PENNSYLVANIA GAME COMMISSION
BUREAU OF WILDLIFE MANAGEMENT
PROJECT ANNUAL JOB REPORT

PROJECT CODE NO.: 06640

TITLE: Beaver Research/Management

JOB CODE NO.: 64001

TITLE: Beaver Management Plan

PERIOD COVERED: 1 July 2016 to 30 June 2017

COOPERATING AGENCIES: None

WORK LOCATION: Statewide

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DATE: 18 September 2017

ABSTRACT As part of population monitoring outlined in the beaver management plan, spring waterfowl survey plots were used measure beaver occupancy. Of 245 plots surveyed throughout Pennsylvania, 20% possessed active beaver sign, while 16% had old beaver sign. The 7-year (2011-2017) average occupancy among physiographic groupings ranged from 1% in the southeast to 40% in the northwest. Over the past 7 years no significant change in beaver occupancy has occurred. The statewide 5-year mean beaver harvest density was 29 beavers trapped per 100 square miles. Average harvest densities ranged from 4 to 150 beavers taken per 100 square miles during 2012-2016. The greatest beaver harvests occurred in Wildlife Management Unit (WMU) 1A and 1B. Five-year mean damage complaint densities averaged 1.3 per 100 square miles. WMUs 1A, 1B, 3C, and 5D had the highest densities of damage complaints with >3 complaints per 100 square miles. We used a beaver management decision matrix to determine bag limit and regulation recommendations using harvest density and damage complaint density information.

OBJECTIVES

To develop and implement a beaver management plan that will stabilize beaver populations within suitable habitats and enhance wetland wildlife habitat in Pennsylvania.

METHODS

Our prior beaver management plan consisted of preseason population estimation, harvest goal setting, and harvest determination. This plan was largely based on the New York Department of Environmental Conservation's beaver management plan (Bishop et. al 1992). The use of

Pennsylvania's most recent beaver management model was discontinued due in part to changes in beaver harvest regulations. Since mandatory beaver tagging was eliminated, analyses of Furtaker Survey results were used to develop regional harvest estimates. Beaver pelt measurement data were no longer collected.

With the adoption of Wildlife Management Units (WMUs) in 2002 and discontinuation of mandatory beaver tagging in 2004, further changes in data collection and analysis were necessary. A new, comprehensive revision of the beaver management plan was implemented to meet project objectives, especially after a change in the harvest estimation method and discontinuation of population monitoring and pelt tagging efforts. The mission of maintaining stable beaver populations in balance with their habitat for the benefit of wetland wildlife species and human users through proper population monitoring, harvest management, and damage control was created and used to identify beaver management plan goals and objectives. Harvest management, population monitoring, damage control, and research needs were addressed in the management plan goals.

Population monitoring

In spring 2017, beaver populations were monitored by conducting ground surveys of 245 random plots established for the Atlantic Flyway Breeding Waterfowl Survey (Fig. 1). While survey participants were conducting their annual spring breeding waterfowl surveys, they were asked to observe beaver sign and report the status of beavers on each survey plot. Beaver status categories were Active (sign <6 months old), Inactive (sign ≥6 months old), or No evidence of beaver activity. To help observers make objective beaver status decisions, we established status category guidelines which included short descriptions and photographs. Based on the beaver status indicators described in the Beaver Status Definitions document, we asked participants to use their best judgment to categorize the beaver status of each plot.

We estimated beaver occupancy both statewide and within physiographic groups of WMUs. Sampling was insufficient to determine beaver occupancy within individual WMUs. In future years, we may be able to conduct additional ground surveys within low beaver density WMUs.

Harvest and complaint density

Measuring biological and social carrying capacities of beaver populations within each WMU, we developed a beaver management decision matrix outlining seasons, bag limits, and other regulations recommendations based on these capacities. Beaver population densities, habitat conditions, and damage complaint levels represented key parameters necessary to construct a decision matrix. The decision matrix would change as parameter and regulatory action information became available.

Beaver population size and habitat condition were lacking at the WMU level. We assumed that harvest density was related to population abundance. Until we obtain beaver population density information at the WMU level, harvest density data will be used as our measure of population density within each WMU. Beaver harvest estimates by WMU for the past 5 seasons were obtained from annual furtaker surveys (Johnson 2016).

Prior to 2010, we estimated WMU-level damage complaint levels using past annual Wildlife Conservation Officer (WCO) furbearer surveys. To divide the total number of beaver complaints reported within a WCO district among WMUs, we calculated the proportion of WMUs within each WCO district and multiplied the total number of complaints by these proportions to achieve WMU-level beaver damage estimates.

Beginning in 2010, we asked WCOs to identify within which WMU each beaver nuisance complaint occurred on the WCO Furbearer Questionnaire (Lovallo and Hardisky 2011). Although somewhat cumbersome recordkeeping for WCOs, this practice greatly improved the accuracy of our data. We were able to obtain WMU-specific damage complaint information directly from this survey. WCOs were also asked to identify and count beaver damage types associated with each nuisance complaint in 2010. We plan to repeat the beaver damage type question on the survey every 10 years to monitor changes in the types of damage complaints reported.

