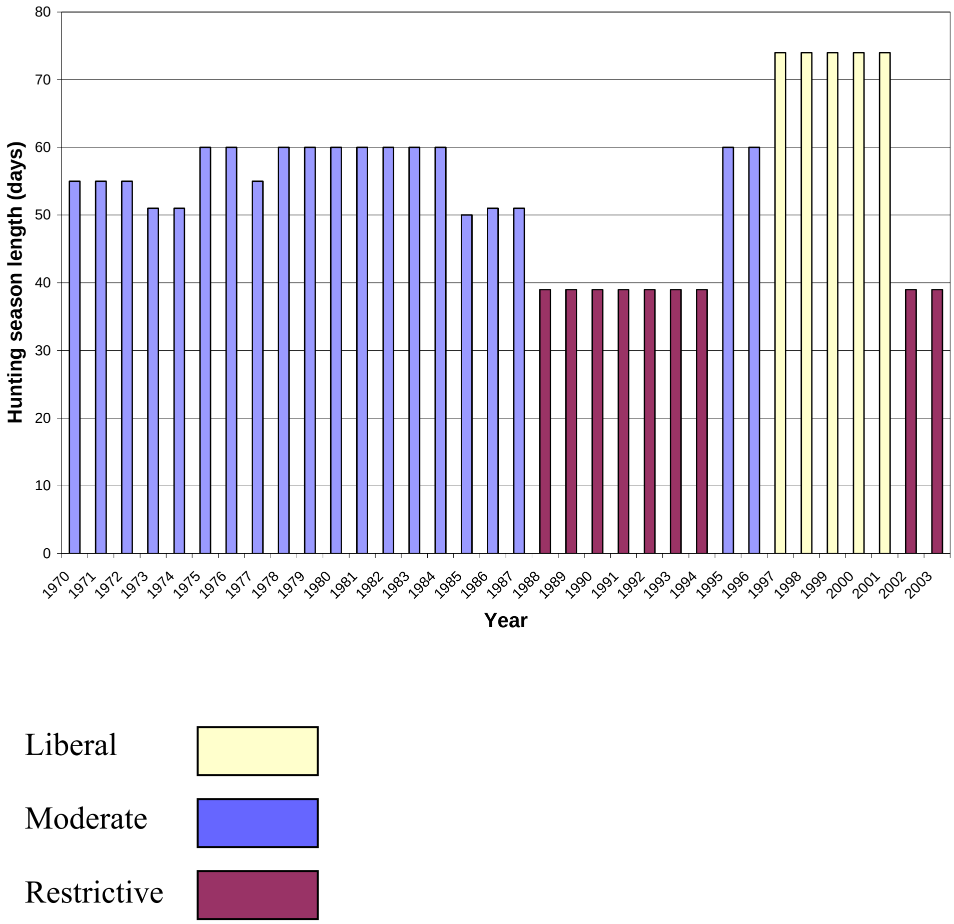


Figure 3. Grouping of years based on bag limits (number of birds per bag) used to model temporal periods for continental northern pintail survival and recovery rates, 1970-2003.

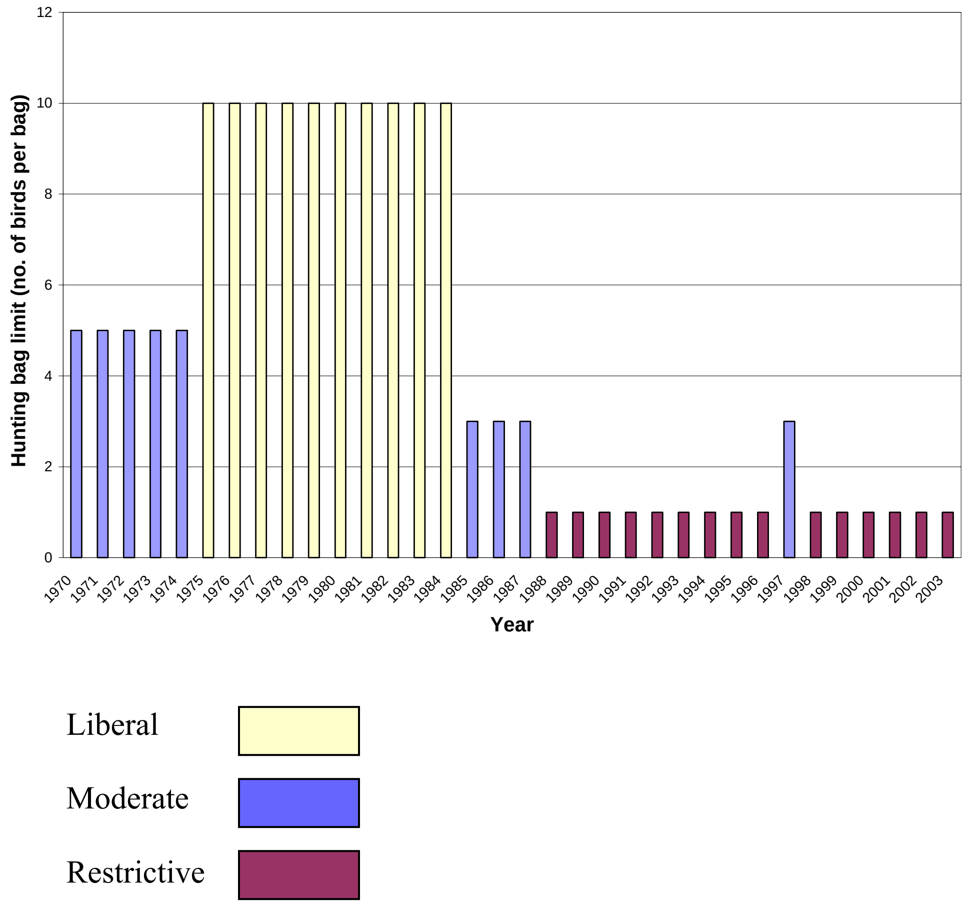
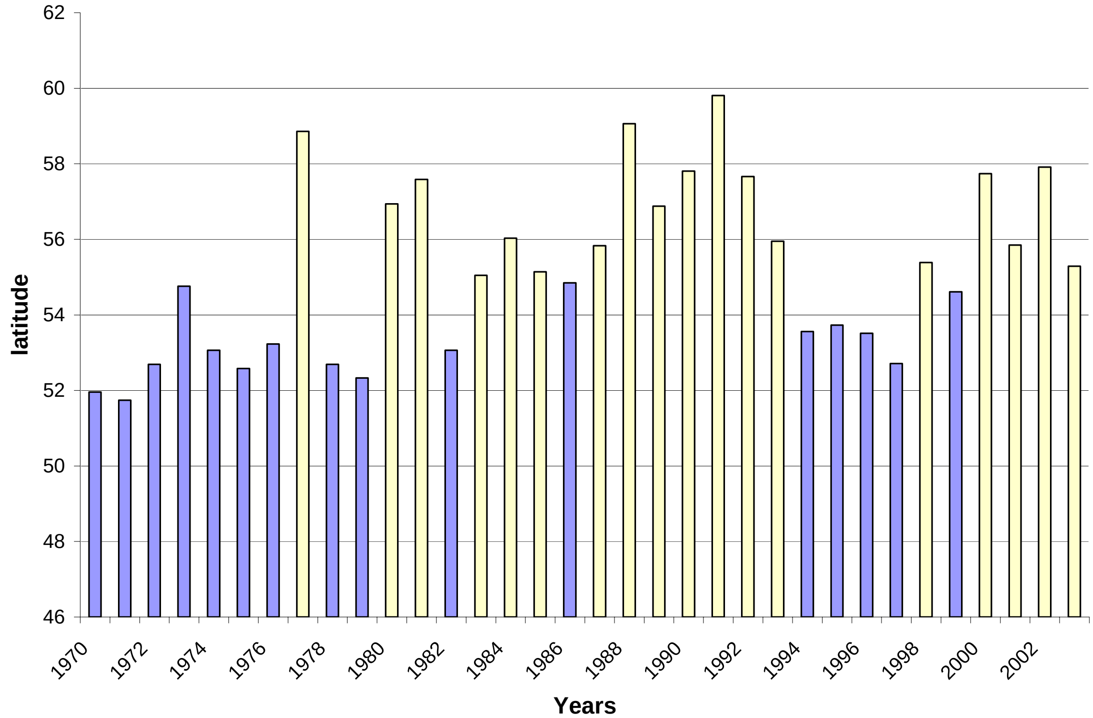


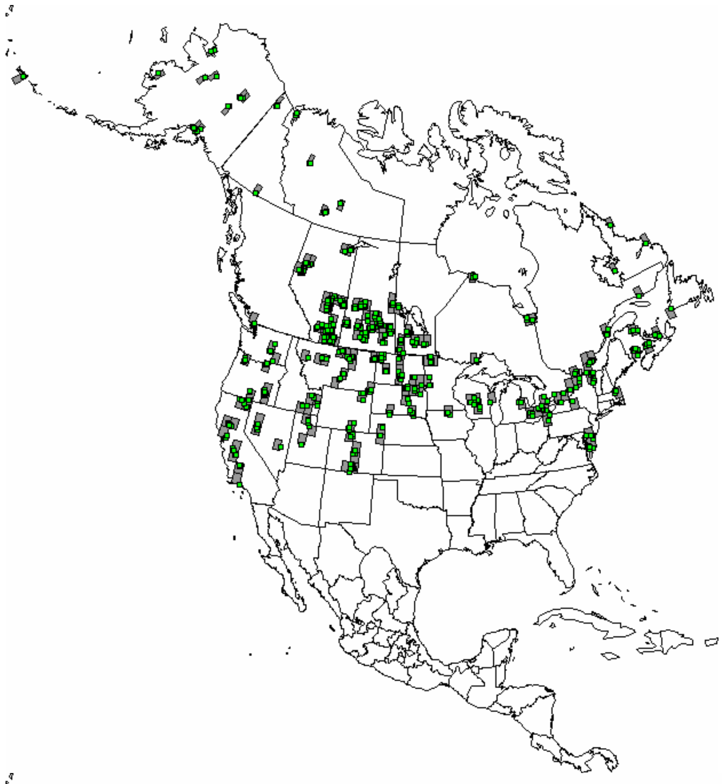
Figure 4. Grouping of years based on the mean latitude of the pintail breeding population divided into overflight temporal periods used to model continental northern pintail survival and recovery rates, 1970-2003.



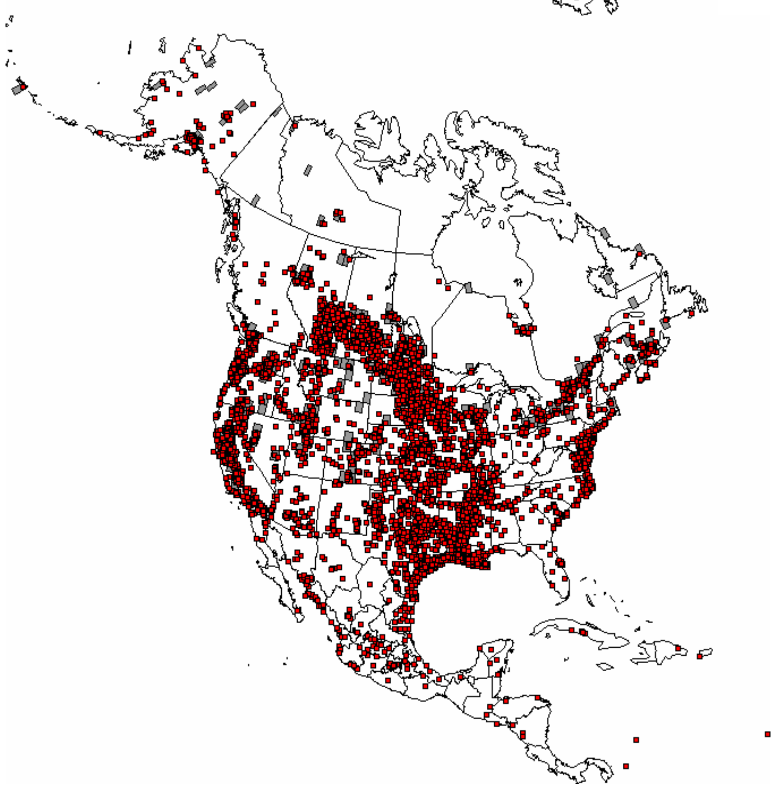
overflight

non-overflight

Figure 5. Northern pintail banding and recovery locations for individual birds used in the Multi-Response Permutation Procedure for determining the regions of analysis.



Bird Banding Locations



Bird Recovery Locations

Figure 6. Annual survival rate estimates for the defined central, western, and eastern regions for adult male, immature male, adult female, and immature female northern pintails, 1970-2003. The bars represent standard errors of the estimates.

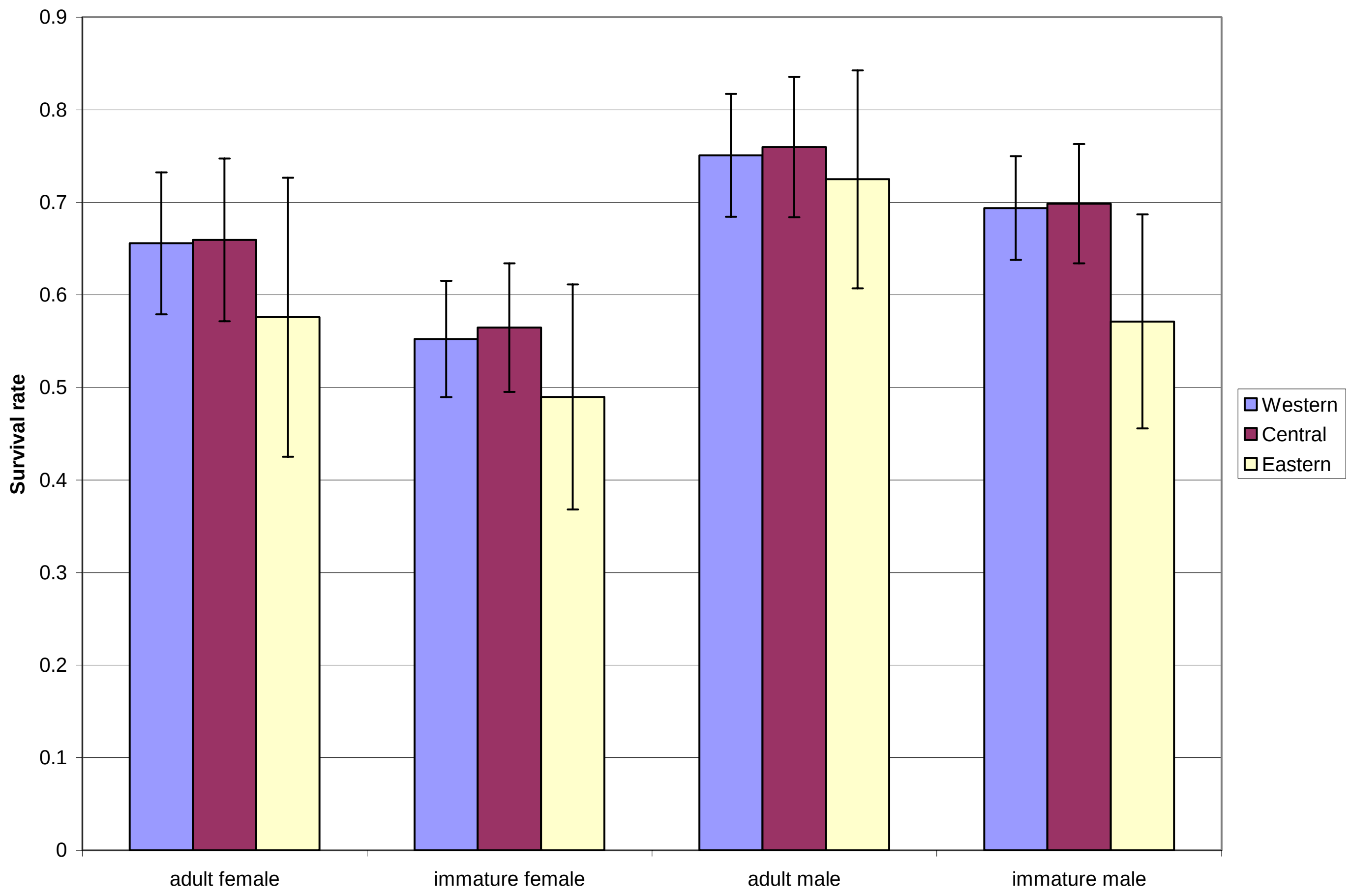


Figure 7. Estimates of annual band recovery rate for the central, western, and eastern regions for adult male, immature male, adult female, and immature female northern pintails, 1970-2003. The bars represent standard errors of the estimates.

