

NLSBA Pedigree & Cluster Analysis
USDA-ARS-National Animal Germplasm Program
June, 2007

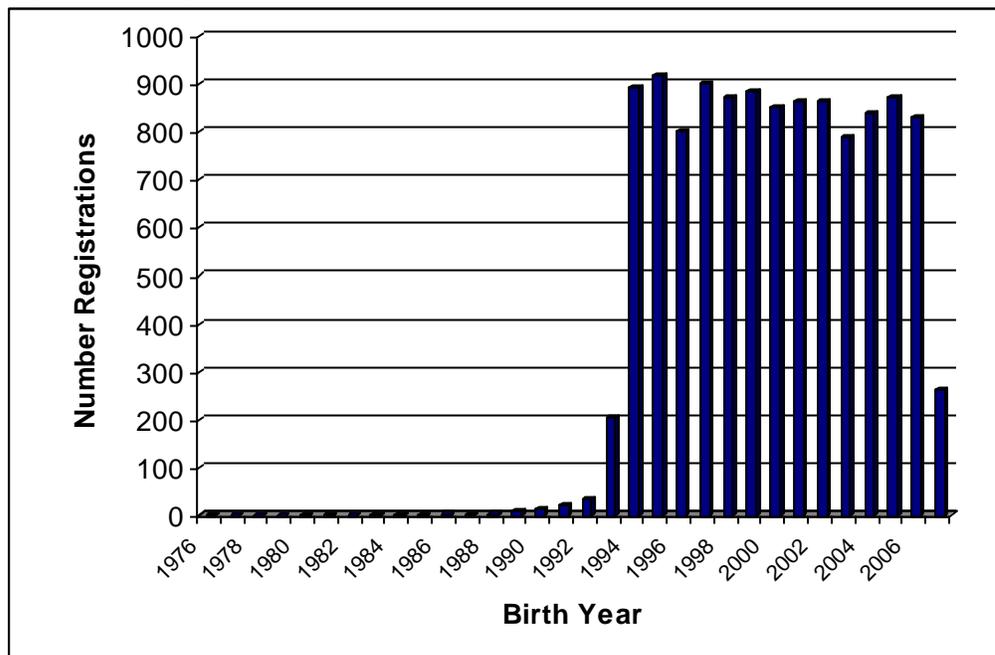
Data file statistics & edits

NLSBA provided NAGP with access to their database for this analysis. There were 13,458 records from animals born from 1976-2007. Of these, 8,972 (66.7%) were ewes and 4,486 (33.3%) were rams. Birth years were unknown for 12.9% of the data. The only data edits needed were for 2 rams that appeared as their own sire. Their sire was converted to unknown. Sires were known for 89.0% of the animals and dams were known for 88.9%. There have been 1,136 sires and 4,501 dams during the lifetime of the database.

Registrations by birth year

The oldest registered animal was born in 1976; registrations did not greatly increase until 1993. The number of registrations by birth year have remained relatively stable since 1994, as shown in Figure 1. Registrations for 2007 are incomplete.