Reproductive monitoring

We determined basic reproductive parameters (litter size, age at first reproduction, reproductive rate) of beaver populations within each WMU or physiographic unit. The only previous fecundity information on beavers was collected nearly 50 years ago (Brenner 1960) and was limited to Crawford County, Pennsylvania. We know little about litter size, intrauterine mortality rates, and age at first reproduction and whether these parameters differ among WMUs.

Measures of reproductive performance and litter size including counts of corpora lutea, corpora albicantia, placental scars, and fetuses are useful in estimating fecundity. Wigley et al. (1984) found that counts of corpora lutea, placental scars, and fetuses yielded statistically similar estimates of litter size, despite pre- and post-implantation losses. Natality and recruitment are key reproductive parameters in monitoring populations. However, many northeastern states and eastern Canadian provinces do not routinely collect this type of information as part of annual monitoring. Those jurisdictions that examine beaver carcasses from harvested, incidentally taken, or road-killed beavers monitor age, sex, reproductive status, and body condition. The sex ratio of trapped beavers often does not differ from 1:1. Sex ratio information does not appear to serve a useful purpose in beaver management (Novak 1987).

As practiced in Pennsylvania's deer management program, reproductive potential can be used as a measure of beaver population health. Habitat for beavers differs regionally. However, we have no measure of what habitat differences might exist nor how these differences affect health and reproductive success. Knowledge of this basic reproductive information is also necessary for population model building.

We collected information on beaver reproductive potential as well as age structure within each WMU or physiographic unit. Beaver carcasses were collected from cooperating trappers during the 2012-2015 seasons. Trappers were offered $5.00 for each useable whole carcass tagged with harvest information and location. A collection quota (maximum) of 200 beaver carcasses was established for each of the 5 physiographic groups of WMUs. For example, physiographic group 1 included WMUs 1A and 1B, physiographic group 2 included WMUs 2A-H, and so on. Up to 1,000 beaver carcasses could be potentially collected each year. We did not collect juvenile (kit) beavers that are less than 1 year old. This youngest age class consists of beavers weighing <28 lbs.

and lacking permanent premolars. Incomplete root canal closure of premolars was used to differentiate adults from subadult beavers. Skulls required boiling to aid in premolar removal. To determine age at first reproduction, females exhibiting placental scars were aged using a cementum annuli technique described by Van Nostrand and Stephenson (1964).

Both male and female carcasses were collected. Because external gender determination of kits and subadults can sometimes be difficult even among biologists (Osborn 1955), we did not depend upon trappers to accurately sex beaver carcasses. Therefore, we accepted adult and subadult carcasses of either gender. Each carcass received from cooperating trappers was tagged with date of harvest, WMU, county, township, watercourse name, and trapper's name.

Four years of monitoring was planned. If the age structure shows no significant variability among WMUs or physiographic groups within Pennsylvania, the data will be pooled into 1 statewide measure annually.

Reproductive tracts were extracted from female carcasses and frozen until examination. Placental scars were counted by placing female reproductive tracts on a light box and examining the uterine horns. Each tract was split and spread over a lighted table. We counted placental scars visible as blood-stained tissue along the uterine horns. Each placental scar was assumed to represent 1 embryo produced by the female. Corpora lutea on the ovaries were also counted as a secondary measure of litter size.

After examination and sample collection, beaver carcasses were composted with layers of sawdust and hay using guidelines established by Penn State Extension (2009). The carcass composting area was fenced to minimize scavenging.

RESULTS

Population monitoring

Of 245 beaver plots surveyed statewide, 20% possessed active beaver sign, while 16% had old beaver sign. Most plots (64%) showed no evidence of past or present beaver activity. Occupancy rates were 30% in physiographic groups 1 (WMU 1A-B) and 3 (WMU 3A-D), while groups 4 (WMU 4A-E) and 5 (WMU 5A-D) remained below 10% (Table 1). Group 2 (WMU 2A-H) remained at a mid-level of 20% occupancy. Over the past 7 years, no significant change in beaver occupancy has occurred. The 7-year (2011-2017) average occupancy rate among physiographic groupings ranged from 1% in the southeast to 40% in the northwest (Fig. 2).

Because of the random distribution of survey plots, sampling was not evenly distributed across all WMUs. Sample sizes of <10 plots occurred in 13 WMUs (Table 2). Where beavers are more densely populated, plot surveys seemed to work well. In areas with low beaver densities, a complete colony count might be achieved by WCOs. In the 2009 WCO Furbearer Questionnaire, over 40% of WCOs believed they could locate and accurately count all known beaver colonies within their districts. Most WCO districts where complete counts were possible occurred in the southern half of Pennsylvania. This was the area where inadequate sampling was taking place using plot surveys. Using both survey plot and complete count data, beaver colony densities could

be calculated for each WMU. Future monitoring efforts should be modified to include complete beaver colony counts by WCOs.