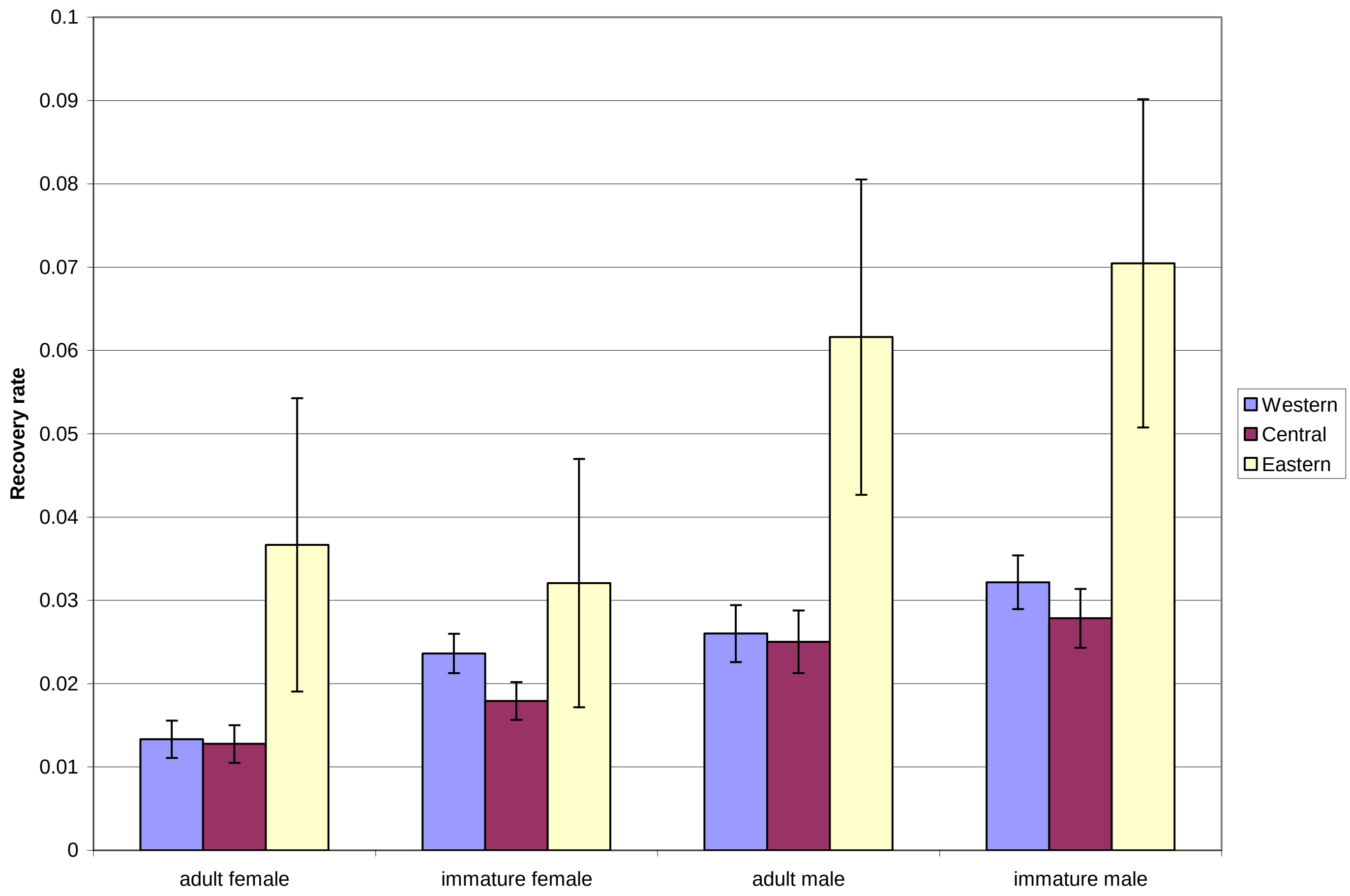


Figure 8. Survival estimates using the Runge and Boomer (2002) model for the banding period 1960 -2002 and our updated model for adult male, immature male, adult female, and immature female northern pintails for the banding period 1970-2003.

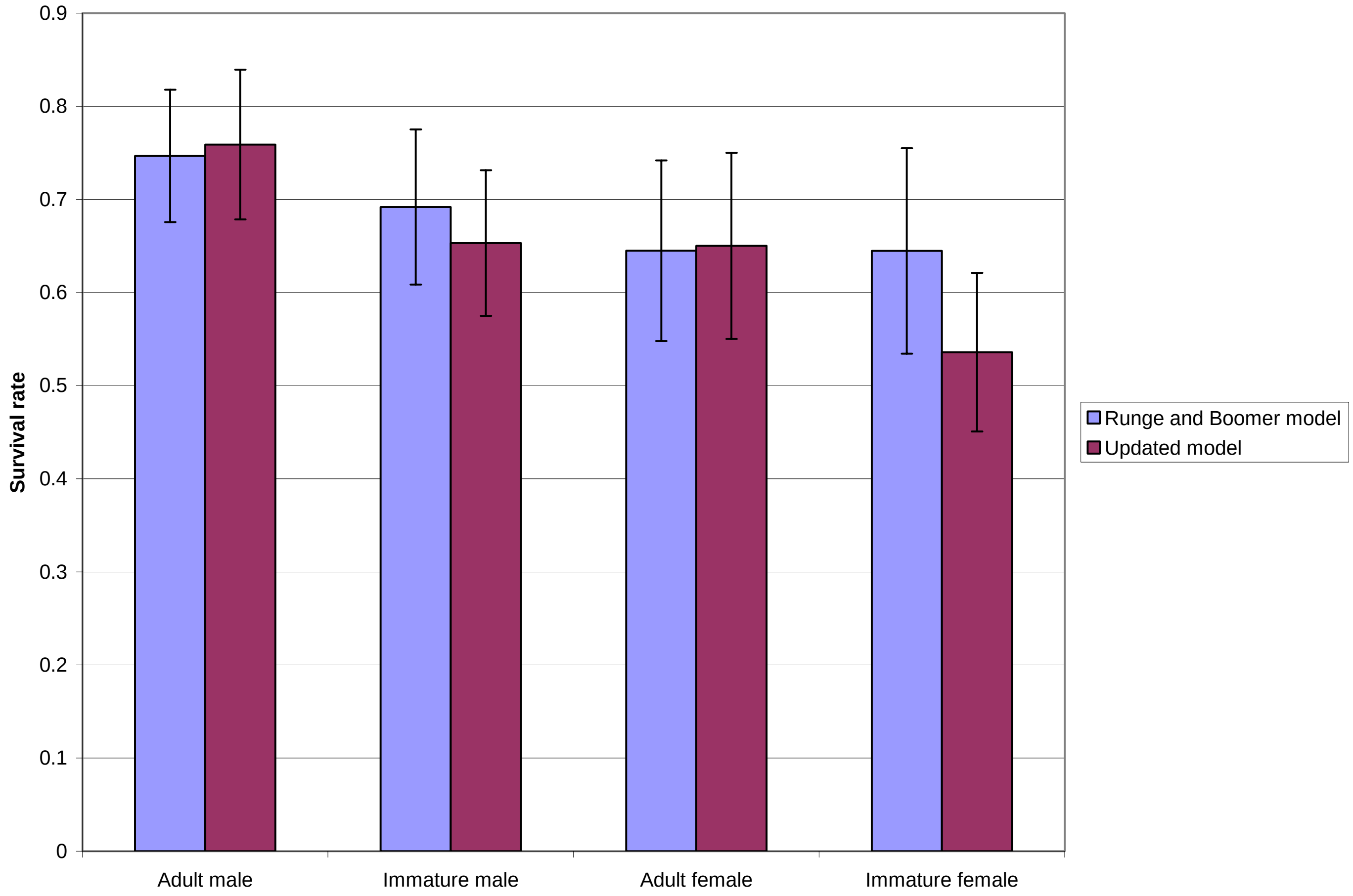


Figure 9. Estimated annual survival rates for the additive time effect in the top model (S(a*s*r+t+a*t+r*t)f(a*s*r*t)) for all northern pintails, 1970-2003.

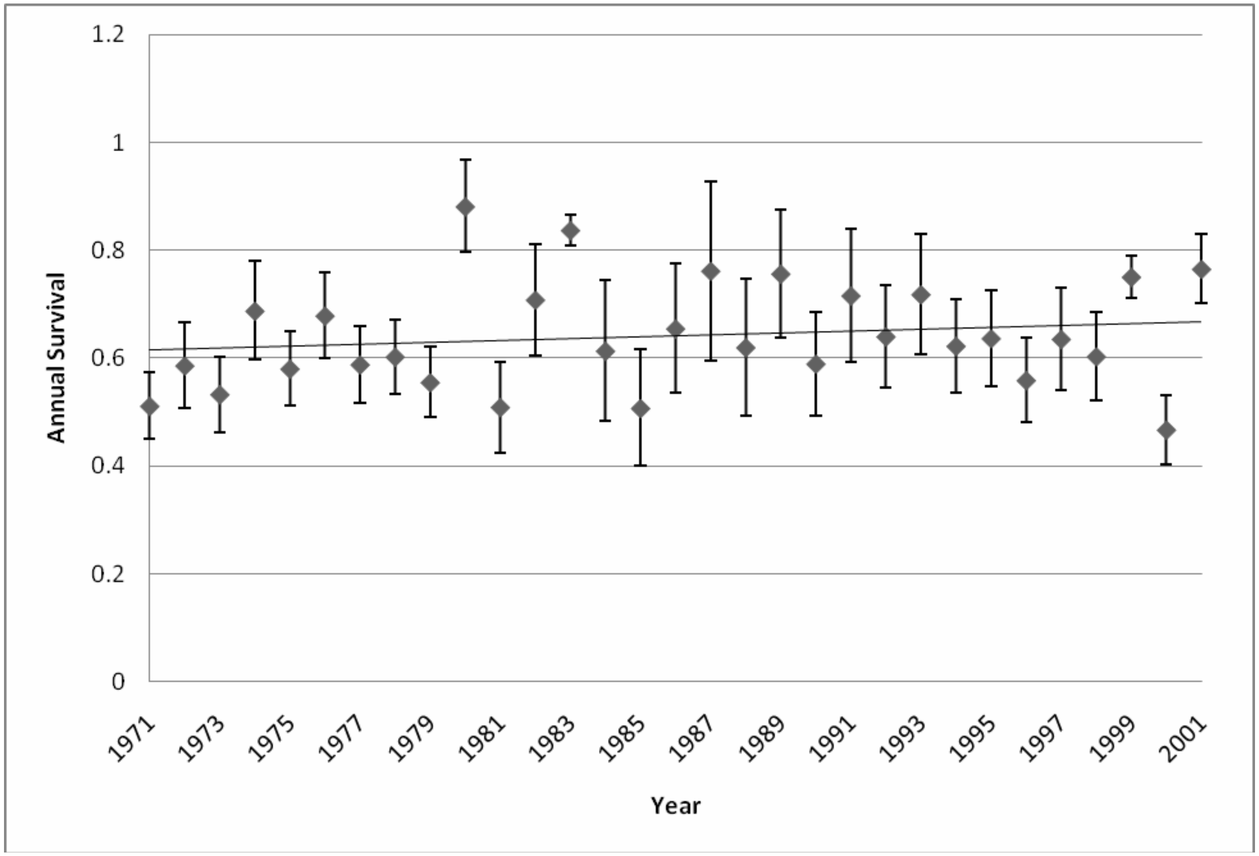


Figure 10. Annual survival rate estimates for the age and time interaction in the top model (S(a*s*r+t+a*t+r*t)f(a*s*r*t)) for adult and immature northern pintails, 1970-2003.

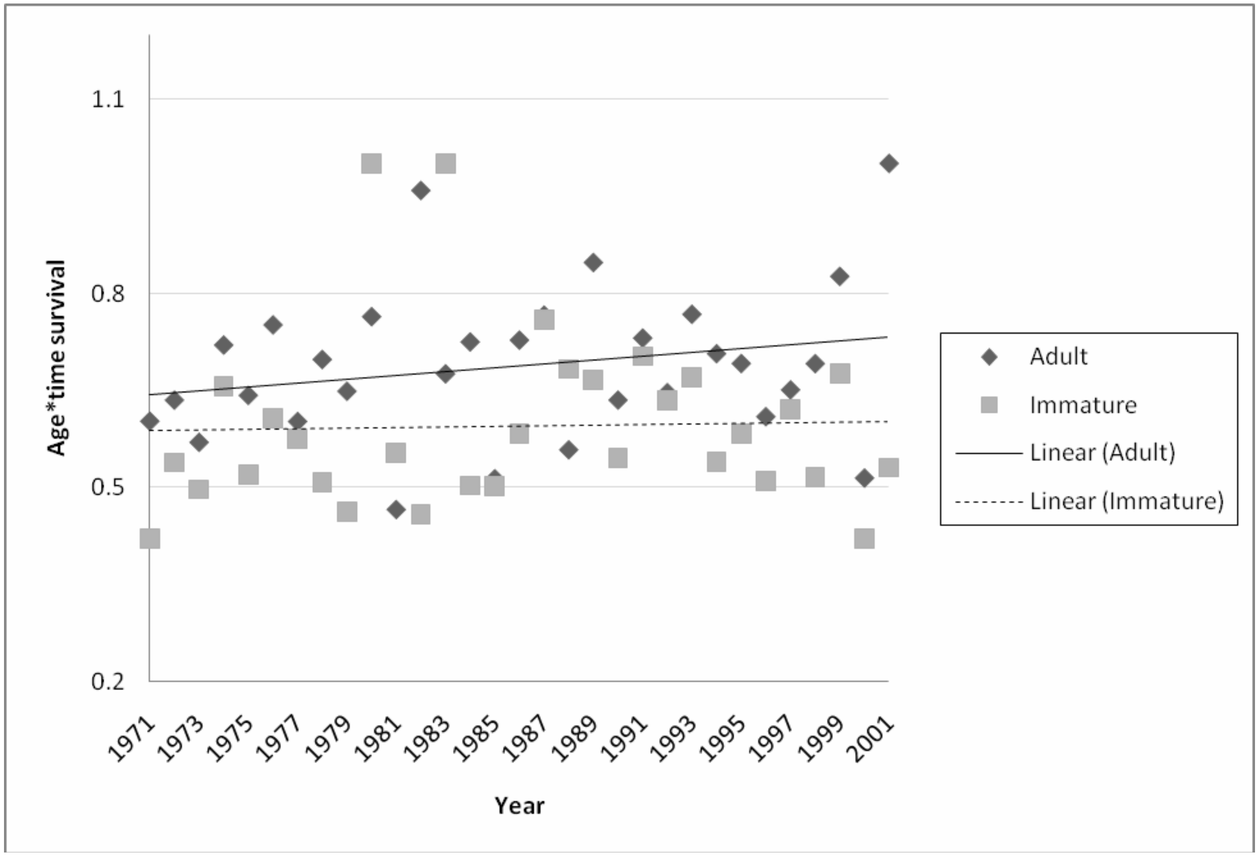


Figure 11. Estimated annual survival rates for the region and time interaction in the top model (S(a*s*r+t+a*t+r*t)f(a*s*r*t)) for adult male, immature male, adult female, and immature female northern pintails, 1970-2003.

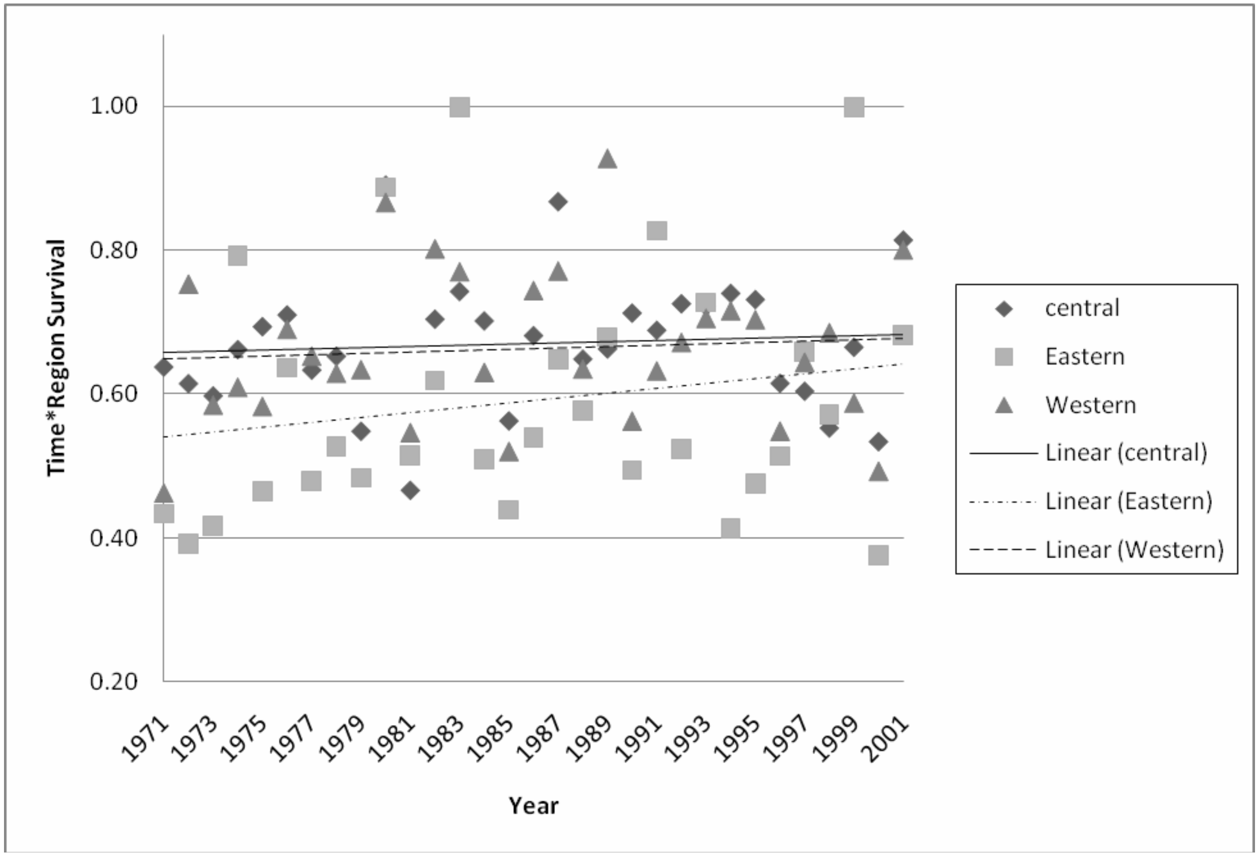


Figure 12. Long-term trends in survival rate estimates of adult female, adult male, immature female, and immature male northern pintails from 1971 to 2001 for each of the 3 regions.