Figure 1. Registrations by Birth Year

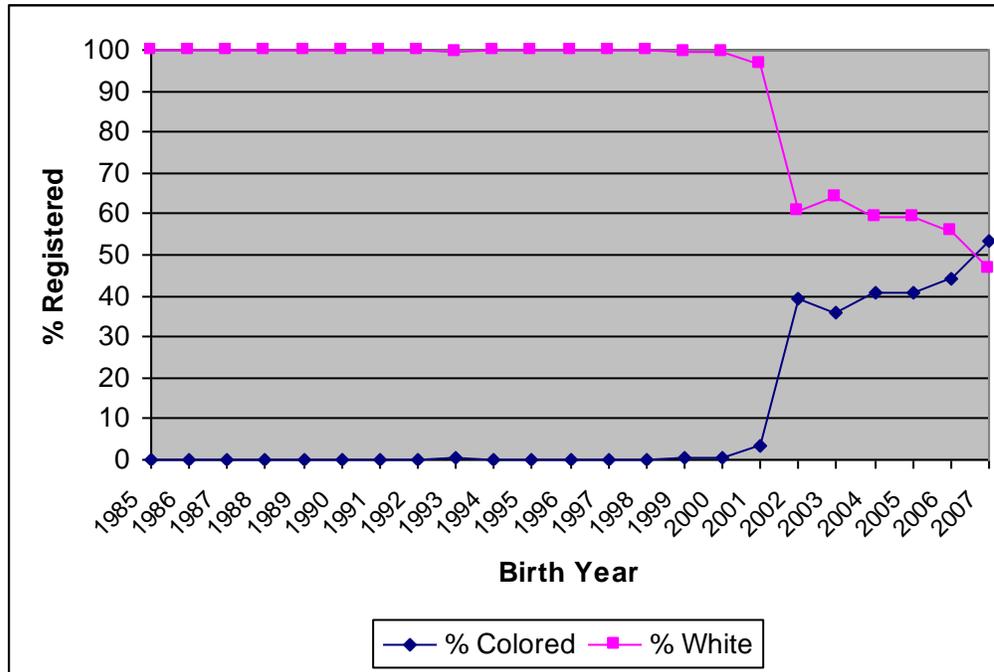


Color

For all of the animals in the file, 14% registered were colored and 86% were white. However, this has not remained consistent over time, as shown in Figure 2. Starting in 2002, there has been an explosion of colored Lincoln registrations.

If the rest of 2007 follows the current trend, more colored Lincolns will be registered than white.

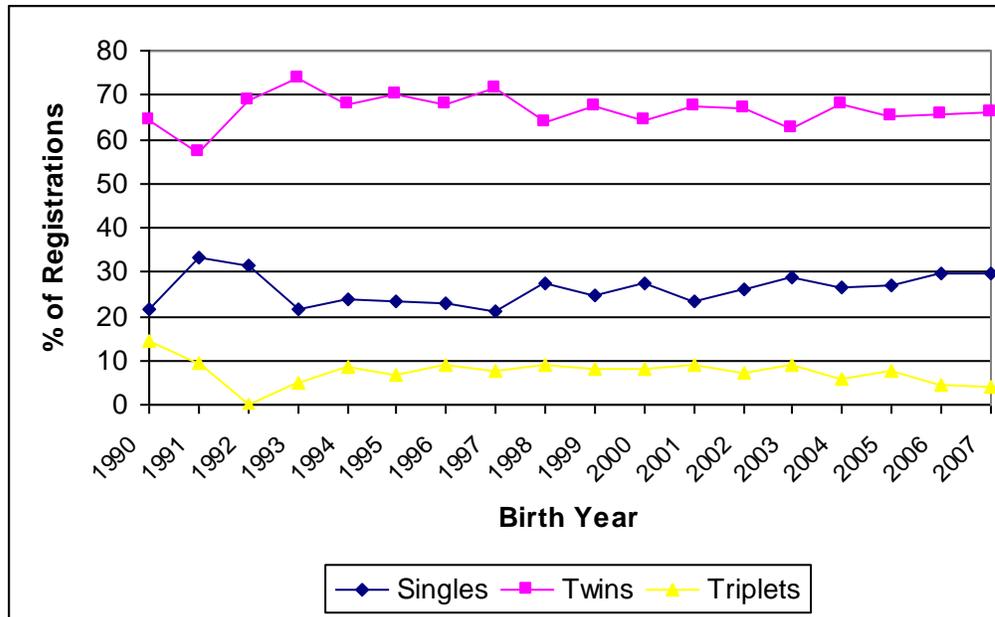
Figure 2. Percent Colored and White Registrations by Birth Year



Birth type

The majority of lambs are born as twins, followed by singles and triplets. Only 0.3% of registered lambs were born as quads or quintets. Figure 3 shows the trend over time for single, twin, and triplet registrations. The trend has remained fairly stable over time, but the proportion of singles has increased in recent years.