Harvest density

After experiencing slowly increasing trends in the beaver harvest prior to 2004 (Table 3), harvest trends over the past 12 years have fluctuated in most WMUs (Table 4). Recent inconsistencies in methods used to calculate the beaver harvest may have accounted for the wide fluctuations in harvest trends. In 2011, junior combination license holder harvests were added to the total harvest. In 2012, the beaver harvests of senior combination license holders were included in total harvest. These changes in methodology likely influenced harvest trends. However, by incorporating combination license holders, future harvest trends will become more accurate.

Over the past 5 seasons (2012-2016), the mean beaver harvest density across the state was about 29 beavers trapped per 100 square miles (Table 5). Average harvest densities ranged from 4 to 150 beavers taken per 100 square miles. The greatest beaver harvest densities occurred in the northwestern WMUs 1A and 1B (Fig. 3). Moderate harvest densities were found in the west, extreme north, and northeast. Lowest densities occurred in central and southeastern portions of Pennsylvania.

Damage complaint density

Statewide beaver damage complaints over the past 5 years averaged 1.3 per 100 square miles (Table 5). The highest density of damage complaints occurred in WMUs 1A, 1B, 3C, and 5D (Fig. 4). Lowest complaint densities were found in the southcentral and southeastern portions of Pennsylvania.

Beaver management decision matrix

A beaver management decision matrix using beaver harvest density and damage complaint density was developed to determine bag limit and regulation recommendations (Table 6). Entering 5-year means of the most recent harvest and complaint densities into the matrix yielded season, bag limit, and regulation recommendations for the 2018-2019 season (Table 5).

Adjustments to the decision matrix were occasionally needed to accommodate changes in the way the beaver harvest is estimated and shifts in the types of beaver complaints reported to the WCOs. Beaver harvests of junior and senior combination license holders were added to the total harvest beginning in 2012. This data addition increased estimates of harvest and harvest density, requiring an increase in decision matrix thresholds for beaver harvest densities in the high to extra high ranges (Table 6).

Complaint density thresholds were also changed slightly to account for beaver complaints received by WCOs of little or no beaver damage. Social tolerance of beaver damage has decreased in urban and suburban areas. More complaints stemmed from fear and lack of knowledge of beavers and their habits. Adjustments were made to the decision matrix thresholds for beaver complaint densities in all categories (Table 6).

Further development of the decision matrix may be necessary to enhance its applicability and accuracy. However, the matrix in its current form represents a science-based framework for beaver harvest management in Pennsylvania.

Reproductive monitoring

Additional collection of beaver carcasses has ended. Age analysis based on cementum annuli from collected beaver skulls has not been completed. Ages of females with known reproductive history, in particular, would be valuable in determining age of first reproduction.

RECOMMENDATIONS

1. Annually determine beaver population status and obtain beaver damage complaint information by WMU from the annual WCO furbearer questionnaire.

2. Conduct beaver colony counts using ground surveys within each WMU to monitor population levels.

3. Determine age at first reproduction for female beavers within each WMU or other defined unit. Prepare final analysis of reproductive data.

4. Annually conduct the WCO Furbearer Questionnaire to continue to monitor the frequency of beaver damage complaints.

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Table 1. Beaver occupancy rates estimated from ground surveys among physiographic groups (Wildlife Management Unit [WMU] groupings) during 2011-2017.

Physiographic group	2011	2012	2013	2014	2015	2016	2017	R[a]
1 (WMUs 1A-B)	0.42	0.40	0.35	0.47	0.45	0.43	0.30	-0.25
2 (WMUs 2A-H)	0.15	0.23	0.27	0.17	0.15	0.13	0.20	-0.31
3 (WMUs 3A-D)	0.30	0.31	0.27	0.33	0.32	0.28	0.30	0.03
4 (WMUs 4A-E)	0.06	0.13	0.00	0.06	0.06	0.06	0.07	-0.15
5 (WMUs 5A-D)	0.00	0.00	0.02	0.02	0.02	0.02	0.00	0.28
Statewide	0.22	0.24	0.22	0.24	0.23	0.21	0.20	-0.40

[a] Correlation coefficient for 7-year (2011-2017) occupancy rate estimates.

Table 2. Distribution of 245 beaver plots surveyed in 2017 among Wildlife Management Units (WMUs).

WMU	Number of survey plots	WMU	Number of survey plots
1A	24	3C	23
1B	33	3D	17
2A	5	4A	3
2B	2	4B	0
2C	8	4C	4
2D	12	4D	5
2E	10	4E	3
2F	8	5A	9
2G	3	5B	17
2H	3	5C	12
3A	8	5D	11
3B	25		

Table 3. Beaver harvest based on mandatory beaver pelt tagging during 1980-2003 within each Wildlife Management Unit (WMU).