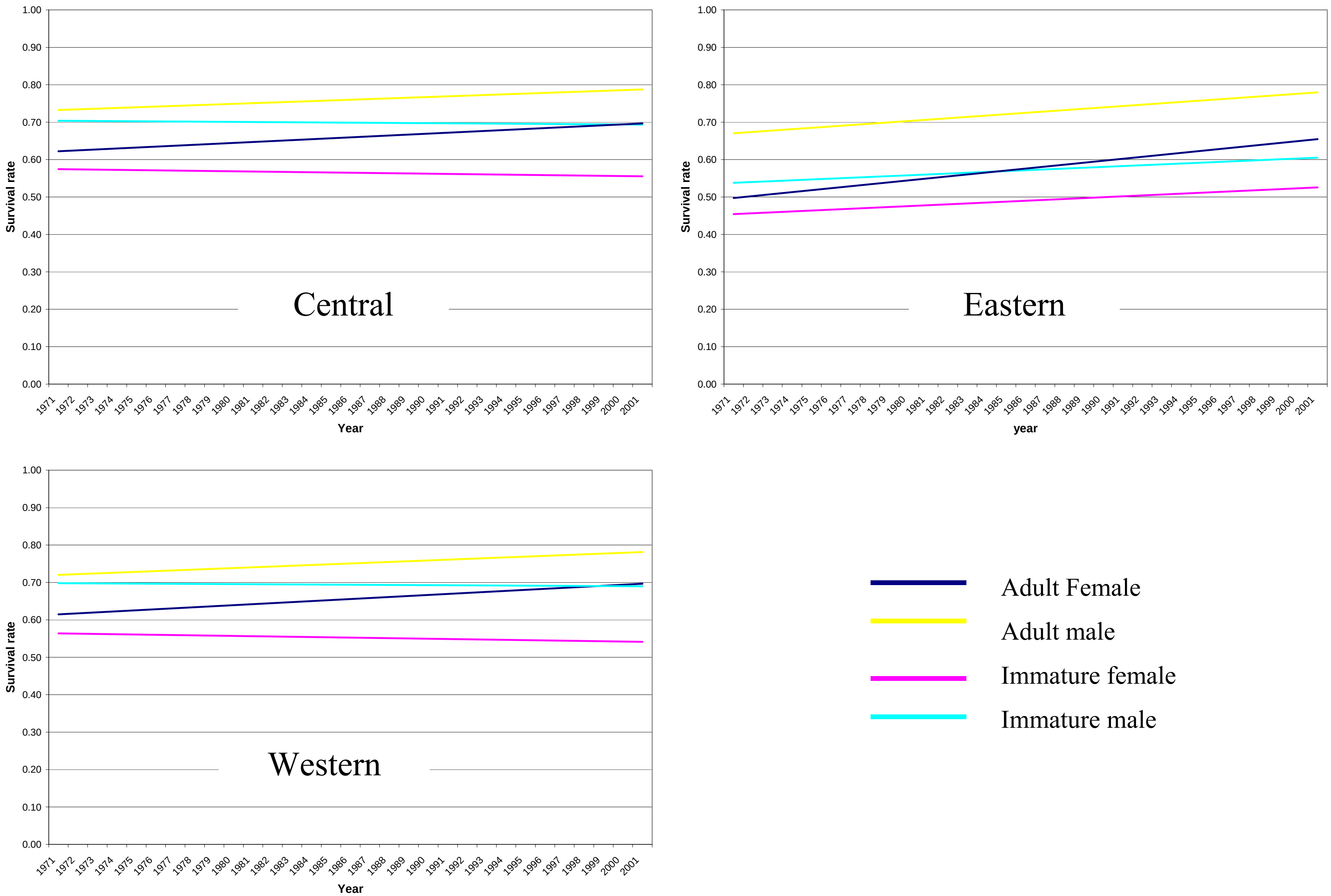
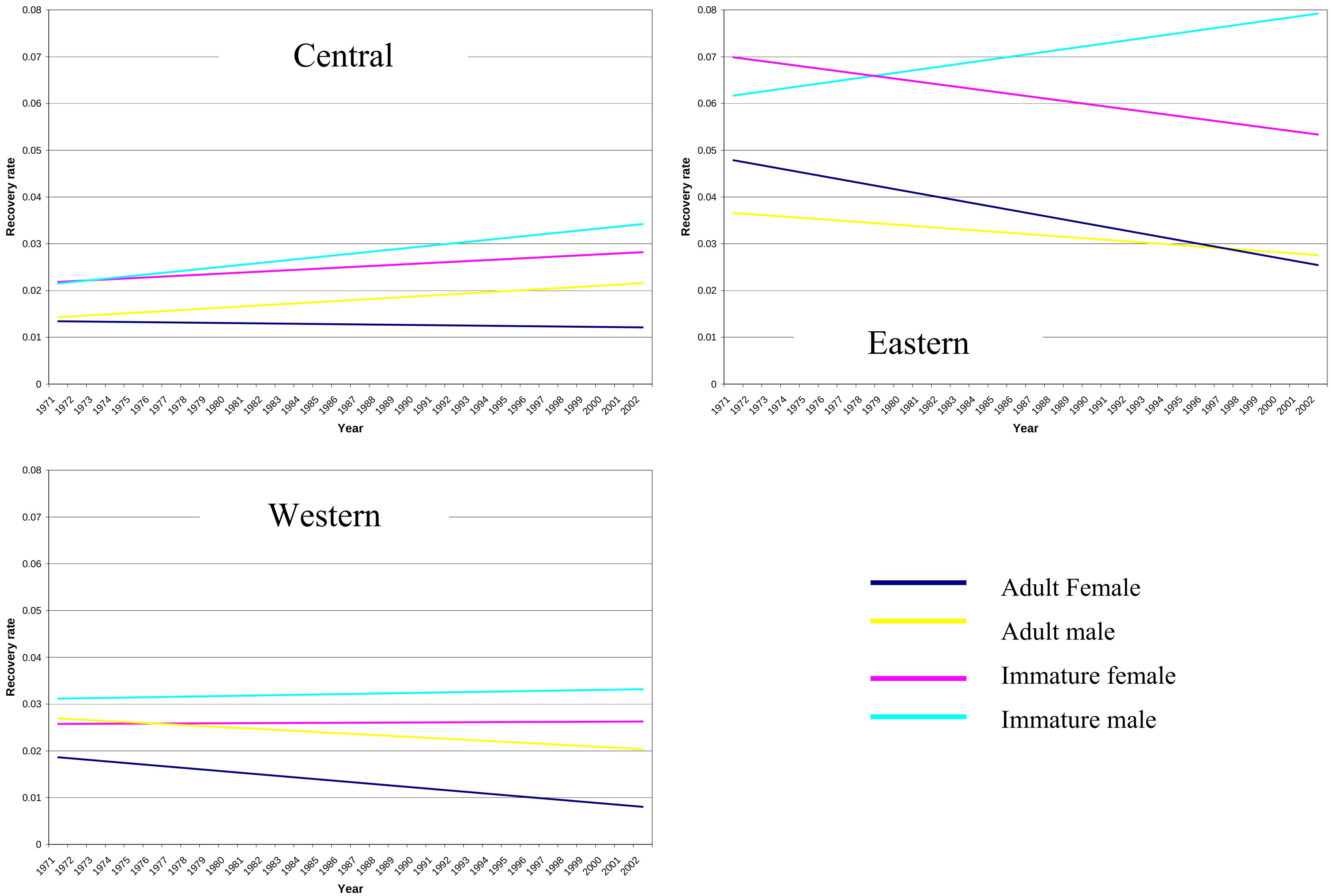


Figure 13. Long-term trends in recovery rate estimates of adult female, adult male, immature female, and immature male northern pintails over time from 1971 to 2001 for all three regions.



Appendix A. Female northern pintail annual survival rate estimates for each year, region, and age class of analysis from the top model S (a*s*r+t+a*t+r*t) f (a*s*r*t).

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1970	0.724	0.118	1.000	0.000	1.000	0.000	0.361	0.061	1.000	0.000	1.000	0.000
1971	0.666	0.070	0.494	0.037	0.437	0.100	0.480	0.069	0.293	0.026	0.293	0.073
1972	0.602	0.089	0.754	0.062	0.355	0.114	0.494	0.070	0.644	0.088	0.291	0.071
1973	0.567	0.074	0.563	0.052	0.365	0.104	0.492	0.054	0.467	0.061	0.330	0.080
1974	0.636	0.069	0.591	0.055	0.764	0.192	0.560	0.054	0.491	0.046	0.731	0.205
1975	0.695	0.076	0.590	0.053	0.441	0.116	0.573	0.064	0.437	0.043	0.350	0.087
1976	0.728	0.109	0.717	0.059	0.640	0.118	0.576	0.084	0.540	0.062	0.510	0.100
1977	0.580	0.087	0.611	0.052	0.403	0.095	0.554	0.072	0.564	0.061	0.413	0.085
1978	0.688	0.076	0.674	0.063	0.543	0.114	0.491	0.056	0.453	0.042	0.376	0.087
1979	0.577	0.073	0.674	0.059	0.492	0.112	0.383	0.042	0.463	0.040	0.338	0.078
1980	0.736	0.168	0.685	0.095	0.712	0.340	1.000	0.000	1.000	0.000	1.000	0.000
1981	0.353	0.070	0.441	0.061	0.382	0.129	0.440	0.063	0.510	0.067	0.507	0.120
1982	0.951	0.164	0.977	0.077	0.910	0.286	0.372	0.056	0.545	0.080	0.264	0.068
1983	0.420	0.074	0.479	0.081	0.999	0.030	1.000	0.000	1.000	0.000	1.000	0.000
1984	0.755	0.138	0.695	0.214	0.546	0.214	0.533	0.113	0.436	0.076	0.339	0.094
1985	0.498	0.087	0.464	0.133	0.357	0.137	0.487	0.106	0.432	0.072	0.381	0.116
1986	0.699	0.126	0.769	0.111	0.537	0.193	0.542	0.115	0.609	0.089	0.406	0.149
1987	0.837	0.171	0.733	0.129	0.570	0.271	0.832	0.171	0.709	0.148	0.597	0.246
1988	0.519	0.102	0.514	0.075	0.421	0.197	0.652	0.131	0.626	0.125	0.594	0.179
1989	0.734	0.141	0.955	0.057	0.738	0.184	0.470	0.098	0.861	0.169	0.513	0.167
1990	0.698	0.099	0.551	0.074	0.453	0.140	0.611	0.106	0.433	0.065	0.394	0.121
1991	0.646	0.085	0.595	0.077	0.789	0.260	0.610	0.094	0.535	0.073	0.788	0.260
1992	0.674	0.078	0.624	0.079	0.440	0.144	0.664	0.097	0.593	0.068	0.465	0.147
1993	0.720	0.080	0.711	0.099	0.713	0.209	0.611	0.113	0.579	0.059	0.636	0.201
1994	0.770	0.073	0.756	0.089	0.418	0.148	0.601	0.098	0.560	0.055	0.272	0.092
1995	0.730	0.075	0.710	0.082	0.448	0.146	0.621	0.084	0.577	0.066	0.363	0.117
1996	0.600	0.062	0.540	0.068	0.477	0.139	0.497	0.055	0.415	0.044	0.411	0.119
1997	0.553	0.053	0.605	0.076	0.594	0.201	0.519	0.056	0.551	0.058	0.597	0.173

Appendix A .(*cont.*)

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1998	0.579	0.051	0.722	0.070	0.583	0.156	0.390	0.042	0.526	0.072	0.429	0.130
1999	0.723	0.057	0.656	0.085	1.000	0.000	0.485	0.053	0.386	0.058	1.000	0.000
2000	0.512	0.047	0.479	0.058	0.334	0.086	0.416	0.046	0.364	0.053	0.282	0.082
2001	1.000	0.000	1.000	0.000	1.000	0.000	0.555	0.091	0.522	0.098	0.320	0.202
2002	1.000	0.000	1.000	0.000	1.000	0.000	0.273	0.053	0.364	0.071	0.241	0.182
Avg.	0.660	0.088	0.656	0.077	0.576	0.151	0.565	0.076	0.552	0.067	0.490	0.118

Appendix B. Male northern pintail annual survival rate estimates for each year, region, and age class of analysis from the top model S (a*s*r+t+a*t+r*t) f (a*s*r*t).

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1970	0.817	0.088	1.000	0.000	1.000	0.000	0.514	0.066	1.000	0.000	1.000	0.000
1971	0.772	0.055	0.616	0.034	0.625	0.095	0.633	0.064	0.446	0.031	0.381	0.083
1972	0.719	0.075	0.834	0.046	0.541	0.121	0.646	0.064	0.779	0.066	0.378	0.081
1973	0.689	0.064	0.679	0.045	0.552	0.111	0.644	0.050	0.630	0.057	0.421	0.087
1974	0.748	0.056	0.704	0.047	0.874	0.118	0.704	0.045	0.652	0.041	0.801	0.168
1975	0.794	0.058	0.703	0.045	0.628	0.107	0.715	0.053	0.602	0.041	0.443	0.093
1976	0.820	0.081	0.806	0.045	0.792	0.085	0.717	0.070	0.700	0.053	0.606	0.096
1977	0.701	0.074	0.721	0.043	0.592	0.094	0.699	0.061	0.715	0.050	0.510	0.086
1978	0.789	0.059	0.772	0.050	0.718	0.093	0.644	0.051	0.617	0.039	0.471	0.091
1979	0.698	0.063	0.772	0.047	0.675	0.097	0.537	0.043	0.626	0.037	0.430	0.085
1980	0.825	0.125	0.781	0.075	0.841	0.223	1.000	0.000	1.000	0.000	1.000	0.000
1981	0.481	0.076	0.565	0.060	0.570	0.131	0.595	0.061	0.669	0.059	0.603	0.116
1982	0.970	0.101	0.986	0.048	0.956	0.148	0.525	0.060	0.699	0.067	0.347	0.078
1983	0.551	0.074	0.601	0.077	0.999	0.014	1.000	0.000	1.000	0.000	1.000	0.000
1984	0.840	0.101	0.789	0.167	0.721	0.176	0.681	0.100	0.600	0.073	0.432	0.103
1985	0.627	0.081	0.587	0.128	0.543	0.146	0.640	0.098	0.600	0.071	0.476	0.122
1986	0.797	0.097	0.846	0.082	0.713	0.158	0.688	0.099	0.752	0.069	0.503	0.154
1987	0.900	0.116	0.818	0.098	0.740	0.214	0.903	0.108	0.825	0.103	0.687	0.220
1988	0.647	0.093	0.634	0.068	0.610	0.188	0.778	0.100	0.765	0.096	0.684	0.161
1989	0.824	0.105	0.972	0.036	0.858	0.117	0.624	0.092	0.923	0.100	0.609	0.158
1990	0.797	0.076	0.668	0.066	0.640	0.128	0.746	0.085	0.597	0.063	0.491	0.126
1991	0.756	0.068	0.707	0.066	0.889	0.154	0.745	0.075	0.691	0.062	0.846	0.203
1992	0.778	0.060	0.732	0.066	0.627	0.136	0.787	0.073	0.739	0.054	0.563	0.145
1993	0.814	0.060	0.802	0.076	0.842	0.135	0.746	0.090	0.728	0.048	0.721	0.174
1994	0.851	0.052	0.836	0.066	0.606	0.145	0.738	0.079	0.712	0.045	0.356	0.106
1995	0.821	0.055	0.801	0.063	0.635	0.134	0.754	0.066	0.726	0.054	0.458	0.125
1996	0.717	0.052	0.658	0.061	0.661	0.126	0.649	0.049	0.580	0.043	0.508	0.121
1997	0.677	0.046	0.715	0.064	0.758	0.154	0.669	0.050	0.705	0.048	0.687	0.154

Appendix B. (*cont.*)

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1998	0.700	0.044	0.810	0.054	0.750	0.122	0.544	0.044	0.683	0.062	0.526	0.132
1999	0.816	0.043	0.758	0.069	1.000	0.000	0.638	0.049	0.550	0.060	1.000	0.001
2000	0.640	0.043	0.602	0.055	0.518	0.100	0.571	0.046	0.526	0.056	0.368	0.094
2001	1.000	0.000	1.000	0.000	1.000	0.000	0.700	0.077	0.680	0.086	0.410	0.225
2002	1.000	0.000	1.000	0.000	1.000	0.000	0.412	0.065	0.526	0.076	0.320	0.217
Avg.	0.760	0.069	0.751	0.063	0.725	0.122	0.699	0.065	0.694	0.056	0.571	0.116

Appendix C. Female northern pintail annual recovery rate estimates for each year, region, and age class of analysis from the top model S (a*s*r+t+a*t+r*t) f (a*s*r*t).