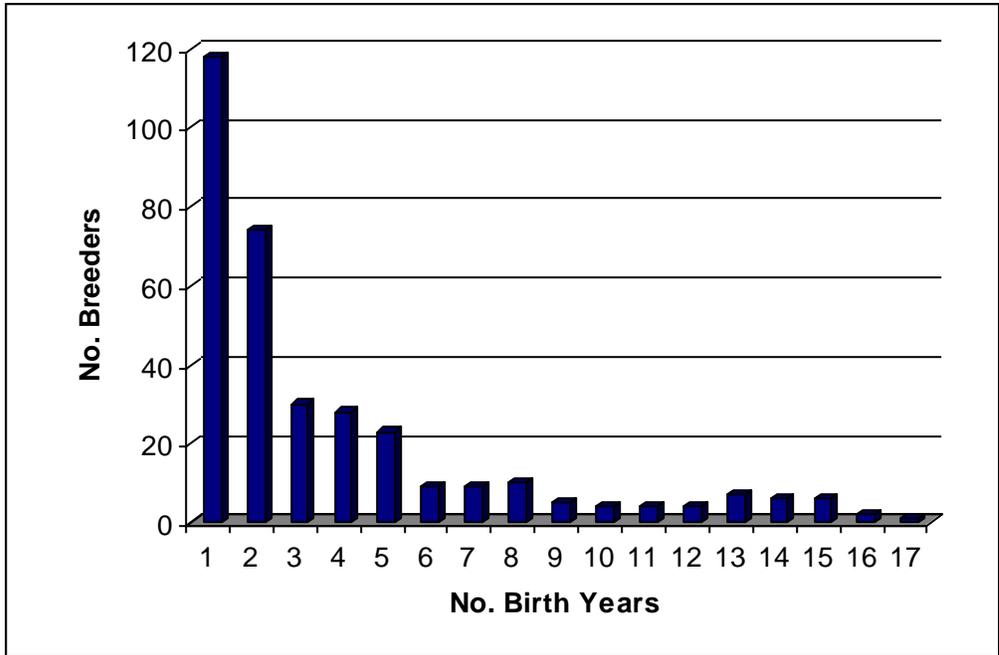
Figure 3. Birth Type by Birth Year



Breeders

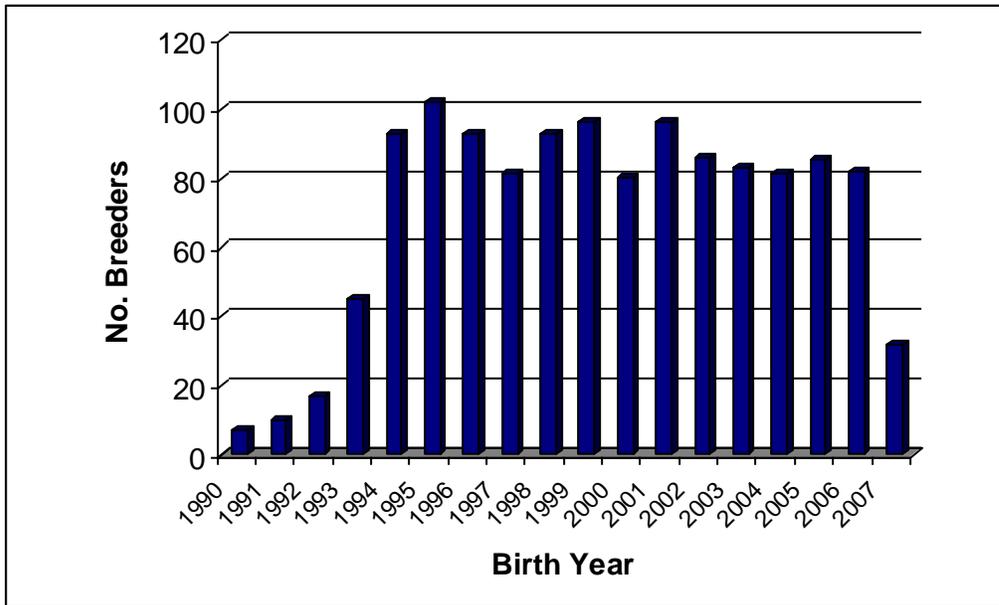
There are 340 breeders in the database. The number of birth years a breeder has registered sheep ranges from 1 to 17, with an average of 3.7 years. The vast majority have only registered sheep for 1 or 2 years, as shown in Figure 4. Conservation of a rare breed requires a careful breeding strategy due to the limited gene pool available from which to select breeding animals. Managing these limited resources is made more difficult if breeders are transient. It is encouraging to see that a fairly large number of breeders have been registering animals for 5+ years.