WMU	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1A	351	447	250	471	234	514	401	402	280	311	181	310	384	271	720
1B	1,219	1,646	675	1,499	600	1,588	941	1,160	770	804	558	875	804	726	1,863
2A	46	53	59	63	53	96	47	42	65	32	35	0	62	51	125
2B	113	131	139	151	121	208	159	164	157	134	96	0	178	135	304
2C	126	149	87	141	104	162	116	166	123	111	76	14	141	128	225
2D	129	197	138	169	118	252	195	253	199	211	129	31	163	149	380
2E	101	158	110	144	116	260	224	231	121	119	88	63	136	126	314
2F	482	603	331	583	338	749	564	642	424	406	280	397	421	336	945
2G	444	654	366	531	426	868	696	731	438	385	295	361	512	400	933
3A	272	407	187	333	250	510	438	447	271	251	182	248	299	264	603
3B	324	478	155	237	162	343	254	366	266	273	206	182	222	136	452
3C	812	1,072	349	596	330	685	506	801	788	855	703	538	526	346	1,135
3D	645	717	219	372	266	588	402	582	515	446	359	339	280	260	634
4A	56	59	42	70	34	90	59	173	68	67	32	65	43	49	83
4B	9	14	10	11	8	26	21	26	12	22	14	23	20	9	28
4C	44	55	28	46	46	58	42	54	48	50	51	35	58	35	99
4D	82	84	46	75	62	142	109	147	71	75	49	82	67	66	167
4E	53	75	36	54	48	63	62	70	62	74	64	69	92	56	207
5A	10	7	4	8	5	7	12	16	24	21	8	21	34	34	57
5B	3	5	3	13	3	13	13	21	11	13	10	4	13	22	57
5C	0	7	11	3	2	14	12	7	11	21	25	12	53	11	34
Total	5,322	7,017	3,245	5,571	3,324	7,235	5,272	6,501	4,723	4,680	3,440	3,669	4,510	3,608	9,363

Table 3 cont.

WMU	1995	1996	1997	1998	1999	2000	2001	2002	2003	R[a]
1A	514	672	828	513	564	654	735	391	556	0.60
1B	1,234	1,777	1,942	1,108	1,047	1,170	1,665	563	1,016	0.14
2A	64	236	286	143	133	112	151	94	84	0.55
2B	173	463	550	328	374	478	533	336	389	0.77
2C	91	289	490	327	338	276	415	163	254	0.63
2D	208	472	601	397	428	412	447	235	311	0.67
2E	233	334	454	382	316	332	366	181	227	0.64
2F	694	971	1265	969	891	853	1151	407	600	0.55
2G	763	906	1243	981	851	927	996	401	606	0.50
3A	473	547	707	664	519	522	534	180	343	0.44
3B	338	556	684	518	511	492	648	271	383	0.50
3C	699	1,062	1,398	853	911	761	1,162	407	699	0.25
3D	492	617	727	583	526	362	694	262	402	0.03
4A	67	189	324	218	190	161	211	78	88	0.57
4B	32	62	147	118	78	99	135	31	81	0.72
4C	62	118	151	129	147	106	210	89	141	0.77
4D	132	187	279	167	176	237	261	139	160	0.72
4E	107	233	276	155	194	192	275	117	149	0.75
5A	23	43	100	64	54	80	86	41	56	0.83
5B	31	26	94	74	52	113	132	87	108	0.84
5C	27	47	104	53	93	87	152	73	118	0.84
Total[b]	6,458	9,808	12,648	8,745	8,393	8,426	10,958	4,548	6,772	0.53

[a] Correlation coefficient for 24-year harvest (1980-2003).

[b] Includes variation due to rounding.

Table 4. Beaver harvest from mail survey estimates and correlation within each Wildlife Management Unit (WMU).