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1970	0.032	0.005	0.032	0.004	0.018	0.018	0.053	0.007	0.053	0.005	0.116	0.023
1971	0.013	0.003	0.024	0.003	0.019	0.013	0.019	0.004	0.030	0.003	0.068	0.013
1972	0.014	0.003	0.022	0.003	0.048	0.021	0.038	0.005	0.039	0.004	0.039	0.012
1973	0.014	0.003	0.018	0.002	0.033	0.024	0.026	0.004	0.026	0.004	0.102	0.018
1974	0.014	0.003	0.018	0.003	0.095	0.048	0.030	0.003	0.041	0.004	0.070	0.018
1975	0.020	0.003	0.023	0.003	0.034	0.024	0.031	0.003	0.032	0.003	0.068	0.018
1976	0.014	0.002	0.022	0.003	0.048	0.021	0.021	0.003	0.036	0.004	0.076	0.014
1977	0.012	0.002	0.015	0.002	0.059	0.019	0.020	0.003	0.031	0.003	0.079	0.014
1978	0.015	0.003	0.018	0.002	0.059	0.019	0.020	0.003	0.031	0.003	0.055	0.011
1979	0.015	0.002	0.014	0.002	0.041	0.020	0.028	0.003	0.031	0.003	0.057	0.015
1980	0.015	0.003	0.016	0.002	0.060	0.025	0.032	0.004	0.030	0.003	0.076	0.020
1981	0.010	0.003	0.012	0.002	0.040	0.020	0.013	0.002	0.015	0.002	0.036	0.011
1982	0.016	0.004	0.014	0.003	0.081	0.030	0.024	0.004	0.023	0.004	0.036	0.012
1983	0.015	0.003	0.014	0.002	0.016	0.012	0.042	0.006	0.027	0.003	0.096	0.024
1984	0.016	0.004	0.013	0.003	0.015	0.011	0.027	0.004	0.014	0.002	0.034	0.010
1985	0.009	0.002	0.010	0.003	0.023	0.018	0.020	0.004	0.017	0.004	0.085	0.023
1986	0.012	0.003	0.012	0.003	0.076	0.029	0.016	0.004	0.021	0.003	0.079	0.023
1987	0.012	0.003	0.009	0.002	0.013	0.013	0.028	0.006	0.021	0.003	0.073	0.030
1988	0.006	0.002	0.007	0.002	0.027	0.020	0.009	0.003	0.008	0.003	0.059	0.024
1989	0.009	0.002	0.010	0.003	0.046	0.028	0.013	0.003	0.013	0.003	0.103	0.025
1990	0.008	0.002	0.008	0.002	0.021	0.012	0.013	0.003	0.010	0.002	0.039	0.016
1991	0.006	0.002	0.007	0.002	0.008	0.008	0.012	0.003	0.013	0.003	0.050	0.020
1992	0.006	0.001	0.007	0.001	0.040	0.018	0.016	0.003	0.020	0.003	0.038	0.016
1993	0.009	0.002	0.006	0.002	0.023	0.012	0.012	0.003	0.016	0.002	0.050	0.016
1994	0.009	0.002	0.008	0.002	0.022	0.012	0.017	0.003	0.016	0.002	0.039	0.014
1995	0.011	0.002	0.011	0.002	0.053	0.022	0.021	0.004	0.022	0.003	0.062	0.023
1996	0.012	0.002	0.008	0.002	0.026	0.008	0.020	0.003	0.019	0.003	0.090	0.026
1997	0.013	0.002	0.011	0.002	0.032	0.013	0.026	0.003	0.035	0.003	0.037	0.019

Appendix C. (*cont.*)

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1998	0.015	0.002	0.014	0.002	0.019	0.010	0.030	0.003	0.026	0.003	0.041	0.016
1999	0.026	0.003	0.014	0.002	0.025	0.011	0.042	0.004	0.040	0.005	0.095	0.032
2000	0.020	0.002	0.018	0.003	0.022	0.008	0.050	0.005	0.043	0.006	0.026	0.013
2001	0.016	0.002	0.015	0.002	0.054	0.010	0.047	0.005	0.048	0.008	0.049	0.002
2002	0.008	0.001	0.010	0.002	0.022	0.006	0.039	0.006	0.045	0.006	0.068	0.040
2003	0.008	0.001	0.005	0.001	0.020	0.005	0.047	0.005	0.032	0.004	0.084	0.030
Avg.	0.013	0.002	0.013	0.002	0.038	0.018	0.025	0.004	0.026	0.003	0.062	0.018

Appendix D. Male northern pintail annual recovery rate estimates for each year, region, and age class of analysis from the top model S (a*s*r+t+a*t+r*t) f (a*s*r*t).

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1970	0.029	0.005	0.033	0.003	0.082	0.039	0.065	0.007	0.057	0.005	0.122	0.024
1971	0.015	0.003	0.029	0.002	0.042	0.018	0.029	0.005	0.041	0.003	0.080	0.014
1972	0.020	0.003	0.030	0.002	0.057	0.018	0.034	0.005	0.043	0.004	0.063	0.016
1973	0.014	0.002	0.022	0.002	0.050	0.022	0.030	0.004	0.030	0.004	0.084	0.019
1974	0.015	0.003	0.035	0.003	0.038	0.023	0.027	0.003	0.043	0.003	0.067	0.019
1975	0.018	0.002	0.032	0.002	0.060	0.028	0.030	0.003	0.041	0.003	0.071	0.018
1976	0.018	0.002	0.033	0.002	0.050	0.018	0.024	0.003	0.044	0.003	0.087	0.015
1977	0.017	0.002	0.023	0.002	0.032	0.011	0.018	0.003	0.032	0.003	0.063	0.011
1978	0.020	0.002	0.027	0.002	0.024	0.010	0.024	0.003	0.034	0.003	0.050	0.010
1979	0.018	0.002	0.028	0.002	0.024	0.011	0.032	0.003	0.049	0.003	0.052	0.013
1980	0.017	0.003	0.029	0.002	0.030	0.013	0.031	0.003	0.036	0.003	0.083	0.019
1981	0.010	0.002	0.019	0.002	0.056	0.021	0.015	0.002	0.020	0.002	0.053	0.011
1982	0.023	0.004	0.030	0.003	0.019	0.012	0.032	0.004	0.024	0.003	0.045	0.012
1983	0.022	0.003	0.025	0.003	0.023	0.012	0.044	0.005	0.027	0.003	0.067	0.017
1984	0.022	0.004	0.023	0.003	0.011	0.008	0.014	0.002	0.017	0.002	0.042	0.011
1985	0.016	0.003	0.020	0.004	0.021	0.013	0.021	0.004	0.020	0.003	0.061	0.017
1986	0.021	0.003	0.021	0.003	0.000	0.001	0.018	0.003	0.026	0.003	0.082	0.022
1987	0.014	0.003	0.020	0.003	0.019	0.014	0.028	0.005	0.030	0.003	0.066	0.026
1988	0.006	0.001	0.011	0.002	0.010	0.010	0.012	0.003	0.013	0.003	0.049	0.020
1989	0.011	0.002	0.015	0.002	0.000	0.002	0.013	0.003	0.015	0.002	0.097	0.023
1990	0.010	0.002	0.012	0.001	0.062	0.023	0.014	0.003	0.016	0.002	0.057	0.017
1991	0.006	0.001	0.013	0.002	0.017	0.012	0.014	0.003	0.016	0.002	0.063	0.021
1992	0.013	0.002	0.015	0.002	0.014	0.010	0.019	0.003	0.024	0.003	0.048	0.016
1993	0.013	0.002	0.018	0.002	0.033	0.017	0.015	0.003	0.025	0.003	0.084	0.022
1994	0.013	0.002	0.018	0.002	0.017	0.012	0.021	0.003	0.024	0.002	0.062	0.017
1995	0.018	0.002	0.021	0.002	0.033	0.017	0.026	0.004	0.028	0.003	0.096	0.030
1996	0.018	0.002	0.017	0.002	0.061	0.021	0.025	0.003	0.028	0.003	0.036	0.017
1997	0.022	0.002	0.026	0.003	0.036	0.017	0.033	0.003	0.040	0.003	0.103	0.032

Appendix D. (*cont.*)

	Adult						Immature					
	Central		Western		Eastern		Central		Western		Eastern	
Year	S	SE	S	SE	S	SE	S	SE	S	SE	S	SE
1998	0.033	0.003	0.036	0.003	0.037	0.017	0.047	0.004	0.036	0.004	0.115	0.026
1999	0.033	0.003	0.033	0.003	0.061	0.025	0.055	0.005	0.044	0.005	0.073	0.025
2000	0.031	0.002	0.031	0.003	0.025	0.013	0.057	0.005	0.045	0.005	0.056	0.019
2001	0.031	0.003	0.032	0.003	0.049	0.021	0.058	0.005	0.069	0.008	0.122	0.035
2002	0.017	0.002	0.017	0.002	0.014	0.010	0.032	0.004	0.049	0.006	0.078	0.046
2003	0.010	0.001	0.014	0.002	0.028	0.013	0.053	0.006	0.049	0.005	0.086	0.029
Avg.	0.018	0.002	0.024	0.002	0.032	0.015	0.028	0.004	0.032	0.003	0.070	0.020

Assessment of Continental Northern Pintail (*Anas acuta*) Band-Recovery Data Part III: Utilizing pre- and post-season band recoveries to determine their efficiency in survival estimation

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Introduction

Nearly all prairie-nesting dabbling duck species have dramatically increased in abundance since the early 1990s except northern pintail (*Anas acuta*), which has decreased from an estimated 9.6 million in 1955 to 2 million by 1988 (Hestbeck 1993, Scheaffer 2003) and have remained at relatively low levels since then. By 2002, pintails reached a low of 1.8 million birds in the traditional survey area (U.S. Fish and Wildlife Service 2004) despite restrictive harvest regulations. By 2007, the estimate of pintails in the traditional survey area had increased to 3.3 million birds (U.S. Fish and Wildlife Service 2007a). Despite the increase since 2002, the current population estimate remains 20% below the long-term average (1955-2005, average number = 4.1 million) and 41% below the goal of 5.6 million stated in the North American Waterfowl Management Plan. Although the pintail remains the most abundant duck in the Pacific Flyway, their numbers are only 25% of levels recorded in the 1970s (Fleskes et al. 2002). The continued low abundance of pintails has caused great concern among managers as evidenced by the United States Fish and Wildlife Service declaring pintails a focal species targeted for increased management emphasis and establishment of a species-specific harvest management strategy (U.S. Fish and Wildlife Service 2007b).

To assess the relative effects of habitat degradation, predation, harvest regulations, and other possible causes of pintail declines, precise estimates of annual survival rates are needed. Such estimates also are necessary for further development of harvest-management options specific to pintails and identification of variables that ultimately affect survival. Precision of survival estimates from band-recovery data depends on the number banded and recovered for a population (Sheaffer and Malecki 1995). Thus, the relationship between the number of birds banded and recovered each year is important to obtain precise survival estimates for a population. The coefficient of variation (CV) typically has been used to assess the precision of survival and recovery rate estimates. Generally, a CV ≤ 0.10 is a desired level of precision; survival estimates from banding analyses with a greater CV are considered less reliable (Brownie et al. 1985, Sheaffer and Malecki 1995).

Since 1988, there have been no specific objectives for pintail banding. Given low recovery rates and increased emphasis on determining factors affecting pintail numbers, an assessment of needed banding is timely. The ability to set and meet annual banding quotas to achieve a desired level of precision would improve the utility of pintail banding data and improve precision of survival estimates. A key to this effort is to match banding effort with management needs and abilities in the field. Currently, the principal banding period for pintails is during August and September (preseason). Recently, pintail banding efforts have increased in North and South Dakota, USA, but efforts are still limited. One suggested alternative for achieving these quotas is to incorporate data from winter banding periods (i.e., postseason).

Preseason banding occurs from July to September whereas winter banding occurs following the hunting seasons in January to February (Nichols and Hines 1987). Brownie et al. (1985) presented a model based on banding twice-a-year where (f) still represents the annual recovery rate, but survival is represented by two periodic survival rates. The first survival period encompasses the time from the midpoint of the postseason banding in January and February to the midpoint of the preseason banding period in July and August. The second survival period is from the midpoint of the preseason banding period to the midpoint of the next year's postseason banding period. The estimate of annual survival rate is the product of the two periodic survival rates.

Annual survival rate estimates from postseason banding combined with preseason banding can be more precise than those estimated from preseason banding information alone (Nichols and Hines 1987). However, analyses incorporating winter banding have resulted in unrealistic or contradictory conclusions. LeMaster and Trost (1994) found that the addition of winter banding provided gains in precision of survival estimates especially for adult female wood ducks (*Aix sponsa*). Otis (1994) concluded that the cost associated with adding a winter banding period would be more than the overall gain in precision of the survival estimates for wood ducks.

We investigated the potential of incorporating postseason band recovery data for northern pintails to increase the precision of annual survival estimates. Our first objective was to determine the optimal number of birds to band based on known survival and recovery rate estimates from preseason band recovery data. The second objective was to compare average annual survival and recovery estimates from preseason banding versus those resulting from combined preseason and postseason band recovery data. Our final objective was to investigate the number of preseason and postseason bands necessary for yearly survival estimates at a desired level of precision. Ultimately, we developed a model that estimated the number of preseason and postseason bands required per year to achieve a desired level of precision.

Methods

Banding and recovery records for northern pintail were obtained from the USGS Bird Banding Laboratory in Laurel, MD. All data were for normal, wild birds shot or found dead during the hunting season. We extracted continental pintail bandings and recoveries for preseason bandings from 1970 to 1980. We also retrieved all continental pintail bandings and subsequent recoveries from postseason banded birds from 1970 to 1980. We restricted the analyses to this timeframe because a sufficient amount of postseason band and recovery data were available only during this period. We limited survival analysis to adult sex classes because ducks may not be reliably aged during postseason banding operations (Miller 1986, Siwarski 2003). We defined the two analyses based on when banding occurred. The analysis for preseason banded data will be called "summer analysis" whereas the analysis for both preseason and postseason band data will be called "combined analysis". The summer preseason data were analyzed using the Brownie approach in program MARK (White and Burnham 1999) to estimate annual survival and recovery rates. Model parameters were defined as:

$S_{i,t}$ = probability a banded bird of group i survives from time t to t+1

$f_{i,t}$ = probability a banded bird of group i is shot, recovered, and reported to the Bird Banding Laboratory during the hunting season at time t.

We used an interactive model of sex and year to estimate annual survival and recovery rates. We were interested in determining the number of bands necessary to achieve a determined level of precision based on average survival and recovery rates from the period of interest. Therefore, we averaged the resulting survival and recovery rates across years to use as the known values of S and f. The corresponding average survival and recovery rates were entered into the following equation to determine the minimum number of bands needed per year to get an average annual survival estimate over the period of study (Brownie et al. 1985).

$$N = \frac{h(S,f,k)}{CV^2}$$

N = number of bands

$$h(S,f,k) = \frac{\left[\sum_{i=1}^{k-1}\left(\frac{1}{T_i^* - C_i^*}\right) - \sum_{i=1}^{k-1}\left(\frac{1}{T_i^*}\right) + \frac{1}{R_1^*} + \frac{1}{R_k^*} - 2\right]}{(k-1)^2}$$

S = survival estimate

f = recovery rate estimate

k = number of years for banding study

CV = coefficient of variation

R_i*= row total
C_i*= column total
T_i* = (R_i*)(C_i*)/f

We manipulated the length of the banding study from 2-5 years by changing *k* in the equation. For each study length, we inputted values of 0.15, 0.10, and 0.05 for the CV to estimate the corresponding increase in the number of bands needed as the desired CV decreased.

We then re-estimated annual survival rates based on data from pre-season banded birds combined with the additional data from postseason bandings, hereafter, combined analysis (Table 1). We estimated annual survival for the combined analysis using the time-specific Brownie model (H_7) for studies in which banding is done twice a year (Brownie et al. 1985:161-164). The periodic survival estimates resulting from the combined analysis are then multiplied to determine the annual survival estimate. We compared the annual survival and recovery estimates for the summer and combined analysis using a chi-square test in program CONTRAST (Hines and Sauer 1989).

We calculated the CVs for survival and recovery rates estimated from the summer and combined analyses for males and females using the Brownie equation. Because our goal was to obtain annual survival estimates with a precision of ≤0.10 for future banding efforts, we then calculated the number of bands needed to reach this goal based on band-recovery data from 1970-1980. For comparison, we also calculated the number of bands needed to achieve annual survival and recovery rate estimates with a CV ≤0.10 for recent recovery data from 1993-2003. To remain consistent, these annual survival estimates were based only on once-a-year banding using the Brownie model H_1 in program MARK with a sex and year interactive model.

We used linear regression to estimate the number of postseason bands required given a specific coefficient of variation, total number of bands, and the number of preseason bands for males and females. We repeated the process to determine the number of preseason bands needed. These two equations provided the number of pre- and postseason bands required given an overall banding quota with a desired level of precision for banding male and female ducks. The models were based on the number of bands necessary per year to estimate an annual survival rate over a 2-year banding period.

Results

There were no differences in average annual estimated survival and recovery rates between summer and combined analyses for both females and males from 1970-1980 (Table 2). Precision was slightly better (i.e., lower standard error) for survival rates estimated using the combined analysis for females (6%) and males (7.5%). For all but one year (1970) for males, annual survival estimates were similar between the summer analysis and the combined analysis for both sexes (Figure 1). For all years, annual recovery rate estimates for females were similar between the summer and combined analyses (Figure 2). In contrast, male recovery estimates differed during 1970-1972 and 1974 between the summer analysis and the combined analysis recovery rate estimates (Figure 2).

The greatest point estimates for annual survival rate were in 1972 and 1974 for males and females, respectively, using both the summer and combined analyses (Table 3). These high survival rates correspond to lower CVs, except for the combined analysis for females in which the lowest CV was in 1975 (Table 3). The largest CV was in 1973 for both male and female pintails using summer and combined analyses. The annual survival rates for the combined analysis did have increased precision compared to the summer analysis in all but two years across both sexes (females 1972, males 1979; Table 3).