Figure 4. Number of Birth Years a Breeder has Registered Sheep



Even though there are a lot of breeders entering and leaving the industry each year, the total number of breeders has remained stable since 1994 (Figure 5). Although the breed isn't expanding, it also isn't shrinking.

Figure 5. Number of Breeders by Birth Year



Exchange of genetics

While mapping out the current location of active rams, defined as those who sired lambs in 2006 and/or 2007, it became clear that the majority of rams were

not being retained by their breeders. Of the 149 active rams, 116 (77.9%) were owned by someone other than the person that bred them. This is a surprisingly large exchange of genetics. Not only are the rams being exchanged, they are moving throughout the country. Eighty-six of the 149 rams are owned in a different state than the one in which they were born.

The 2006-2007 lamb crop is primarily concentrated in the Northeast and the eastern section of the Midwest with another group in the Pacific Northwest. The most lambs in this period were born in Illinois (163), Michigan (121), and Oregon (92).

Current breeding population

There were 149 rams and 722 ewes that produced the lambs born in 2006 and 2007 (to date). The birth year of the rams ranged from 1998 to 2006. There were 5 2006 born rams that have already had offspring in 2007, indicating a relatively young age at puberty for such a large-framed breed. Table 1 shows the number of lambs these rams sired in 2006-2007. The industry is using a large number of rams, with the most dominant ram siring only 60 lambs in this period of time; the next highest had 37 lambs.

Table 1. Number of Rams that Sired 2006-2007 Born Lambs

No. '06-'07 lambs	No. rams
1	26
2-5	56
6-10	33
11-15	17
16-20	8
>20	9

The ewes that produced the 2006-2007 lamb crop ranged in birth year from 1994 to 2006. There were 5 2006 born ewe lambs that have already had lambs in 2007, indicating age at puberty is early on the female side as well.

Inbreeding (F)

The pedigree was traced back until ancestors were unknown. The final pedigree file contained 13,558 animals. Since the breed registry is relatively new, the pedigrees are shallow and inbreeding levels are likely higher than shown here. The average inbreeding across the breed was 2.7%, with a range from 0 to 53.1%. The frequency distribution of inbreeding percentage is shown in Table 2. The vast majority have an inbreeding coefficient of 0, but some of these are animals with unknown pedigrees, such as foundation animals.

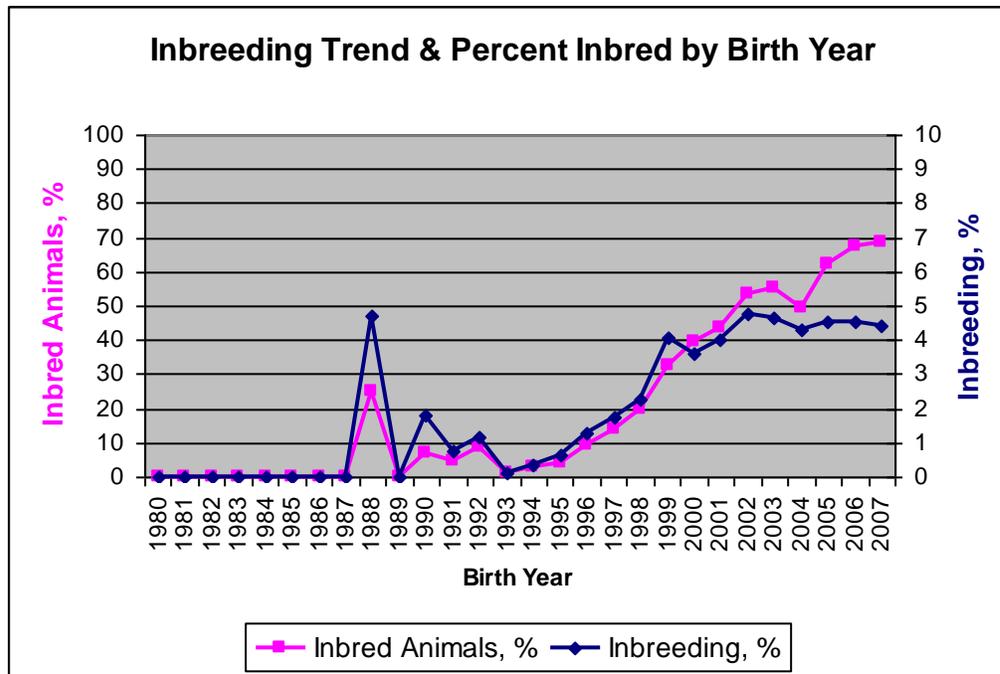
Table 2. Frequency Distribution of Inbreeding Across Lincoln Pedigree