WMU	2005[a]	2006	2007	2008	2009	2010	2011[b]	2012[c]	2013	2014	2015	2016	R[d]
1A	2,395	2,285	1,295	762	1,171	1,271	3,197	933	1,142	2,111	2,136	743	-0.17
1B	2,257	2,664	1,976	1,490	2,401	2,437	3,963	1,750	2,752	3,987	5,240	2,204	0.49
2A	386	292	461	762	149	112	684	298	260	415	400	50	-0.27
2B	366	292	106	137	79	128	177	354	182	271	267	124	-0.08
2C	396	715	480	603	159	416	318	407	208	505	484	136	-0.44
2D	732	379	806	535	923	527	885	903	883	1,642	451	99	0.05
2E	257	542	288	410	228	216	307	664	571	433	484	421	0.39
2F	356	628	969	774	605	543	1,604	474	1,220	1,407	1,218	570	0.42
2G	960	574	173	455	615	535	543	720	260	505	451	285	-0.41
2H									208	162	184	111	0.41
3A	851	531	787	307	665	168	861	541	597	758	784	681	0.12
3B	505	942	681	501	189	392	283	414	337	1,010	234	136	-0.38
3C	1,178	1,841	1,113	569	853	863	1,486	265	2,077	1,912	2,253	632	0.19
3D	396	801	528	387	685	719	1,427	336	753	397	567	706	0.08
4A	386	130	106	148	10	64	248	0	104	108	133	37	-0.46
4B	238	119	221	46	30	96	35	26	78	216	250	50	-0.12
4C	495	87	67	216	179	80	307	149	104	144	100	74	-0.44
4D	505	238	221	182	129	120	201	198	675	216	167	173	-0.12
4E	247	141	365	387	109	56	71	485	493	289	284	136	0.10
5A	257	184	288	216	89	32	153	56	130	126	133	12	-0.69
5B	188	303	288	239	139	88	71	190	78	108	50	37	-0.80
5C	119	184	48	57	208	64	649	343	467	126	267	161	0.33
5D	69	76	29	23	0	0	0	164	26	469	117	62	0.37
Unknown	742	260	249	739	89	327	743	41	1,532	289	266	248	
Total[e]	14,281	14,208	11,545	9,945	9,704	9,254	18,212	9,712	15,134	17,606	16,920	7,640	0.15

[a] The harvest mail survey was not conducted in 2004.

[b] Harvests of junior combination license holders were added to estimates beginning in 2011.

[c] Harvests of junior and senior combination license holders were added to estimates beginning in 2012.

[d] Correlation coefficient (2005-2016).

[e] Includes variation due to rounding.

Table 5. Average 5-year (2012-2016) beaver harvest and nuisance complaint densities and proposed season bag limit within each Wildlife Management Unit (WMU).

WMU	Harvest /100 mi^2	Relative harvest density	Complaints /100 mi^2	Relative complaint density	Proposed 2018-19 season bag limit
1A	76.53	high	3.18	high	40
1B	150.48	high	4.07	high	40
2A	15.72	medium	1.14	medium	20
2B	17.58	medium	1.20	medium	20
2C	11.23	medium	0.85	medium	20
2D	32.00	medium	0.96	medium	20
2E	40.80	medium	1.09	medium	20
2F	40.56	medium	1.06	medium	20
2G	14.26	medium	0.49	low	5
2H	16.64	medium	0.93	low	5
3A	44.56	medium	1.51	medium	20
3B	19.22	medium	1.22	medium	20
3C	65.15	medium	3.87	high	40
3D	26.25	medium	2.01[a]	medium	20
4A	4.40	low	0.45	low	5
4B	7.79	low	0.06	low	5
4C	6.65	low	0.31	low	5
4D	10.42	medium	0.50	low	5
4E	19.44	medium	0.39	low	5
5A	7.03	low	0.37	low	5
5B	3.51	low	0.19	low	5
5C	11.03	medium	0.98	medium	20
5D	20.06	medium	3.76	high	20[b]
Statewide	29.47	medium	1.27	medium	

[a] The 5-year average complaint density in WMU 3D barely meets the requirement for a high complaint area rating. We recommend the bag limit of 20 remain unchanged in this WMU until a clear complaint category distinction is apparent.

[b] An unusually high 2014 harvest estimate increased the 5-year average harvest density in WMU 5D from the low to medium category. This change in estimated harvest density would normally increase the recommended bag limit category to 40 per season for WMU 5D. The 2014 level of harvest decreased significantly in subsequent years. We recommend a 20-beaver bag limit for WMU 5D until harvest trends stabilize and are able to assess harvest density more accurately.

Table 6. Beaver management decision matrix using beaver harvest density and damage complaint density to determine bag limit and regulation recommendations.

		Social capacity Damage complaint density (5-year mean)		
	Conditions within a Wildlife Management Unit	Low < 0.75 complaints/ 100 mi^2	Medium 0.75-2 complaints/ 100 mi^2	High >2 complaints/ 100 mi^2
Biological capacity Harvest density (5-year mean)	Extremely Low < 3 beavers harvested/100 mi^2	**Closed season**	B-gripping[a] limit =2 Bag limit[b] = **5**	B-gripping limit =2 Bag limit = **20**
	Low 3-10 beavers harvested/100 mi^2	B-gripping limit =2 Bag limit = **5**	B-gripping limit =2 Bag limit = **20**	B-gripping limit =2 Bag limit = **20**
	Medium 11-75 beavers harvested/100 mi^2	B-gripping limit =2 Bag limit = **5**	B-gripping limit =2 Bag limit = **20**	B-gripping limit =10 Bag limit = **40**
	High 76-200 beavers harvested/100 mi^2	B-gripping limit =2 Bag limit = **20**	B-gripping limit =10 Bag limit = **40**	B-gripping limit =10 Bag limit = **40**
	Extremely High >200 beavers harvested/100 mi^2	B-gripping limit =10 Bag limit = **40**	No B-gripping limit No lodge/dam trap distance restriction[c] Bag limit = **Unlimited**	No B-gripping limit No lodge/dam trap distance restriction Bag limit = **Unlimited**