One advantage of the combined analysis is the partitioning of survival into winter/summer and hunting season survival. Summer survival occurs from January to August (postseason banding to preseason banding period), whereas hunting season survival occurs from August to January (preseason banding to postseason banding). Winter/summer survival was greater than hunting season survival for both male and female pintails (Table 4). Females have a lower average survival rate during the winter/summer period and annually, but greater survival during the hunting season period compared to male pintails (Table 4).

Comparing male survival and recovery rates using summer analysis from 1970-1980, summer analysis from 1993-2003, and the combined analysis from 1970-1980 indicated similar average annual survival and recovery rates (Table 5). Generally, recovery rates were lower for 1993-2003. Female pintails had similar average annual survival and recovery estimates regardless of using summer or combined analyses (Table 6). The survival and recovery rates for females were lower than the estimates for males.

The average number of male birds banded during 1970-1980 was 7,967 compared to 5,809 during 1993-2003 (Table 7). An average of 6,533 female pintails was banded during 1970-1980 compared to 6,317 during 1993-2003 (Table 8). The fewer number of banded birds, combined with the lower recovery rate, resulted in a greater average CV during the 1993-2003 period for both males and females. To obtain a CV of 0.10 for annual male survival estimates requires an average of 10,194 preseason bands annually based on band-recovery data from 1993-2003 (Table 7), whereas the same CV for the survival estimates for females would require an average of 22,145 birds banded preseason each year (Table 8). This level of banding would be 70% and 72% more than the number of birds banded during 1970-1980 or 1993-2003, respectively.

For male pintails, a study period of at least 3 years at a CV = 0.05 based on the most recent years of banding from 1993-2003 provides an acceptable level of precision for average annual survival rates (Figure 3). Banding 1,818 male pintails per year will provide an average annual survival estimate every three years with a CV< 0.10. It would be possible to get a CV = 0.10 with 2 years of banding based on the level of banding from 1970-1980, but that level of banding has not been achieved in recent years. A 3-year banding period would also be the minimum required for female pintails at the current banding effort. Based on the 1993-2003 banding levels, banding 3,881 female pintails per year would provide an average annual survival estimate every 3 years with a CV = 0.10 (Figure 4). The more years used to estimate an average annual survival rate, the lower the average CV and the fewer bands are needed per year to achieve the desired CV.

We used the desired coefficient of variation and optimal band totals to model the number of pre- and postseason banding requirements for male and female pintails for annual survival rates (Table 9). The equations indicated a similar beta value for the number of total bands for males and females using the pre- and postseason equations. In contrast, the beta coefficient for the CV variable was greater for the male equations. All of the equations were significant and had relatively high r^2 values (Table 9). We calculated the number of pre- and post-season bands needed for the average CV and total bands from 1970-1980 and 1993-2003 (Table 10). The number of postseason bands is a fraction of the total bands for female pintails, whereas the postseason bands are close to 30% of the total bands for male birds (Table 10).

Discussion

Historically, winter banding has been used in survival analyses for wood ducks and mallards (*Anas platyrhynchos*) (Brownie et al. 1985, Nichols and Hines 1987, LeMaster and

Trost 1994, Otis 1994). When Brownie et al. (1985) formulated models for banding twice-a-year, their goal was to gain information about the effects of exploitation and environmental conditions rather than designing optimal banding allocations to maximize precision of estimates. In fact, they found that precision of adult survival rates from banding using model H_7 was not very different from precision of estimates obtained using model H_1 (Brownie et al. 1985).

Our study found few differences in precision between banding once or twice-a-year. Much of the more recent information on winter banding also showed small gains in precision (LeMaster and Trost 1994, Otis 1994). Otis (1994) found that a gain in precision was not necessarily a tradeoff with an increase in the number of bands. Our study indicated an increase in precision by including winter banding, but the differences in the resulting point estimates of survival rates were not significantly different. We also found that the coefficient of variation influenced the survival rates and precision similar to LeMaster and Trost (1994).

Nichols and Hines (1987) pointed out some limitations of including winter banding in estimating survival rates. First, there is a much shorter survival period for birds banded preseason to the hunting period versus postseason banded birds. Our results indicated that annual survival estimates using pre- and postseason banding were lower than those estimated with preseason data only. Winter survival seems to drive the estimate for annual survival for banding twice-a-year especially in cases where there is 100% estimated summer survival.

Another potential issue is that birds banded preseason tend to have increased recovery rates compared to birds banded post-season (Nichols and Hines 1987). Our data did not fully support this conclusion as the annual recovery rates for the summer analysis were lower than those estimated from the combined analysis. The average recovery rates for females were essentially equal for both methods and for males preseason banding estimates were slightly larger. Perhaps of greater concern for the northern pintail banding analyses is that recovery rates were lower in the most recent years of banding, which requires an increased banding effort to achieve the desired level of precision. A final issue would be that bias associated with survival rate estimates is probably larger and harder to detect by including winter banding (Nichols and Hines 1987). As Otis (1994) pointed out, there are extra modeling parameters when you incorporate winter banding, which increases error variance of the models.

There are situations where the addition of winter banding provides better insight into survival of a population. For example, the additional postseason bands are easier to associate with a set of hunting regulations or environmental conditions (Nichols and Hines 1987). In addition, we can separate out periodic survival estimates in addition to obtaining annual survival estimates.

Our study found that obtaining a CV $\leq$0.10 for annual survival over a 3 year banding period requires an increased banding effort than currently exists for northern pintail, regardless of banding once or twice-a-year. Recent years of pre-season banding have yielded CVs >0.13 over a 10-year banding period. To reduce this CV to 0.10 for males requires banding levels more similar to that achieved in the 1970s, a 22% increase from current banding levels. This amount of banding could be split into pre- and postseason effectively for males in which both the pre- and postseason would have equal banding effort. Unfortunately, getting female banding levels to achieve CV $\leq$0.10 for annual survival estimates would require a large preseason banding effort. In fact, we would need to increase current levels of banding by 70% for female birds.

Our recommendation based on banding levels from 1993-2003 would be to obtain average annual survival rate estimates at a minimum of every 3 years to achieve a CV=0.10. It has been suggested that the best way to estimate annual survival is to meet preseason quotas (LeMaster and Trost 1994), but this has not been accomplished for northern pintails in recent years. Banding 2,000 males and 4,000 females every year would provide accurate average annual survival rate estimates with a CV=0.10 at an achievable banding effort. By increasing the number of years of the banding study, one could decrease the necessary number of bands placed annually, but increased the period of inference.

Our analyses provide a framework for a northern pintail banding program based on preseason banding; we see few benefits to adding a winter banding period for estimating survival. There were no real changes in precision, costs of starting a winter program could be high, and there are problems with aging birds. In addition, few opportunities exist to change management options on a yearly basis, so annual survival estimates may not be needed. Obtaining average annual survival estimates over a 3-year or greater study period will provide sufficient information about changes in northern pintail survival over time and to relate changes to regulations.

Literature Cited

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985. Statistical inference from band recovery data: a handbook. Second ed. U. S. Fish and Wildlife Service Resource Publication 156.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. September-March survival of female Northern Pintails radiotagged in San Joaquin valley, CA. Journal of Wildlife Management 66: 901-911.

Hestbeck, J. B. 1993. Survival of northern pintails banded during winter in North America, 1950-88. Journal of Wildlife Management 57: 590-597.

Hines, J. E., and J. R. Sauer. 1989. Program CONTRAST - a general program for the analysis of several survival or recovery rate estimates. Fish and Wildlife Technical Report 24:1-7.

LeMaster, E. T. and R. E. Trost. 1994. Summer survival rate estimates of adult wood ducks: implications for banding programs. Journal of Wildlife Management 58:107-114.

Miller, M. R. 1986. Molt chronology of Northern Pintails in California. Journal of Wildlife Management: 57-64.

Nichols, J. D., and J. E. Hines. 1987. Population ecology of the mallard: VIII. Winter distribution patterns and survival rates of winter-banded mallards. United States Fish and Wildlife Service. Resource Publication 162. 154 pp.

Otis, D. L. 1994. Optimum sample size allocation for wood duck banding studies. Journal of Wildlife Management 58: 114-123.

Scheaffer, S. E. 2003. Northern pintail: prospectus for an action group. New York Wildlife and Fisheries Cooperative Research Unit, Ithaca, NY, USA.

Scheaffer, S. E., and R. A. Malecki. 1995. Waterfowl management: recovery rates, reporting rates, reality check! Wildlife Society Bulletin 23: 437-440.

Siwarski, T. M. 2003. Reliability of determining adults from juvenile ducks by presence or absence of notched tail feathers in various species of North American Ducks. Thesis Louisiana State University.

U.S. Fish and Wildlife Service. 2004. Trends in duck breeding populations, 1955-2003. Office of Migratory Bird Management, U.S. Department of the Interior, Laurel, Maryland, USA. 11pp.

U.S. Fish and Wildlife Service. 2007a. Waterfowl population status. U. S. Department of the Interior, Office of Migratory Bird Management, Laurel, Maryland, USA. 60pp.

U.S. Fish and Wildlife Service. 2007b. Northern Pintail Harvest Strategy. Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Department of Interior, Washington, D.C.

White, G. C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement: 120-138.

Table 1. Expected number of recoveries for Model H_7 of Brownie et al. (1985) for studies in which ducks are banded preseason (N) and postseason (M).

Year	Banding period	N. banded	Year of recovery 1	2	3
1	preseason	N_1	N_1f_1	$N_1h_1n_1f_2$	$N_1h_1n_1h_2n_2f_3$
	postseason	M_1		$M_1n_1f_2$	$M_1n_1h_2n_2f_3$
2	preseason	N_2		N_2f_2	$N_2h_2n_2f_3$
	postseason	M_2			$M_2n_2f_3$
3	preseason	N_3			N_3f_3

h_i = the survival rate during the period between the i^{th} pre- and post-season bandings
n_i – the survival rate during the period between the i^{th} postseason and the $(i+1)^{th}$ preseason bandings
N = number of pre-season bands
M = Number of post-season bands
f_i = recovery rate

Table 2. Average annual survival and recovery rate estimates for continental adult northern pintails based on banding once-a-year and twice-a-year, 1970-1980.

Sex	Banding period	Survival	SE	χ^2	*P*	Recovery	SE	χ^2	*P*
Female	once a year	0.538	0.048			0.028	0.002		
Female	twice a year	0.512	0.045	0.156	0.69	0.029	0.001	0.802	0.37
Male	once a year	0.678	0.040			0.038	0.007		
Male	twice a year	0.647	0.037	0.323	0.57	0.036	0.001	0.741	0.39

Table 3. Annual estimated survival rates, standard errors, and associated coefficient of variation (CV) for adult male (M) and adult female (F) northern pintails banded in North America estimated from banding once-a-year and twice-a-year from 1970-1980.

		Annual survival				Coefficient of variation (CV)		
		Once-a-year		Twice-a-year				
Year	Sex	S	S.E.	S	S.E.	Once a year	Twice a year	Δ
1970	F	0.458	0.038	0.405	0.036	0.135	0.136	- 0.001
1971	F	0.544	0.044	0.523	0.043	0.137	0.133	0.004
1972	F	0.624	0.057	0.585	0.054	0.137	0.129	0.008
1973	F	0.473	0.041	0.471	0.040	0.232	0.218	0.014
1974	F	0.629	0.049	0.607	0.047	0.114	0.107	0.007
1975	F	0.439	0.035	0.433	0.035	0.189	0.091	0.098
1976	F	0.622	0.051	0.587	0.049	0.118	0.109	0.009
1977	F	0.560	0.051	0.539	0.049	0.164	0.151	0.013
1978	F	0.493	0.046	0.465	0.044	0.190	0.176	0.014
1979	F	0.533	0.064	0.504	0.060	0.138	0.130	0.008
Avg.	F	0.537	0.048	0.512	0.046	0.155	0.138	0.017
1970	M	0.642	0.035	0.550	0.031	0.084	0.081	0.003
1971	M	0.648	0.034	0.620	0.032	0.095	0.088	0.007
1972	M	0.782	0.043	0.752	0.042	0.082	0.074	0.008
1973	M	0.706	0.040	0.695	0.039	0.120	0.113	0.007
1974	M	0.647	0.034	0.616	0.033	0.102	0.094	0.008
1975	M	0.713	0.039	0.683	0.037	0.092	0.083	0.009
1976	M	0.734	0.041	0.699	0.039	0.087	0.076	0.011
1977	M	0.678	0.041	0.655	0.040	0.101	0.090	0.011
1978	M	0.611	0.039	0.586	0.037	0.117	0.102	0.015
1979	M	0.623	0.055	0.482	0.043	0.090	0.092	- 0.002
Avg.	M	0.678	0.040	0.634	0.037	0.097	0.089	0.008

Table 4. Annual (preseason to preseason banding), summer (postseason to preseason banding), and winter survival (preseason to postseason banding) for adult northern pintail banded pre- and postseason 1970-1980 using Brownie model H_7.

	Female			Male		
Year	Annual Survival	Summer Survival	Winter Survival	Annual Survival	Summer Survival	Winter Survival
1970	0.405	0.773	0.523	0.550	0.889	0.618
1971	0.523	0.802	0.652	0.620	0.960	0.645
1972	0.585	0.961	0.608	0.693	1.000	0.693
1973	0.471	0.732	0.643	0.695	0.952	0.731
1974	0.607	0.911	0.666	0.492	1.000	0.492
1975	0.433	0.675	0.641	0.671	1.000	0.671
1976	0.587	0.900	0.652	0.663	1.000	0.663
1977	0.539	0.720	0.749	0.638	1.000	0.638
1978	0.465	0.743	0.626	0.586	0.823	0.710
1979	0.504	0.963	0.523	0.320	1.000	0.320
Avg.	0.512	0.818	0.628	0.593*	0.962	0.618

* This average differs from Table 2 because summer survival values were truncated to 1.000 for male pintails when estimates were > 1

Table 5. Comparison of survival and recovery rates for adult male northern pintails banded once-a-year 1970-1980, banded twice-a-year 1970-1980, and banded once-a-year 1993-2003.

1970-1980					1993-2003		
Once-a-year			Twice-a-year		Once-a-year		
Year	Survival	Recovery	Survival	Recovery	Year	Survival	Recovery
1970	0.642	0.025	0.550	0.058	1993	0.711	0.024
1971	0.648	0.049	0.620	0.041	1994	0.805	0.020
1972	0.782	0.039	0.752	0.036	1995	0.757	0.023
1973	0.706	0.033	0.695	0.025	1996	0.581	0.021
1974	0.647	0.025	0.616	0.034	1997	0.728	0.034
1975	0.713	0.031	0.683	0.036	1998	0.656	0.036
1976	0.734	0.033	0.699	0.034	1999	0.803	0.041
1977	0.678	0.032	0.655	0.026	2000	0.616	0.036
1978	0.611	0.025	0.586	0.030	2001	0.735	0.038
1979	0.623	0.028	0.482	0.041	2002	0.404	0.025
Avg.	0.678	0.038	0.647	0.036		0.680	0.030

Table 6. Comparison of survival and recovery rates for adult female northern pintails banded once-a-year 1970-1980, banded twice-a-year 1970-1980, and banded once-a-year 1993-2003.

1970-1980					1993-2003		
Once-a-year			Twice-a-year		Once-a-year		
Year	Survival	Recovery	Survival	Recovery	Year	Survival	Recovery
1970	0.458	0.046	0.405	0.049	1993	0.502	0.018
1971	0.544	0.031	0.523	0.032	1994	0.571	0.015
1972	0.624	0.029	0.585	0.031	1995	0.669	0.019
1973	0.473	0.022	0.471	0.022	1996	0.473	0.015
1974	0.629	0.029	0.607	0.030	1997	0.603	0.023
1975	0.439	0.027	0.433	0.099	1998	0.470	0.020
1976	0.621	0.029	0.587	0.031	1999	0.629	0.032
1977	0.560	0.021	0.539	0.022	2000	0.467	0.027
1978	0.493	0.024	0.465	0.025	2001	0.466	0.026
1979	0.533	0.026	0.504	0.027	2002	0.390	0.026
Avg.	0.538	0.028	0.512	0.029		0.524	0.022

Table 7. The coefficient of variation (CV) associated with yearly band totals and the resulting number of bands needed to obtain a desired CV = 0.10 using data from banding once-a-year 1970-1980, banding twice-a-year 1970-1980, and banding once-a-year 1993-2003 for adult male northern pintails in North America.

1970-1980							1993-2003			
Once-a-year				Twice-a-year			Once-a-year			
Year	no. bands	CV	bands for CV = 0.10	no. bands	CV	bands for CV = 0.10	Year	no. bands	CV	bands for CV = 0.10
1970	7674	0.084	5424	9838	0.081	6495	1993	5045	0.133	8916
1971	7526	0.095	6749	8950	0.089	28081	1994	6112	0.117	8322
1972	7636	0.082	5194	9390	0.074	5207	1995	6386	0.113	8150
1973	6178	0.120	8877	6935	0.114	8990	1996	6304	0.160	16130
1974	8167	0.102	8480	9920	0.093	8635	1997	6405	0.096	5921
1975	7492	0.092	6317	9466	0.082	6428	1998	7224	0.099	7045
1976	8308	0.087	6235	11161	0.076	6474	1999	4720	0.092	3976
1977	9271	0.101	9542	11943	0.091	9866	2000	6692	0.110	8144
1978	7745	0.117	10681	10763	0.101	11012	2001	5448	0.097	5169
1979	9673	0.090	7922	14751	0.092	12513	2002	3754	0.283	30162
avg.	7967	0.097	7542	avg. 10312	0.089	10370	avg.	5809	0.130	10194

Table 8. The coefficient of variation (CV) associated with yearly band totals and the resulting number of bands needed to obtain a desired CV = 0.10 using data from banding once-a-year 1970-1980, banding twice-a-year 1970-1980, and banding once-a-year 1993-2003 for adult female northern pintails in North America.