F	n	% of pedigree
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0	9481	69.9
>0-0.05	1701	12.5
>0.05-0.10	971	7.2
>0.10-0.15	582	4.3
>0.15-0.20	277	2.0
>0.20-0.25	363	2.7
>0.25-0.30	97	0.7
>0.30-0.35	56	0.4
>0.35-0.40	23	0.2
>0.40-0.45	0	0.0
>0.45	7	0.05

The average inbreeding level of animals born so far in 2007 is 4.4% with 68.6% of those animals having an inbreeding coefficient greater than 0. The inbreeding trend and percent of inbred animals is shown in Figure 6. Average inbreeding has remained stable over the past 7 years even as the percent of inbred animals has steadily increased.

Figure 6. Inbreeding Trend and Percent Inbred Animals by Birth Year



Cluster analysis

The ever-present decision facing the NAGP is which males to collect for the gene bank. In order to capture the maximum genetic diversity of each breed, we try to sample lowly related males from across the population. The lowest related males should have the fewest alleles in common, allowing us to capture all (or most) of the allelic diversity within the breed. Pedigree relationship data is used

to group the available pool of animals into groups that are similar to each other (highly related) and lowly related to other groups. Then, individual males within each cluster can be targeted for collection. If chosen males are not available, a substitute from the same cluster can be used instead.

The cluster analysis included the relationship between the 149 rams that sired the 2006-2007 lamb crop. These are the males assumed to be available from which to collect. If they are not available, it is known they have offspring, so a son might be available as a replacement. The analysis resulted in 16 distinct groups of rams. The average relationship between the 149 rams was 2.4%. Table 3 shows the average relationship within each of the 16 clusters.

Table 3. Within Cluster Relationship of 149 Lincoln Rams

Cluster	n	Avg. Rel.
1	12	0.12
2	5	0.40
3	12	0.15
4	4	0.49
5	8	0.14
6	8	0.21
7	20	0.12
8	5	0.32
9	12	0.12
10	3	0.42
11	5	0.38
12	11	0.17
13	3	0.42
14	11	0.25
15	7	0.29
16	23	0.01

All of the clusters have a high average relationship with the exception of cluster 16. To put the relationships into perspective, a 0.25 relationship is the equivalent of a half-sib and 0.125 is equivalent to a cousin. Cluster 16 is a cluster where the animals that don't fit anywhere else got placed. They would be expected to have a high level of genetic diversity and should be sampled heavier than other clusters.

As stated earlier, the clusters not only have a high degree of relatedness within each cluster, but a low degree of relatedness between clusters. This can be seen in Table 4.

Table 4. Between Cluster Relationship of 149 Lincoln Rams

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.12	0.02	0.00	0.00	0.00	0.02	0.04	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00
2		0.40	0.00	0.00	0.00	0.01	0.10	0.05	0.01	0.00	0.02	0.02	0.01	0.00	0.01	0.00
3			0.15	0.00	0.01	0.02	0.01	0.01	0.01	0.00	0.03	0.03	0.03	0.01	0.00	0.00

4				0.49	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01
5					0.14	0.03	0.02	0.02	0.03	0.00	0.00	0.02	0.01	0.01	0.05	0.01
6						0.21	0.04	0.04	0.02	0.00	0.11	0.01	0.02	0.05	0.03	0.01
7							0.12	0.08	0.02	0.00	0.04	0.03	0.02	0.00	0.01	0.01
8								0.32	0.01	0.00	0.04	0.03	0.02	0.00	0.01	0.02
9									0.12	0.00	0.02	0.04	0.01	0.00	0.01	0.01
10										0.42	0.00	0.00	0.00	0.00	0.00	0.00
11											0.38	0.01	0.01	0.02	0.00	0.01
12												0.17	0.02	0.00	0.01	0.01
13													0.42	0.03	0.01	0.00
14														0.25	.01	0.00
15															0.29	0.01
16																0.01

Appendix 1 is a list of rams, their cluster, and current owner.