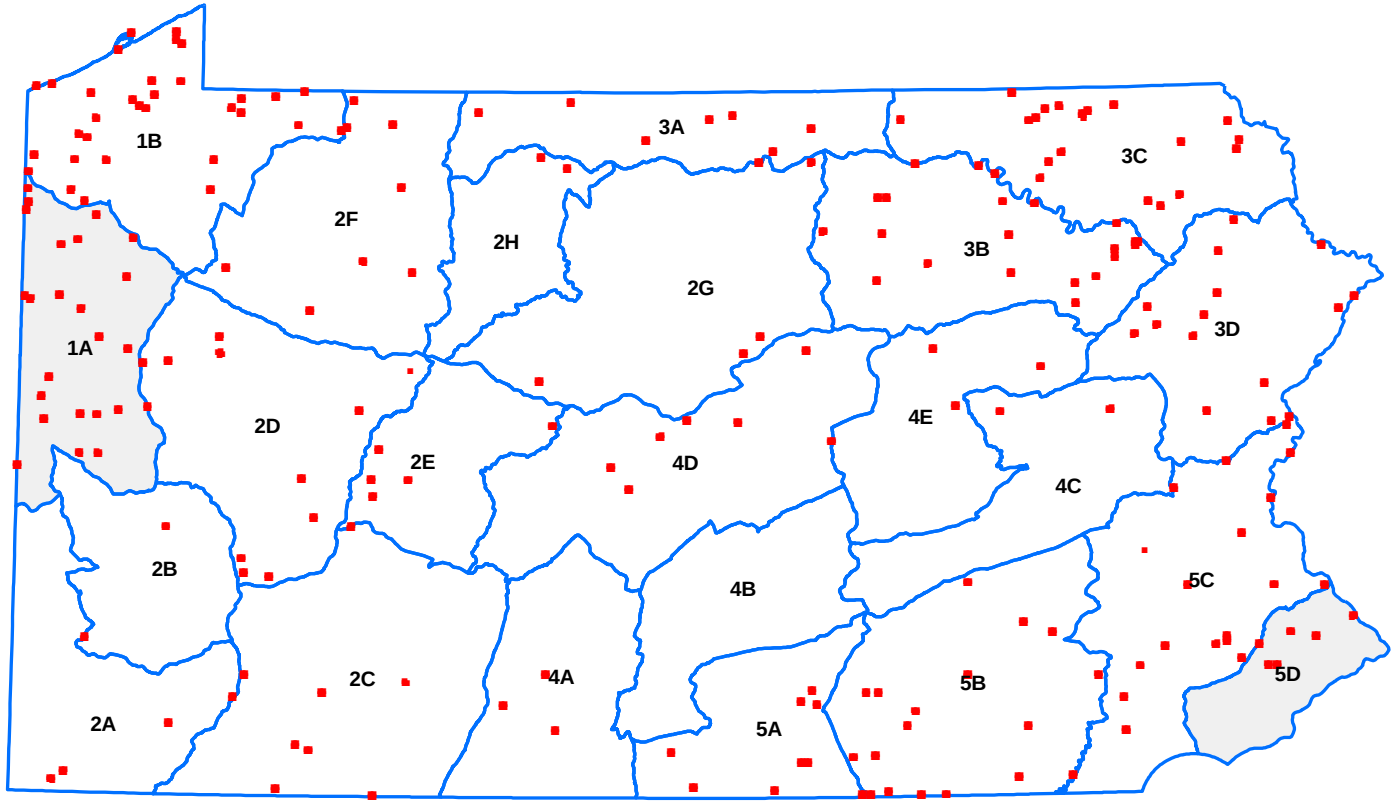

Figure 1. Distribution of beaver plots surveyed within Wildlife Management Areas during spring 2017.