1970-1980							1993-2003			
Once-a-year				Twice-a-year			Once-a-year			
Year	no. bands	CV	bands for CV = 0.10	no. bands	CV	bands for CV = 0.10	Year	no. bands	CV	bands for CV = 0.10
1970	6823	0.135	12481	8142	0.137	15212	1993	4884	0.232	26271
1971	6748	0.137	12707	7573	0.133	13389	1994	6280	0.194	23581
1972	5307	0.137	9987	6569	0.123	10692	1995	5994	0.147	12944
1973	4596	0.232	24637	5215	0.218	24719	1996	6727	0.231	36011
1974	7445	0.114	9607	8739	0.108	10152	1997	8867	0.123	13506
1975	6625	0.189	23734	7711	0.091	6434	1998	7198	0.195	27338
1976	7140	0.118	9868	8938	0.109	10608	1999	5691	0.124	8755
1977	6651	0.164	17794	8179	0.149	18272	2000	6879	0.173	20484
1978	5616	0.190	20331	7085	0.178	22348	2001	6387	0.183	21380
1979	8381	0.138	15884	10356	0.129	17292	2002	4260	0.271	31176
avg.	6533	0.155	15703	7851	0.138	14912		6317	0.187	22145

Table 9. Model results for adult male and adult female pintails banded twice-a-year based on the estimated CV and total bands for birds banded 1970-1980.

	Beta Coefficients					
Model	Intercept	Coefficient of variation	Total bands	r^2	*F* stat	*p*-value
Female post-season	-84.55	-1357.92	0.216	0.776	29.46	2.99E-6
Female pre-season	84.55	1357.92	0.788	0.979	290.22	5.23E-15
Male post-season	-878.49	12297.22	0.226	0.486	8.05	0.003
Male pre-season	878.49	-12297.22	0.774	0.918	95.19	5.84E-1

Table 10. The number of pre-season and post-season bands needed for annual survival rates based on the average number of adult northern pintails banded from 1970-1980 and from 1993-2003 in North America.

Sex	period	Total No. bands	CV	Pre-season bands	Post-season bands	Bands for CV=0.10	Pre-season bands	Post-season bands
Female	1970-1980	6533	0.155	5929	603	15703	15172	531
Female	1993-2003	6317	0.187	5888	429	22145	21886	259
Male	1970-1980	7967	0.097	5855	2112	7542	5489	2053
Male	1993-2003	5809	0.130	3778	2031	10194	7543	265

Figure 1. Annual survival estimates for adult northern pintail comparing banding once-a-year (preseason) and banding twice-a-year (postseason), 1970-1980 using 2 years of banding.*Survival estimates differed between banding efforts ($P \leq 0.05$).

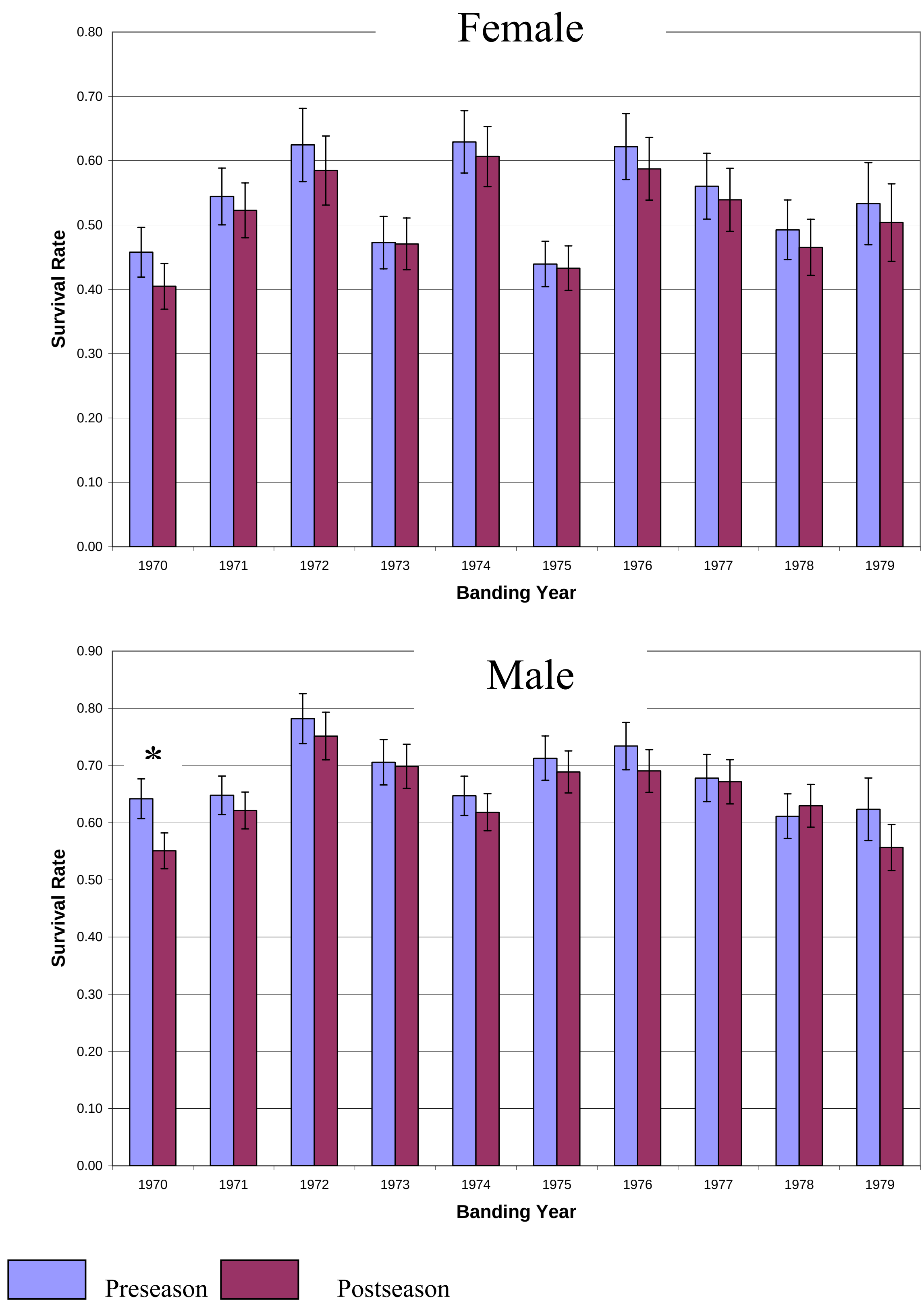


Figure 2. Annual recovery estimates for adult northern pintail comparing banding once-a-year (preseason) and banding twice-a-year (postseason), 1970-1980 using 2 years of banding. *Recovery estimates differed between banding efforts ($p \leq 0.05$).

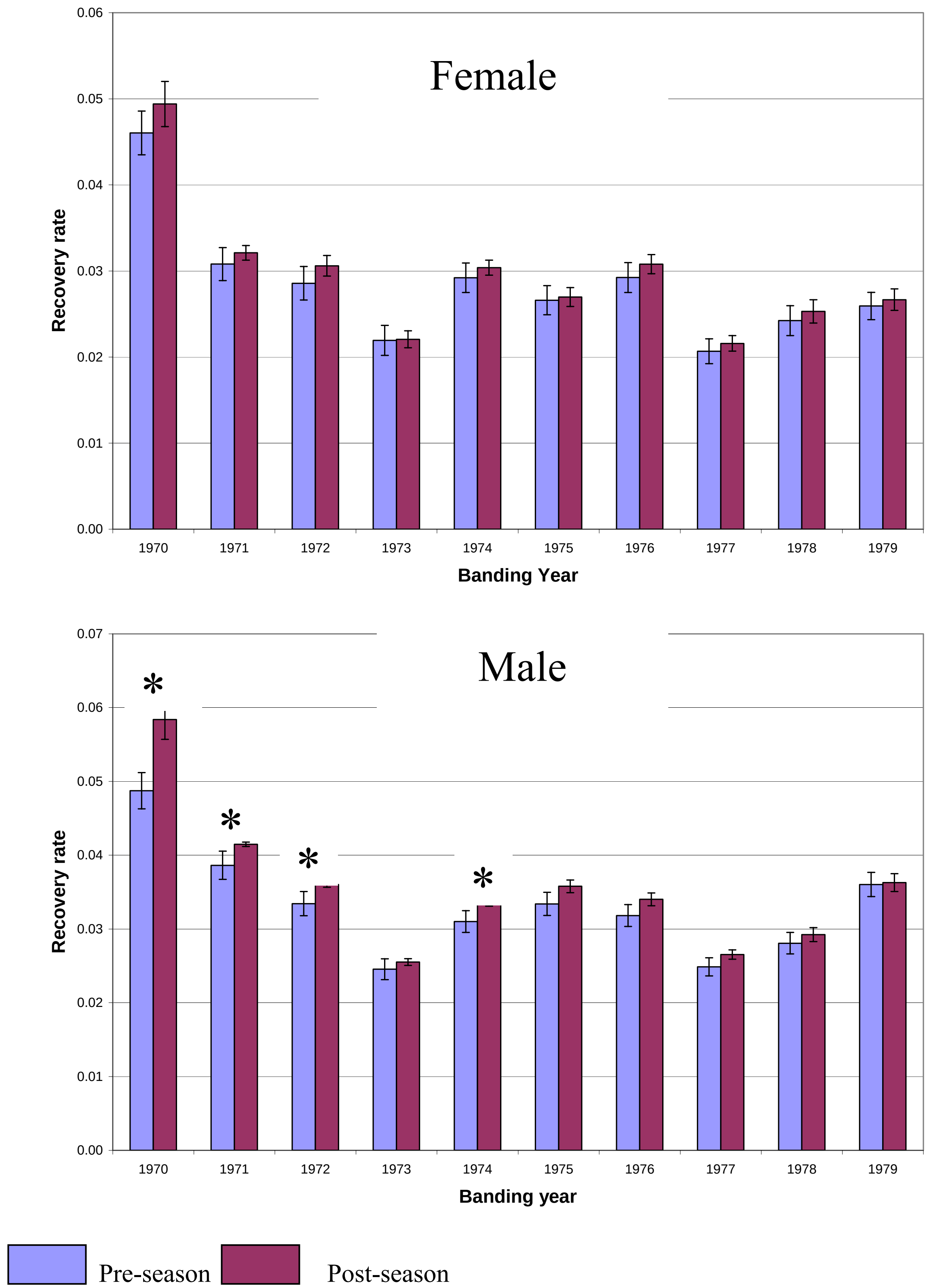
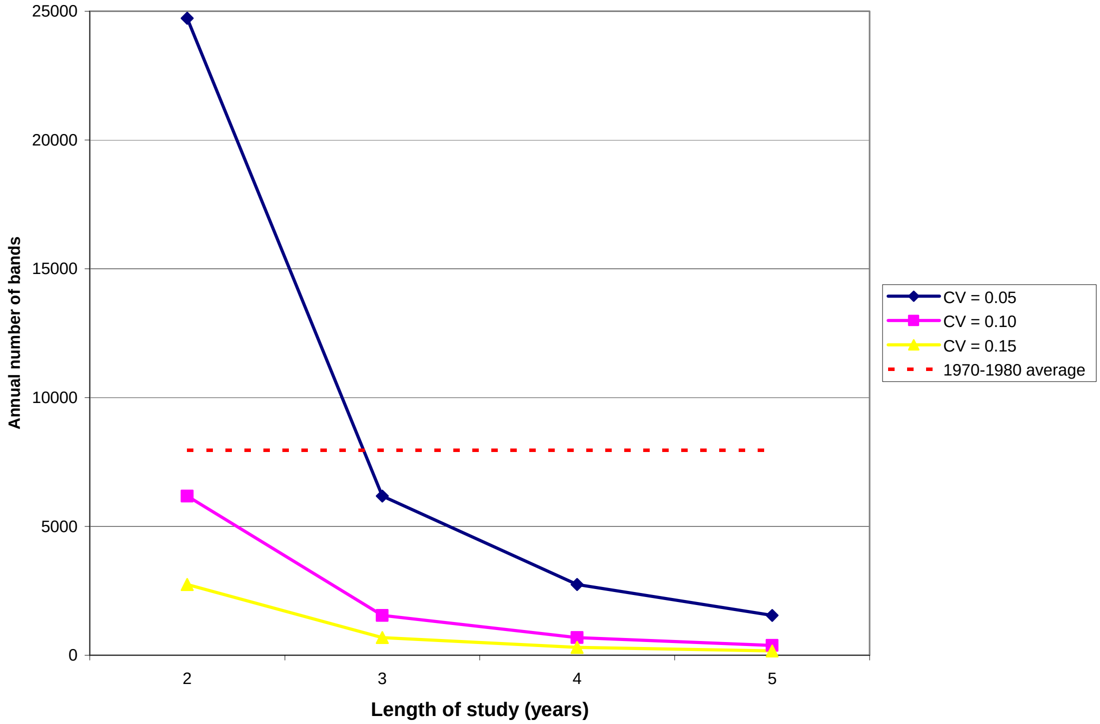


Figure 3. Number of bands required per year based on a CV=0.05, 0.10, and 0.15 for average annual survival over a banding study of 2-5 years for adult male northern pintails during 1970-1980 (upper graphic) and 1993-2003 (lower graphic). The average number of bands applied during 1970-1980 and 1993-2003 are shown with the dashed line.



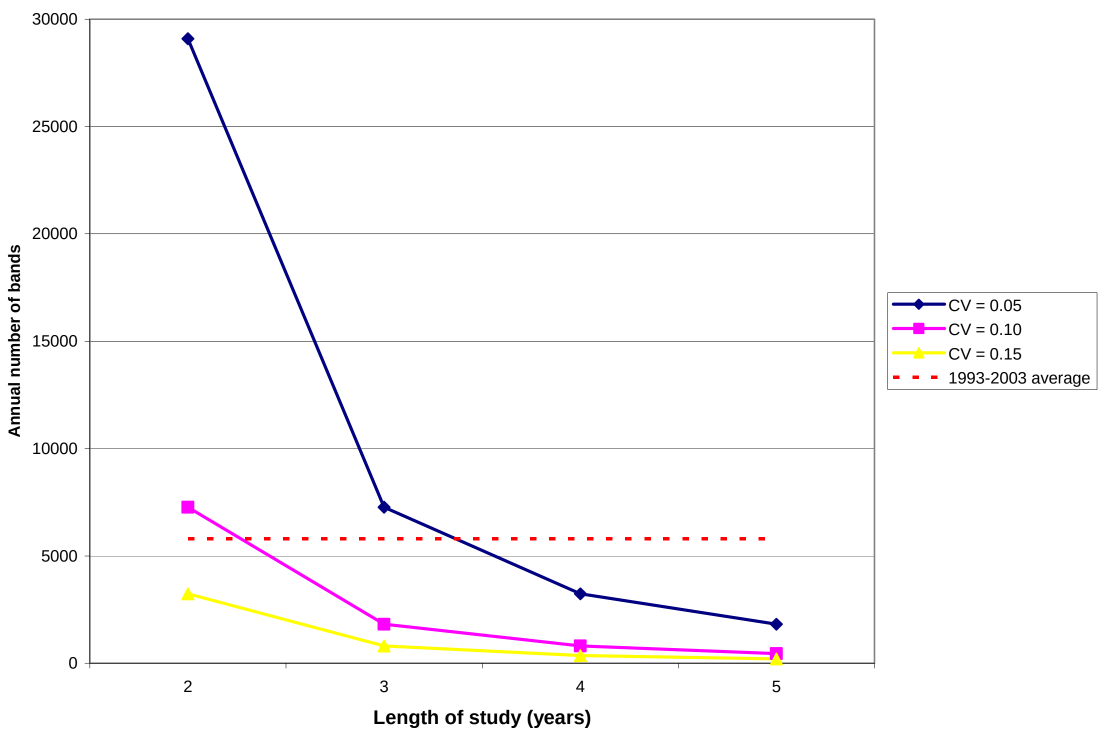
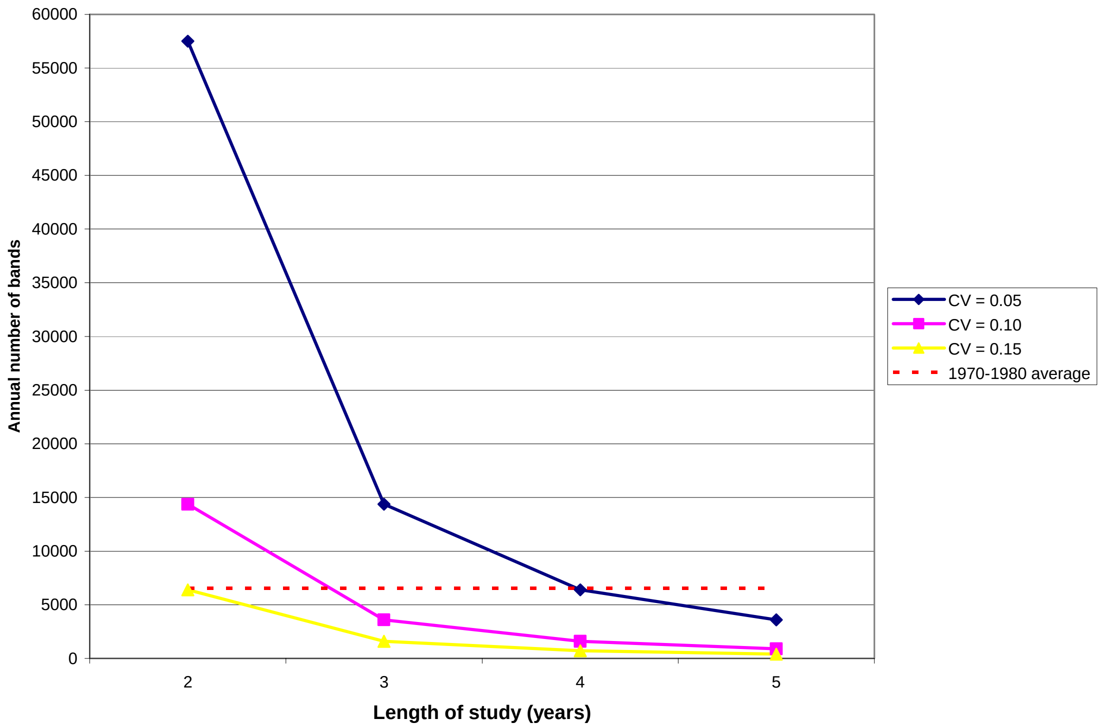
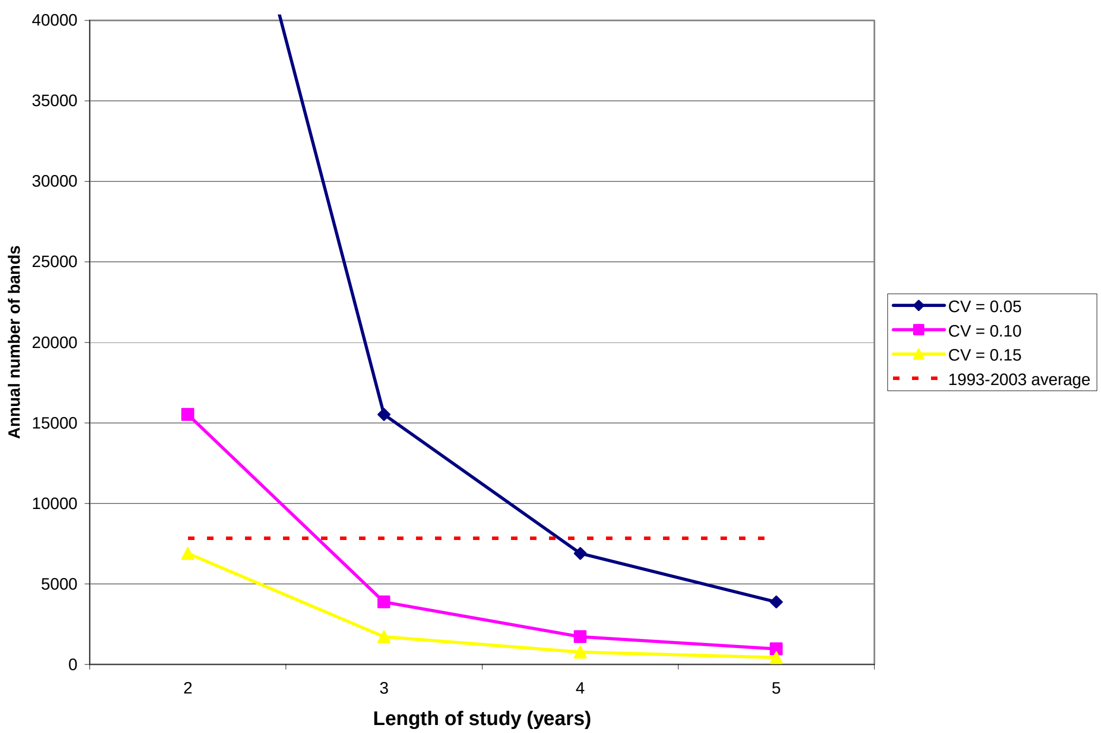