Appendix 1. Rams by Cluster and Owner

ID	Cluster	Owner	Owner State
5245	1	RACHAEL CAVENER	MO
5981	1	CAMPBELL BROTHERS	OH
6242	1	HARVEY WARRICK & ED HAMMETT	MI
6670	1	DUSTI VANDERWENDE	DE
6672	1	MEEK FAMILY	RI
6718	1	MCKENNA MATER	MI
7070	1	ZACHARY TODD & CAMERON MILLINIX	MD
7380	1	ADAM GRAYBEAL	MD
7480	1	K BENJAMIN	MI
7886	1	JESSICA SHELBY	IN
88313	1	CAMPBELL BROTHERS	OH
89029	1	JOSEPH H & CAROL J HADDOCK	VT
7328	2	TAYLOR MEEK	RI
7591	2	MINDY GIBSON	MO
7618	2	BRUCE & ELIZABETH NEWTON	NH
88991	2	BEVERLY T BOERSMA	IL
90399	2	WENDY CAMERON	MA
6621	3	SHARON PRIBBERNOW	WI
6624	3	JOYCE & GERALD COGGINS & FAMILY	NC
6625	3	JAN BRASH	ND
6693	3	BILL & DIANE DUBRAY	WA
6695	3	PENNY DODDS	OR
6953	3	BILL & DIANE DUBRAY	WA
7191	3	PENNY DODDS	OR
7205	3	CHRISTINE L BAZANT	OR
7213	3	KAY & DAVID HATCH	IL
89848	3	WATKINS	WI
C5697	3	JANE LANDVATTER	WI
C88759	3	EDWIN & LINDA WISE	WI
86576	4	PHILIP & LINDSEY REISTER	WA
89633	4	BEVERLY T BOERSMA	IL
89635	4	BEVERLY T BOERSMA	IL
89872	4	LINDSEY REISTER	WA
5881	5	FRANK & BETTY DAVIS	PA
6995	5	DAWN LANTZ	WA

7397	5	KATY CAIN	CA
88364	5	BOB & SHARRY BONE	NM
89351	5	CAMPBELL BROTHERS	OH
C6578	5	JOSEPH H & CAROL J HADDOCK	VT
C88687	5	DONALD E BISCHOF	OR
C88830	5	BRIAN LARSON	MI
6266	6	EILEEN P HORDYK	WA
6268	6	JIM & DONNA LEIN	IA
6734	6	LAUREN SIMPSON	MT
7511	6	LAUREN SIMPSON	MT
87373	6	MIKE CLIFFORD	CA
88838	6	LORAIN POWELL	CA
88921	6	JOSEPH H & CAROL J HADDOCK	VT
89608	6	JIM & DONNA LEIN	IA
5955	7	RACHAEL CAVENER	MO
6603	7	EDWIN & LINDA WISE	WI
6750	7	DUSTI VANDERWENDE	DE
6784	7	SAE JIN TROMBLEY	NY
6988	7	KIERNAN SHEA	NJ
7242	7	FRANK & BETTY DAVIS	PA
87260	7	RICHARD CROME	IL
87438	7	DUSTI VANDERWENDE	DE
87516	7	BEVERLY T BOERSMA	IL
88501	7	JIM & DONNA LEIN	IA
88824	7	BRIAN LARSON	MI
89487	7	MIKE CLIFFORD	CA
89489	7	PER PETERSSON	WA
89568	7	RACHEL MANNING	MD
89701	7	WENDY CAMERON	MA
89729	7	DUSTI VANDERWENDE	DE
89916	7	ELENA BODE	MD
89952	7	SHARON PRIBBERNOW	WI
90208	7	RICHARD CROME	IL
90371	7	KAYLI MOHR	IL
89006	8	DONALD E BISCHOF	OR
89008	8	DIANE KLINGELHOFER	MD
89619	8	PER PETERSSON	WA
89620	8	KAROL WILLIE	OR
89915	8	K MANSFIELD	WV
6446	9	DR ELIZABETH PANTZER	IN
6760	9	JENNIFER GARRETT	MI
6795	9	JENNIFER GARRETT	MI
7167	9	BOB & SHARRY BONE	NM
7699	9	NANCY IRLBECK	CO
88187	9	CHARLOTTE SANFORD-CRANE	MD
88683	9	TRAVIS COGGINS	NC
88751	9	JACKMAN	MI
89268	9	ROY & MYRTLE DOW	CO
89697	9	GARTH & JANE TEN NAPEL	TX
89766	9	BRIAN LARSON	MI