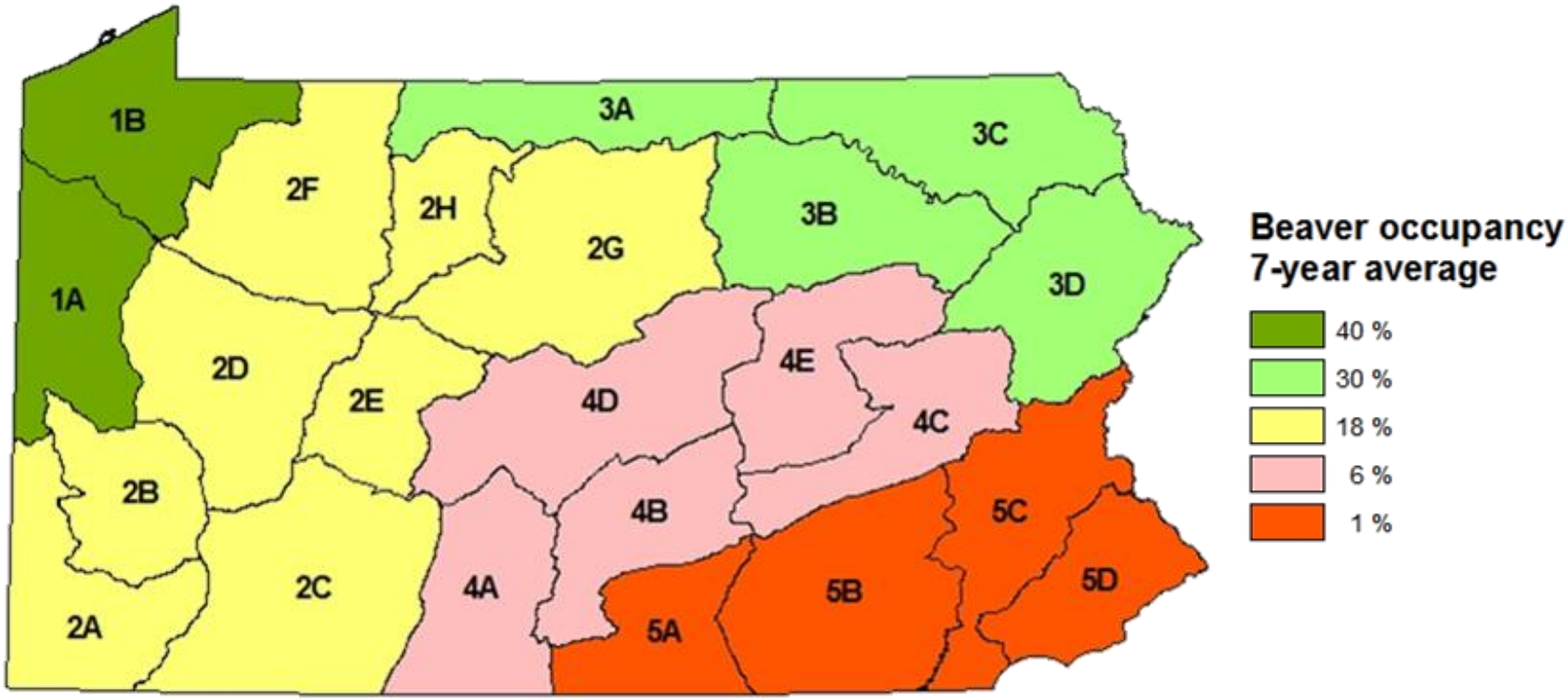

Figure 2. Estimated beaver percent occupancy during 2011-2017 averaged among physiographic groups (Wildlife Management Unit groupings).