Figure 4. Number of bands required per year based on a CV=0.05, 0.10, and 0.15 for average annual survival over a banding study of 2-5 years for adult female northern pintails during 1970-1980 (upper graphic) and 1993-2003 (lower graphic). The average number of bands applied during 1970-1980 and 1993-2003 are shown with the dashed line.





Appendix A: The recovery matrix of the number of female pintails banded and recovered in North America, 1970-1980.

	Period	bands	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1970	preseason	6823	314	81	44	26	12	16	7	4	3	4	2
	postseason	1319	23	14	11	6	5	4	1	0	1	0	0
1971	preseason	6748		223	89	46	24	17	16	5	6	2	2
	postseason	825		20	10	2	5	1	0	2	0	0	0
1972	preseason	5307			172	55	45	22	10	7	5	3	2
	postseason	1262			25	13	9	3	5	4	2	1	0
1973	preseason	4596				120	43	33	14	9	12	2	2
	postseason	619				8	6	9	1	3	0	1	0
1974	preseason	7445					249	112	45	28	11	8	7
	postseason	1294					21	14	11	5	5	2	3
1975	preseason	6625						90	66	35	22	15	15
	postseason	1086						15	14	3	6	2	2
1976	preseason	7140							239	73	42	28	27
	postseason	1798							29	17	10	13	4
1977	preseason	6651								151	77	45	27
	postseason	1528								21	14	6	7
1978	preseason	5616									163	48	34
	postseason	1469									23	9	11
1979	preseason	8381										242	88
	postseason	1975										22	26
1980	preseason	4716											119
	postseason	722											22

Appendix A (*cont.*): The recovery matrix of the number of male pintails banded and recovered in North America, 1970-1980.

	Period	bands	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1970	preseason	7674	374	164	86	68	68	38	29	32	13	11	8
	postseason	2164	74	43	18	16	13	6	13	6	5	6	2
1971	preseason	7526		317	128	83	79	47	54	32	20	18	12
	postseason	1424		43	29	12	28	12	7	3	4	0	2
1972	preseason	7636			311	131	102	79	63	31	31	17	17
	postseason	1754			58	35	24	19	11	5	8	6	2
1973	preseason	6178				171	114	81	49	45	31	34	20
	postseason	757				25	10	14	5	4	4	3	0
1974	preseason	8167					294	160	90	65	57	41	30
	postseason	1753					68	43	30	26	16	14	4
1975	preseason	7492						303	159	88	54	41	41
	postseason	1974						67	33	20	18	16	10
1976	preseason	8308							301	124	116	81	56
	postseason	2853							75	47	31	30	21
1977	preseason	9271								241	142	135	111
	postseason	2672								49	51	44	30
1978	preseason	7745									257	125	109
	postseason	3018									52	42	50
1979	preseason	9673										411	148
	postseason	5078										164	103
1980	preseason	5615											196
	postseason	2931											34

Assessment of Continental Northern Pintail (*Anas acuta*) Band-Recovery Data

Part IV: Estimating regional survival rates of northern pintails

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Introduction

Nearly all prairie-nesting dabbling duck species have dramatically increased in abundance since the early 1990s except northern pintail (*Anas acuta*), which has decreased from an estimated 9.6 million in 1955 to 2 million by 1988 (Hestbeck 1993, Scheaffer 2003) and have remained at relatively low levels since then. By 2002, pintails reached a low of 1.8 million birds in the traditional survey area (U.S. Fish and Wildlife Service 2004) despite restrictive harvest regulations. By 2007, the estimate of pintails in the traditional survey area had increased to 3.3 million birds (U. S. Fish and Wildlife Service 2007a). Despite the increase since 2002, the current population estimate remains 20% below the long-term average (1955-2005, average number = 4.1 million) and 41% below the goal of 5.6 million stated in the North American Waterfowl Management Plan. Although the pintail remains the most abundant duck in the Pacific Flyway, their numbers are only 25% of levels recorded in the 1970s (Fleskes et al. 2002). The continued low abundance of pintails has caused great concern among managers as evidenced by the United States Fish and Wildlife Service declaring pintails a focal species targeted for increased management emphasis and establishment of a species-specific harvest management strategy (U.S. Fish and Wildlife Service 2007b).

Managers have stated an interest in managing pintails on a regional basis. It has been shown that long-term trends in pintail breeding population (BPOP) vary by region (Miller and Duncan 1999), which may indicate possible regional differences in survival. Studies on other waterfowl have also found that geographic location can have an effect on survival (Nichols and Hines 1987). An evaluation of geographic differences in pintail survival will provide additional information for management of this species.

Results from a previous analysis indicate that the top model to estimate survival and recovery rates of northern pintails across the continent included an age, sex, and region component with additive time effects (Rice et al. 2007). This suggests there is an interactive regional effect for each age and sex class, but not an interactive temporal effect for northern pintail survival rates. Therefore, our objective was to investigate potential models to estimate survival rates for identified banding regions. We then compared the top models for each region to the overall top model for continental survival rates.

Methods

We obtained banding data for normal, wild birds shot or found dead during hunting season from the United States Geological Survey Bird Banding Laboratory for 1970-2003. All birds were banded during July and August (preseason). Records were grouped according to age and sex. We used the Brownie approach in Program MARK (White and Burnham 1999) to compare 15 different models for each region to estimate survival and recovery rates. Survival probability is the probability that a banded bird in year t survives to the banding period in year t+1. The recovery probability is the probability that a banded bird was shot, recovered, and reported during the hunting season in year t. When reporting trends and averages, we removed survival estimates of 1970 and 2002 and 1970 and 2003 recovery rates due to unreliable estimates that are typically produced at the beginning and end of banding periods (e.g., survival estimates of 1.0).

To account for spatial variation, we first geographically stratified the sampling region into homogeneous units and pooled data from sites within each stratum (Royle and Dubovsky 2001). We accomplished this using a Multi-Response Permutation Procedure (MRPP) to identify banding blocks with dissimilar recovery distributions based on a cluster analysis (J.

Dubovsky, pers. comm.). The aim of the MRPP analysis was to find patterns of geographic similarity between recovery locations and banding reference areas. Banding degree blocks in which birds have similar recovery distributions were aggregated using cluster analyses. Therefore, we used the 3 region delineation, which was referenced as western, central, and eastern regions to test for any spatial effects in the model set (Figure 1).

We included estimates of annual survival in our model set, but were also interested in whether pintail survival differed among other temporal periods of interest. Therefore, we grouped years into temporal periods based on bag limits, season lengths, and overflight versus non-overflight years on the breeding grounds. The regulations were based on each corresponding flyway where the Pacific Flyway regulations were used for the western region, the Central Flyway regulations were used for the central region, and the Atlantic Flyway regulations were used for the eastern region. The bag limits and season lengths were divided into 3 temporal periods based on relative liberal, moderate, and restrictive regulations (Figure 2). However, these temporal periods were not related to similar, categorical distinctions included in Adaptive Harvest Management. The periods for season length were similar to those used by Sheaffer et al. (1999). The overflight period was divided into 2 periods using the average latitude of the breeding pintail population to divide the periods (Figure 3).

We developed a candidate model set *a priori* based on the sources of variation of interest for each region. This included models for various combinations of age, sex, and temporal period. We considered both interactive and additive effects resulting in 15 models tested for each region. We discriminated among models and selected the best approximating model using Akaike's Information Criterion (AIC; Burnham and Anderson 1998). AIC provides an estimate of the expected, relative distance between the fitted model and the unknown process that actually generated the observed data (Burnham and Anderson 1998). This is a generalized approach and can be used with both nested and non-nested models (Williams et al. 2002). We utilized program CONTRAST (Sauer and Williams 1989) to compare between survival rates for age and sex classes in each region using their associated variances.

Results

The majority of pintails were banded in the western (53%) and central (44%) regions whereas relatively few were banded in the eastern region (3%) (Table 1). The same pattern was found for the number of birds recovered from birds banded across the continent with 56% recovered in the western region, 38% found in the central region, and 6% in the eastern region. On average, 10,360 northern pintails were banded each year (Table 1).

All of the top models for estimation of survival rates in each region included a temporal period rather than yearly survival estimates. The best supporting model for the estimation of survival rates in the central region was the interaction between age, sex, and season length (AIC_c weight = 0.53; Table 2). The second competing model (AIC_c weight = 0.47) included age, sex, and bag limits. There was a clear best-fitting model in the western region that included age, sex, and overflight (Table 3). The highest ranked model in the eastern region included age, sex, and bag limits (Table 4).

The survival estimates for the central region indicated a difference between the restrictive years and the liberal ($\chi^2_2 = 9.59$, $P = 0.002$) and moderate years ($\chi^2_2 = 10.96$, $P < 0.0001$) for adult females (Table 5). This pattern was also found for adult males with greater survival in the restrictive years compared to the liberal years ($\chi^2_2 = 14.84$, $P < 0.001$) and moderate years ($\chi^2_2 = 32.09$, $P < 0.0001$). There were no differences between liberal, moderate, or restrictive years for immature females or immature males (Table 5). The same pattern could be seen when using the second ranked model with bag limits (Table 6). Survival during the restrictive years differed from liberal and moderate years for adult females (χ^2_2= 7.06, $P < 0.008$) and adult males (χ^2_2= 14.22, $P < 0.001$). There were no differences between survival for immature females and immature males (Table 6).

The western region had no differences in survival for adult females (χ^2_2= 1.39, $P = 0.24$) during overflight versus non-overflight years (Table 7). However, survival was greater during overflight years for immature females ($\chi^2_2 = 4.19$, $P = 0.04$), adult males ($\chi^2_2 = 8.76$, $P = 0.003$), and immature males ($\chi^2_2 = 7.72$, $P = 0.006$) compared to non-overflight years (Table 7).

The survival estimates for the eastern region from the top model including bag limits indicated that adult females (χ^2_2= 2.05, $P = 0.36$), immature females ($\chi^2 = 1.44$, $P = 0.49$), and immature males (χ^2_2= 2.17, $P = 0.34$) did not differ between liberal, moderate, and restrictive years (Table 8). However, there was a significant difference between survival for adult males in liberal versus restrictive years (χ^2_2= 11.66, $P < 0.001$).

The best approximating model for recovery rates in the western and central regions includes an age, sex, and time interaction. The best supporting model for recovery rates in the eastern region included an age, sex, and bag limit interaction. This model corresponds to the survival rate parameters in the eastern region.

Discussion

The variability due to the number of bandings and recoveries in each region, especially the eastern region, may be contributing to the various top models for each region. The continental survival analysis indicated that the eastern region may be contributing to the regional effect because of the low banding and recovery numbers. The Eastern region had only 12,000 birds banded and less than 1,500 birds recovered. Both the Central and Western regions had greater than 150,000 birds banded and 9,000 birds recovered. Investigating the individual regions removes the regional effect from the continental analysis and provides more accurate survival rates for each region.

Our objective was to compare the models for survival rates in each region and we found that there was a different temporal parameter in the best approximating model among the central, western, and eastern regions. The central region had a season length component, the western region had an overflight component, and the eastern region had a bag limit component. We compared this with the continental analysis and found that there was no temporal interaction on a continental scale whereas there was a temporal period in each of the top models for each region.

The survival rates for adult pintails were more affected by temporal periods than the immature pintails, which could be an indication that restrictive season lengths increase adult pintail survival. Season length or bag limits had no effect on juvenile survival estimates.

The top model in the eastern region included temporal groupings based on bag limits, but in survival rates of adult males differed among periods of different bag limits, with greater survival rates during restrictive bag limits. The eastern region model seems to be driven by the adult males, but additional concern was apparent for immature females. The survival rate for immature females ranged from 0.373 to 0.507, which was much less than other age and sex classes. Concentrating on increasing survival of immature females may be the better management option for the eastern region.

The top model for the western region included overflight versus non-overflight years based on the average latitude of the northern pintail breeding population. Immature females, adult males, and immature males demonstrated increased survival during overflight years. There was no significant difference in survival for adult females between overflight and non-overflight years, but even so, survival was greater during overflight years. The western region is unique in that many pintails travel to Alaska and the Yukon-Kuskokwim Delta region during the summer breeding period, which is higher than the average latitude. In addition, this population seems to have remained relatively stable through the long term rather than exhibiting signs of a decline (Nicolai et al. 2005).

The rank order of survival estimates for each age and sex class was similar among all regions with adult males having the greatest survival and immature females having a lowest annual survival estimates. The eastern region had survival estimates that were lower than the central and western regions for all age and sex classes. This may be an artifact of the data available in each region or it may be an indication that pintails in the eastern region have reduced survival rates.

The evaluation of individual regions resulted in three different top models, but all included a temporal period rather than a yearly time component. This is different from the continental survival estimates in which the top model had an additive time component, but no temporal period (Rice et al. 2007). This may indicate that evaluating survival rates on a continental basis provides a different picture of the factors influencing northern pintail. In regard to evaluation of harvest regulations, it would be more effective to evaluate regional changes over temporal periods rather than focus on the continental scale.

References

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. September-March survival of female Northern Pintails radiotagged in San Joaquin valley, CA. Journal of Wildlife Management 66:901-911.

Hestbeck, J. B. 1993. Survival of northern pintails banded during winter in North America, 1950-88. Journal of Wildlife Management 57:590-597.

Miller, M. R., and D. C. Duncan. 1999. The northern pintail in North America: status and conservation needs of a struggling population. Wildlife Society Bulletin 27:788-800.

Nichols, J. D., and J. E. Hines. 1987. Population ecology of the mallard: VIII. Winter distribution patterns and survival rates of winter-banded mallards. United States Fish and Wildlife Service. Resource Publication 162. 154 pp.

Scheaffer, S. E. 2003. Northern pintail: prospectus for an action group. New York fisheries and Wildlife Cooperative Research Unit, Ithaca, NY, USA.