90240	9	JAMIE COLEMAN	CT
6494	10	CHRISTIANE PAYTON	OR
6614	10	CHRISTIANE PAYTON	OR
6973	10	ROBERT LAMOUREUX	CT
6806	11	CHRISTINE L BAZANT	OR
7357	11	SUSAN A HANKS	IN
7362	11	SUSAN A HANKS	IN
86335	11	SUSAN A HANKS	IN
90063	11	NAOMI GUNKEL	PA
6626	12	WATKINS	WI
6792	12	EDWIN & LINDA WISE	WI
6919	12	CHRISTIANE PAYTON	OR
7463	12	CLETUS ZENK FAMILY	MI
87580	12	WATKINS	WI
88333	12	HARVEY K WARRICK	MI
88907	12	RICHARD & DIANNE FETTE	IA
89411	12	NORM PARKER	WI
89438	12	ROY & MYRTLE DOW	CO
89806	12	LAUREN SIMPSON	MT
90781	12	SUSAN A HANKS	IN
87582	13	JIM & DONNA LEIN	IA
89609	13	HAHN	KY
89745	13	EDWIN & LINDA WISE	WI
5592	14	HAHN	KY
6068	14	MIKE CLIFFORD	CA
6558	14	CAMPBELL BROTHERS	OH
6560	14	LORAIN POWELL	CA
6568	14	KATY CAIN	CA
6573	14	ZACHARY TODD & CAMERON MILLINIX	MD
7312	14	MARKUS, MACKENZIE & MARAN TENNIS	IL
7316	14	NOAH DART	IL
7426	14	MIKE CLIFFORD	CA
7432	14	KELLY WRIGHT	MD
7620	14	EMMALINE LONG	NY
6583	15	DIANE KLINGELHOFER	MD
6785	15	CAMPBELL BROTHERS	OH
6862	15	DAVID POPIELINSKI	NY
7092	15	JAY & RACHEL FEELEY	VT
7120	15	SAE JIN TROMBLEY	NY
7287	15	AUBREY DESJARLAIS	CT
7337	15	TAYLOR MEEK	RI
5744	16	ROBERT LAMOUREUX	CT
6334	16	LLOYD & PHYLLIS BURGNER	WI
6653	16	DAVID POPIELINSKI	NY
6775	16	MARKUS, MACKENZIE & MARAN TENNIS	IL
7115	16	ROGER WATKINS	WI
7175	16	JODI MILSKE FAMILY	WI
81562	16	HARVEY K WARRICK	MI
86983	16	JOHN N HARDING	IL
87158	16	DEBBIE BENDER	WI

87440	16	WILLIAM & CELINDA BANKHEAD	MD
87479	16	ROBERT EADE	IL
88550	16	ANDRE MILLER	ME
88705	16	DELBERT A KESSI	OR
89056	16	CODY THOMPSON	WA
89393	16	JOHN N HARDING	IL
89461	16	BILL & DIANE DUBRAY	WA
89462	16	BILL & DIANE DUBRAY	WA
89528	16	BOB HEGGEMEIER	IL
89654	16	RALPH GROEFSEMA	ID
89676	16	AARON W F JOHNSON	OR
89932	16	JOHN N HARDING	IL
90076	16	DONALD WOODS	IL
C7273	16	AI IMPORT	--