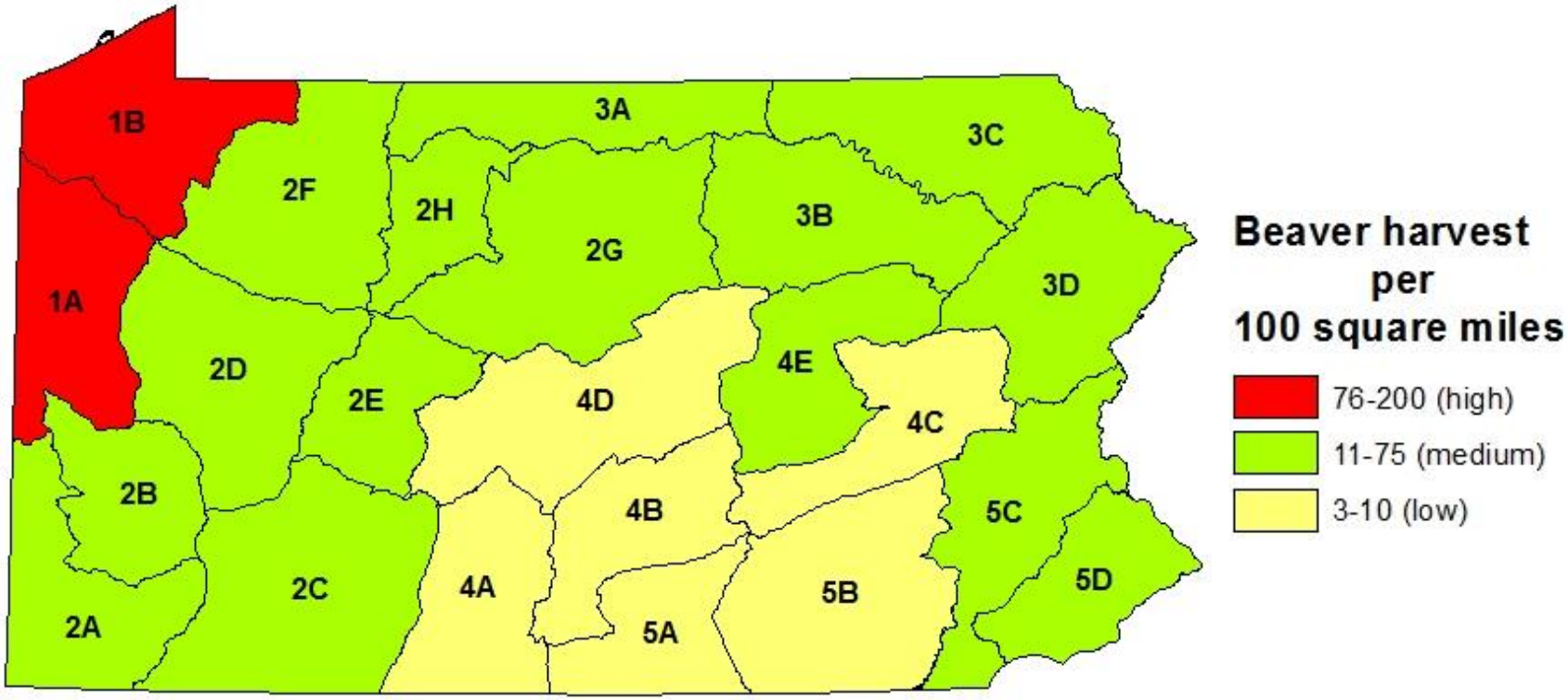

Figure 3. Mean 5-year (2012-2016) beaver harvest density within Wildlife Management Units.

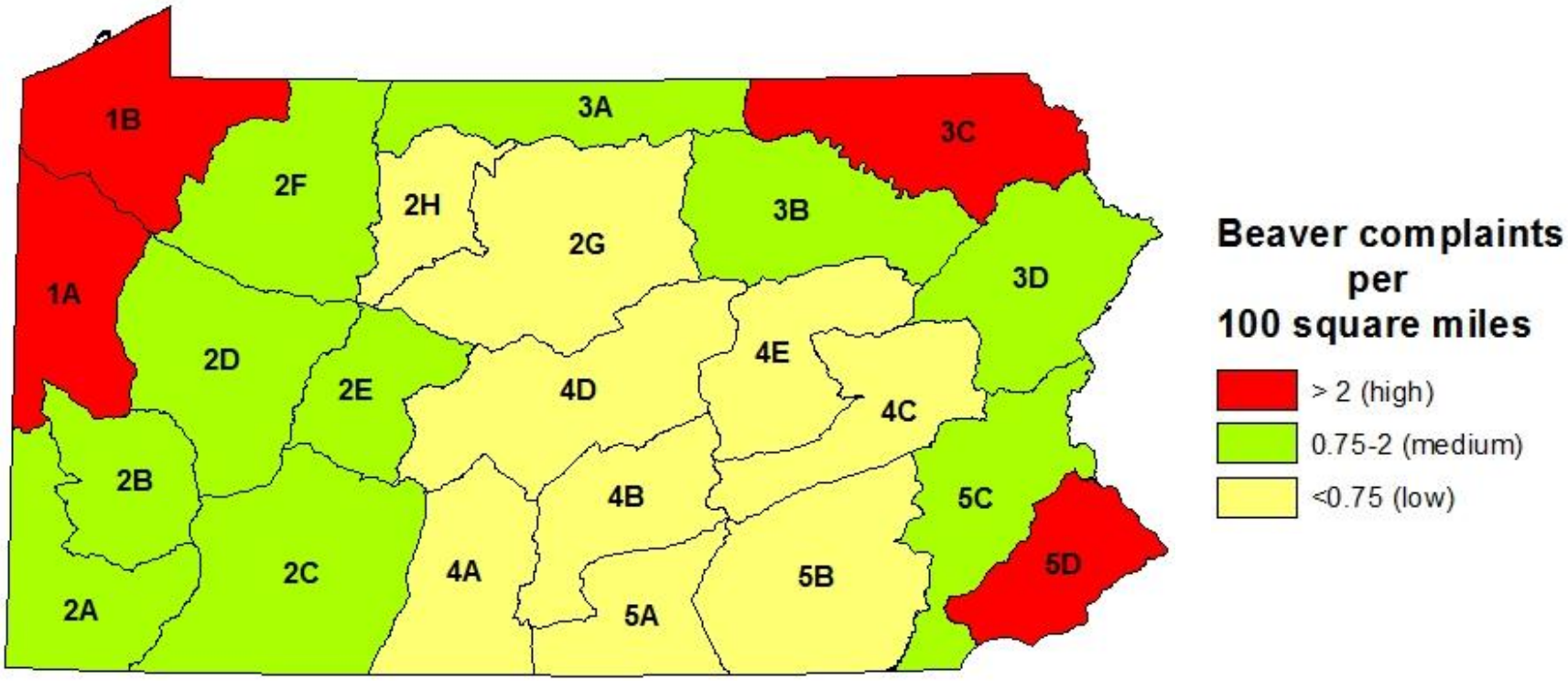

Figure 4. Mean 5-year (2012-2016) beaver complaint density within Wildlife Management Units .