U.S. Fish and Wildlife Service. 2007a. Waterfowl population status. U. S. Department of the Interior, Office of Migratory Bird Management, Laurel, Maryland, USA. 60pp.

U.S. Fish and Wildlife Service. 2007b. Northern Pintail Harvest Strategy. Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Department of Interior, Washington, D.C.

Table 1. The mean and total number of continental bandings and recoveries in the central, eastern, and western regions for adult male, adult female, immature male, and immature female northern pintails, 1970-2003.

Region	Age/sex group	Mean number/year		Total	
		Banded	Recovered	Banded	Recovered
Central					
	Adult females	1283	45	43617	1534
	Adult Males	1272	87	43248	2950
	Immature Females	1048	60	35643	2025
	Immature Males	920	82	31286	2779
	TOTAL	4523	274	153794	9288
Eastern					
	Adult females	77	6	2615	197
	Adult Males	42	5	1442	157
	Immature Females	120	14	4069	477
	Immature Males	115	17	3904	587
	TOTAL	354	42	12030	1418
Western					
	Adult females	1153	42	39210	1442
	Adult Males	1666	148	56644	5047
	Immature Females	1335	76	45389	2575
	Immature Males	1329	135	45185	4600
	TOTAL	5483	401	186428	13664

Table 2. Model set results from program MARK used to analyze band recoveries of northern pintails banded in the central region and recovered in the central region, 1970-2003. Variables of interest were used to estimate survival and recovery rates by age, sex, and temporal period. *

Survival	Recovery	AICc	ΔAIC	AICc weights	Model likelihood	No. of parameters	Deviance
a*s*sl	a*s*t	99855.19	0.00	0.528	1.000	148	1589.16
a*s*bl	a*s*t	99855.42	0.23	0.472	0.893	148	1589.39
a*s*of	a*s*t	99875.22	20.32	0.000	0.000	144	1617.49
a*s	a*s*t	99878.22	23.02	0.000	0.000	140	1628.21
a*s*t	a*s*t	99936.78	81.59	0.000	0.000	268	1430.10
a*s+t	a*s*t	100063.96	208.76	0.000	0.000	138	1817.96
a*s*sl	a*s*sl	100064.96	209.76	0.000	0.000	24	2047.20
a*s*t	a*s*sl	100084.81	229.62	0.000	0.000	143	1828.80
a*s*t	a*s*of	100425.42	570.22	0.000	0.000	138	2179.42
a*s*t	a*s*bl	100444.20	589.01	0.000	0.000	142	2190.20
a*s*t	a*s+t	100451.97	596.77	0.000	0.000	134	2213.98
a*s*bl	a*s*bl	100577.97	722.77	0.000	0.000	24	2560.22
a*s*of	a*s*of	100602.78	747.59	0.000	0.000	16	2601.03
a*s	a*s	101539.57	1684.30	0.000	0.000	8	3553.82
t	t	101630.61	1775.40	0.000	0.000	67	3526.80

* a = age s = sex t = time of = overflight bl = bag limits sl = season length

Table 3. Model set results from program MARK used to analyze band recoveries of northern pintails banded in the western region and recovered in the western region, 1970-2003. Variables of interest were used to estimate survival and recovery rates by age, sex, and temporal period. *

Survival	Recovery	AICc	ΔAIC	AICc weights	Model likelihood	No. of parameters	Deviance
a*s*of	a*s*t	143942.64	0.00	0.796	1.000	144	1718.69
a*s*bl	a*s*t	143946.82	4.17	0.099	0.124	148	1714.85
a*s*sl	a*s*t	143946.86	4.21	0.097	0.122	148	1714.88
a*s	a*s*t	143951.88	9.24	0.008	0.001	140	1735.94
a*s*t	a*s*t	144025.10	82.46	0.000	0.000	268	1552.60
a*s+t	a*s*t	144191.29	248.64	0.000	0.000	138	1979.35
a*s*sl	a*s*sl	144238.93	296.28	0.000	0.000	24	2255.19
a*s*t	a*s*sl	144252.11	309.46	0.000	0.000	142	2231.10
a*s*t	a*s*of	144447.12	504.47	0.000	0.000	138	2235.18
a*s*t	a*s*bl	144453.05	510.41	0.000	0.000	143	2235.18
a*s*of	a*s*of	144505.39	562.75	0.000	0.000	16	2537.66
a*s*bl	a*s*bl	144529.04	586.39	0.000	0.000	24	2545.30
a*s*t	a*s+t	144683.17	740.53	0.000	0.000	136	2475.24
a*s	a*s	144815.94	873.30	0.000	0.000	8	2864.21
t	t	147080.88	3138.2	0.000	0.000	67	5011.10

* a = age s = sex t = time of = overflight bl = bag limits sl = season length

Table 4. Model set results from program MARK used to analyze band recoveries of northern pintails banded in the eastern region and recovered in the eastern region, 1970-2003. Variables of interest were used to estimate survival and recovery rates by age, sex, and temporal period. *

Survival	Recovery	AICc	ΔAIC	AICc weights	Model likelihood	No. of parameters	Deviance
a*s*bl	a*s*bl	12383.73	0.00	0.793	1.000	24	1067.86
a*s*sl	a*s*sl	12386.50	2.77	0.198	0.250	24	1070.63
a*s	a*s	12392.76	9.03	0.009	0.011	8	1108.98
a*s*of	a*s*of	12401.10	17.37	0.000	0.010	16	1101.28
a*s*t	a*s+t	12476.31	92.59	0.000	0.000	135	935.46
a*s*t	a*s*bl	12476.70	92.97	0.000	0.000	144	917.41
a*s*of	a*s*t	12480.56	96.84	0.000	0.000	144	921.28
a*s*t	a*s*sl	12480.78	97.05	0.000	0.000	143	923.55
a*s*sl	a*s*t	12481.99	98.27	0.000	0.000	148	914.51
a*s	a*s*t	12483.13	99.40	0.000	0.000	140	932.04
a*s+t	a*s*t	12484.53	100.80	0.000	0.000	138	937.53
a*s*t	a*s*of	12484.70	100.97	0.000	0.000	140	933.61
a*s*bl	a*s*t	12489.42	105.70	0.000	0.000	148	921.94
a*s*t	a*s*t	12599.50	215.77	0.000	0.000	268	783.47
t	t	15261.50	2877.7	0.000	0.000	34	3925.54

* a = age s = sex t = time of = overflight bl = bag limits sl = season length

Table 5. Survival rates and standard errors (SE) for northern pintails banded in the central region using the best approximating model with an age, sex, and season length interaction, 1970-2003.

Sex	Age	Season length[a]	survival rate	SE
Female	Adult	Liberal	0.614	0.019
		Moderate	0.624	0.010
		Restrictive	0.704	0.022
Female	Immature	Liberal	0.644	0.051
		Moderate	0.704	0.038
		Restrictive	0.588	0.081
Male	Adult	Liberal	0.738	0.015
		Moderate	0.736	0.006
		Restrictive	0.812	0.012
Male	Immature	Liberal	0.775	0.046
		Moderate	0.729	0.028
		Restrictive	0.726	0.061

[a] season length periods are defined as follows: liberal (1997-2001), moderate (1970-1987, 1995-1996), and restrictive (1988-1994, 2002-2003).

Table 6. Survival rates and standard errors (SE) for northern pintails banded in the central region using the second best approximating model with an age, sex, and bag limit interaction, 1970-2003.

Sex	Age	Bag limit	Survival rate	SE
Female	Adult	Liberal	0.614	0.014
		Moderate	0.621	0.021
		Restrictive	0.663	0.011
Female	Immature	Liberal	0.744	0.057
		Moderate	0.597	0.046
		Restrictive	0.692	0.044
Male	Adult	Liberal	0.736	0.009
		Moderate	0.719	0.016
		Restrictive	0.779	0.007
Male	Immature	Liberal	0.684	0.038
		Moderate	0.793	0.042
		Restrictive	0.750	0.034

[a] bag limit periods are defined as follows: liberal (1975-1984), moderate (1970-1974, 1985-1987, 1997), and restrictive (1988-1996, 1998-2003).

Table 7. Survival rates and standard errors (SE) for northern pintails banded in the western region using the best approximating model with an age, sex, and overflight interaction, 1970-2003.

Sex	Age	Overflight	Survival rate	SE
Female	Adult	Non-overflight	0.638	0.011
		Overflight	0.659	0.014
Female	Immature	Non-overflight	0.592	0.028
		Overflight	0.704	0.047
Male	Adult	Non-overflight	0.741	0.001
		Overflight	0.759	0.006
Male	Immature	Non-overflight	0.617	0.017
		Overflight	0.708	0.028

[a] overflight periods are defined as follows: overflight (1977, 1980-1981, 1983-1985, 1987-1993, 1998, 2000-2003), and non-overflight (1970-1976, 1978-1979, 1982, 1986, 1994-1997, 1999).

Table 8. Survival rates and standard errors (SE) for northern pintails banded in the eastern region using the best approximating model with an age, sex, and bag limit interaction, 1970-2003.

Sex	Age	Bag limits[a]	Survival rate	SE
Female	Adult	Liberal	0.603	0.032
		Moderate	0.610	0.052
		Restrictive	0.546	0.031
Female	Immature	Liberal	0.412	0.069
		Moderate	0.507	0.087
		Restrictive	0.373	0.072
Male	Adult	Liberal	0.642	0.025
		Moderate	0.697	0.044
		Restrictive	0.758	0.023
Male	Immature	Liberal	0.468	0.064
		Moderate	0.411	0.065
		Restrictive	0.577	0.092

[a] bag limit periods are defined as follows: liberal (1975-1984), moderate (1970-1974, 1985-1987, 1997), and restrictive (1988-1996, 1998-2003).

Figure 1. The 3 region Multi-Response Permutation Procedure analysis for northern pintail in North America between 1970 and 2003 resulting in the western, central, and eastern regions.

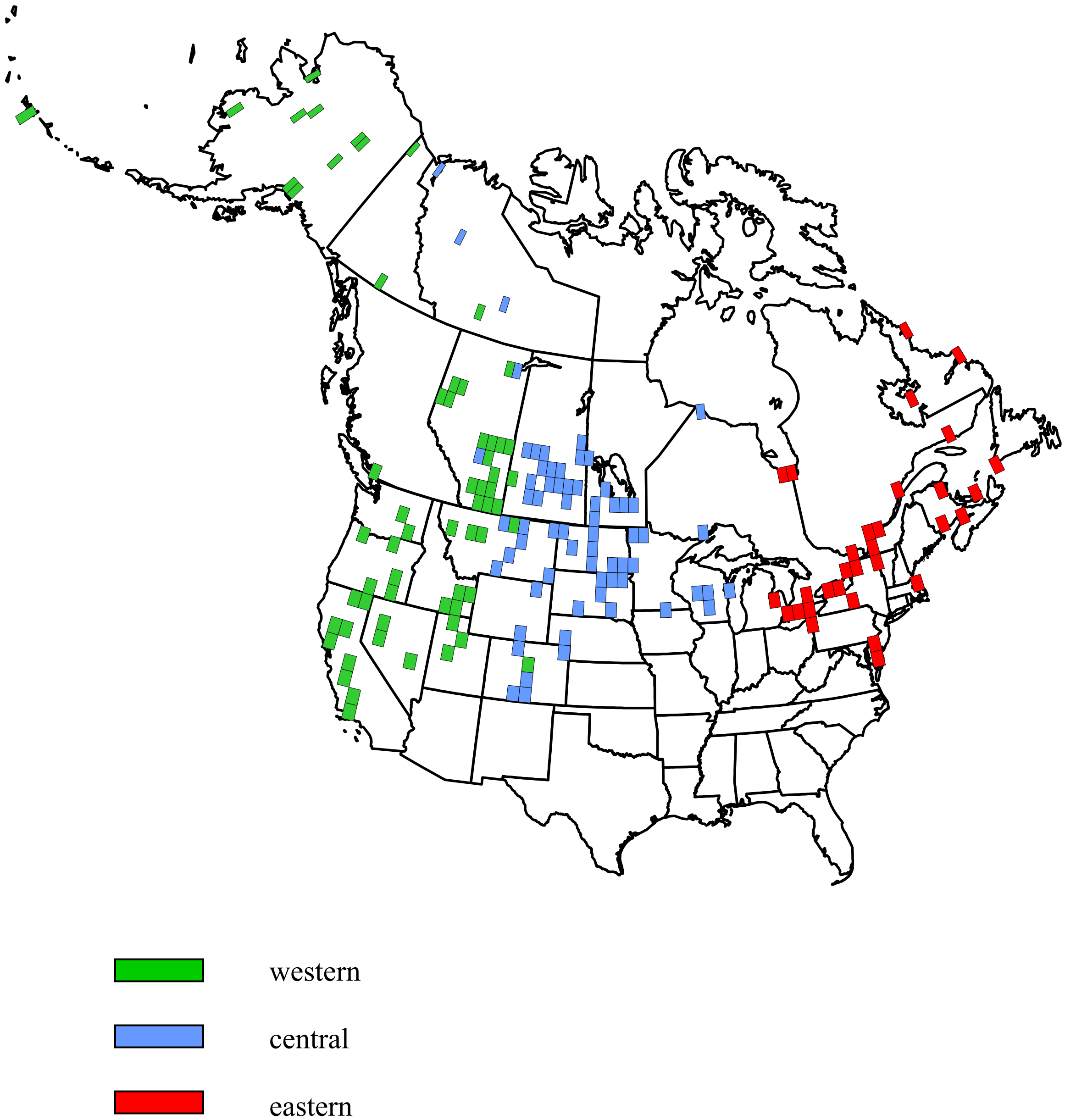

Figure 2. Grouping of years based on hunting season length and bag limits used to model temporal periods for continental northern pintail survival and recovery rates, 1970-2003.

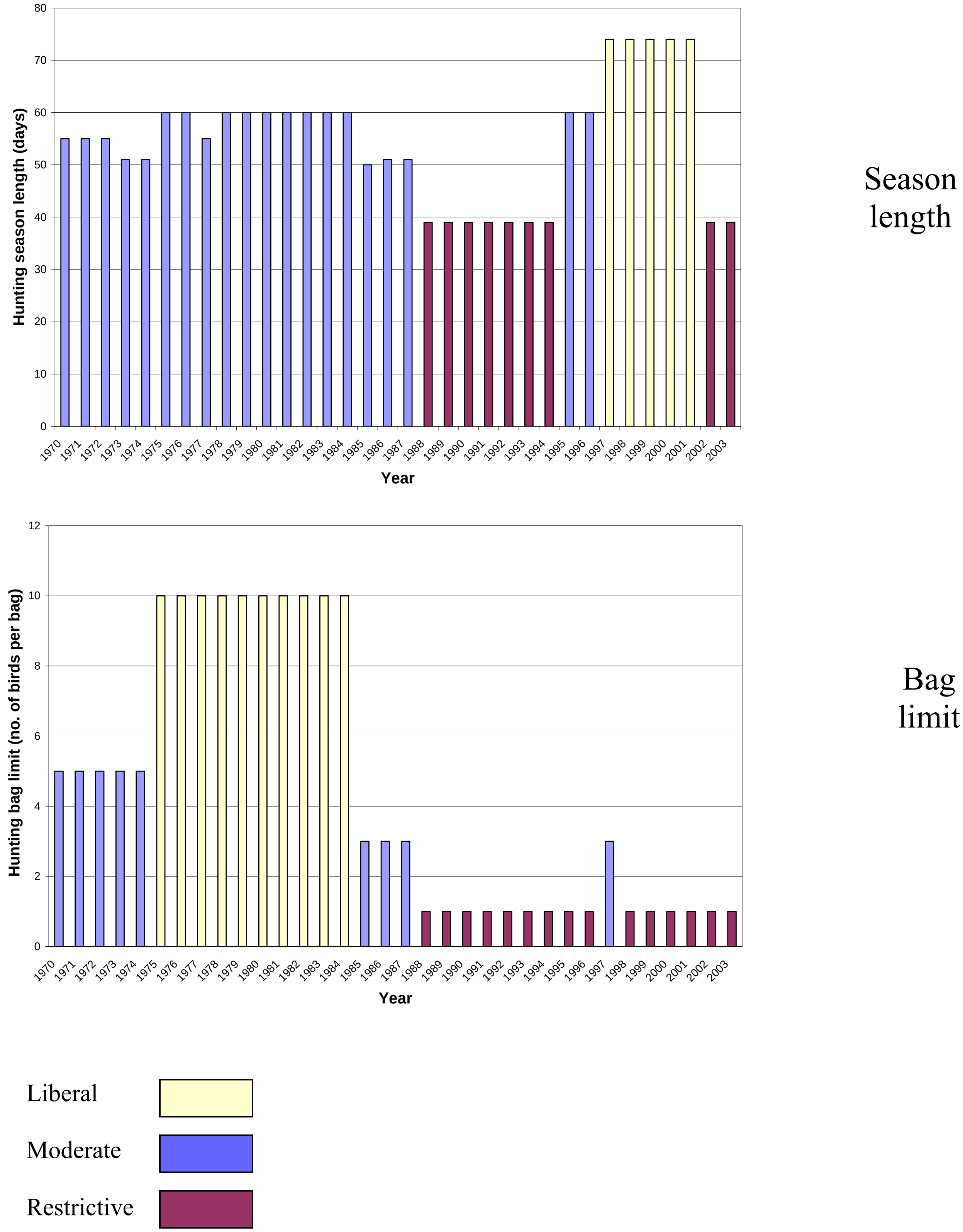

Figure 3. Grouping of years based on the mean latitude of the pintail breeding population divided into overflight temporal periods used to model continental northern pintail survival and recovery rates, 1970-2003.