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This project was a joint effort by the Wyoming Game and Fish Department, Ecosystem Science and Management Department and Wyoming Natural Diversity Database (WYNDD) at the University of Wyoming to collect, organize and centralize Wyoming energy-related wildlife monitoring data into a searchable database. State and federal agencies and private industry are required to observe and report the status of specific wildlife species before an area can be used for energy development. However, once the data is collected, it is often stored away within the agency requiring the report. These data were not organized or available to other agencies or the public for evaluation. Wildlife monitoring reports from the Buffalo field office of the Bureau of Land Management were collected as a test to develop and organize a database centralizing this information and making it available to other agencies. The database houses metadata on a wide variety of wildlife species found in Wyoming. In the future, other agencies and organizations can participate by entering their reports into the database. Not only will this transform the paper reports into digital copies, but it will enhance communication and transfer of knowledge between agencies. Combining this information with data already catalogued by WYNDD provides a central location for agencies to submit and find energy-related wildlife monitoring information in Wyoming.

ENERGY DEVELOPMENT AND WILDLIFE MONITORING DATABASE ORGANIZATION IN WYOMING

By

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DEDICATION PAGE

I would like to thank my husband, Nick Walrath, for encouraging me to continue my education, supporting me along the way, and enduring two years of driving back and forth on I-80. I could not have completed this project without his dedicated love and understanding. I thank my parents, Allen and Cheri Jones, for teaching me to appreciate nature and nurturing my curiosity for science. They gave me a childhood filled with camping, hiking, fishing, hunting and exploration, all of which led me down this path. I thank my in-laws, Ron and Kris Brooks, my brother, Gabriel Jones, and all of my friends and family for their love and support these past years. I also want to thank my elementary school teacher, Teresa Clark, for an incredible education and teaching me to never stop learning.

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TABLE OF CONTENTS

LIST OF TABLES/FIGURES

INTRODUCTION

Background

Energy development provides a major source of revenue for the state of Wyoming and has experienced periods of rapid growth and decline over the past few decades. This development includes oil and gas, coal and uranium and wind farms. According to the Petroleum Association of Wyoming (PAW), Wyoming ranked seventh in production of crude oil and second in natural gas production in 2010 (PAW 2010). Such development occurs over large landscapes. For example, the Bureau of Land Management (BLM) estimates that 43% of Wyoming's public lands have wind resources with potential for wind energy development (BLM 2010). Resulting energy resource related land disturbances often lead to direct and indirect impacts on the wildlife and the habitats they use within and surrounding the development, including greater sage-grouse (*Centrocercus urophasianus*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), raptors and prairie dogs (*Cynomys* spp; Sawyer 2006, Walker 2007, Doherty 2008, Smallwood 2009). One of the major direct impacts is the loss or degradation of wildlife habitat (Holloran 2005, Sawyer 2006, Walker 2007). Other adverse impacts to wildlife include physiological stress, displacement, habitat fragmentation, introduction of predators and alteration of habitat function (USFWS 2010).

The future of energy development in Wyoming hinges on harmonious interactions between wildlife species and energy development. Implementation of protective wildlife policies is becoming increasingly more common with regards to wildlife conservation. For example, the greater sage-grouse, once widely populated throughout sagebrush ecosystems, is now a Candidate Species determined as warranted but precluded under the Endangered Species Act (USFWS 2010). Thus, in order for continuous development to occur, managers must make sure certain criteria are met with respect to wildlife species and habitat. For projects occurring on federal land, NEPA (National Environmental Policy Act) requires federal and state agencies, and private industry to monitor and report on the status of wildlife species and habitat associated with proposed energy development (NEPA 2011). Unfortunately, after those data are collected, they are often housed within the agency that collected them and are either forgotten or become inaccessible to other users (Karl et al. 1999). This common scenario is a serious shortcoming and may further exacerbate a lack of communication between agencies. For this information to be valuable, it must be accessible, searchable and available to others. A centralized database will greatly facilitate the accessibility and may even improve the accuracy of wildlife monitoring reports, as well as fill in current gaps in our habitat knowledge (Karl et al. 1999). A database containing all of the energy development related wildlife monitoring data in Wyoming is essential for this information to be useful.

Study Area

Due to the extensive energy development occurring in the Powder River Basin (PRB), the Wyoming Game and Fish Department (WGFD) designated it as the test case to gather wildlife monitoring data. The PRB is located in northeast Wyoming in Sheridan, Johnson, Campbell and Converse counties. Open pit coal mining started in this area during the 1970s and is one of the top coal extraction areas in the United States. Currently the PRB is one of the largest and fastest growing areas of CBNG development in North America (Berquista et al. 2007, Flores et al. 2001). The associated CBNG infrastructure (wells, roads, pipelines, compressor stations, power lines, vehicle traffic and storage ponds) can have pronounced impacts on the surrounding habitat and wildlife (Knick et al. 2003). Vegetation in the PRB is predominately comprised of northern mixed grass communities, agricultural lands and mixed shrub communities including sagebrush (Braun et al. 2002). The Powder River is one of the few remaining free-flowing prairie stream systems that still has an intact native fish population (USFWS 2010). The PRB provides habitat for sage-grouse, grassland and sage-dependent birds, pronghorn, mule deer, elk, a variety of raptors and many other wildlife species. Overlapping development and habitat make this area a valuable source of energy-related wildlife monitoring data.

Objectives

My first objective was to collect and organize energy-related wildlife monitoring reports accumulated by the Wyoming BLM at the Buffalo Field Office in Buffalo, WY. My next objective was to design a user friendly database to store these reports and locate an appropriate organization to permanently house the database. The University of Wyoming houses the Wyoming Natural Diversity Database (WYNDD), which contains information on rare plant and animal species in Wyoming (WYNDD 2011). This database currently provides known locations for species acquired through vegetation and wildlife monitoring efforts. By combining the energy-related wildlife monitoring data with WYNDD, this database will become the primary source for accessible wildlife monitoring data in Wyoming. In the future, agencies may have the ability to send any wildlife data they collect to WYNDD where it will be entered into the database. Agencies may also have the option to enter data remotely. This will enable the database to maintain current and historical records, providing the most information possible. Thus, the final objective of my project was to develop a mechanism or process for database use and expansion.

Thesis Structure

My thesis is organized by how I developed the database. It discusses how I collected and organized the data, developed the database design, constructed and housed the database, and how I generated the analyses. These descriptions are followed by gradient maps created for each wildlife species documented, as well as the total number of reports available for every major category included in the database. The results include the category totals found in the PRB and are followed by a discussion of the database's capabilities and its future management. A brief conclusion ties these components of my thesis together.

MATERIALS AND METHODS

Data collection

Wildlife monitoring reports accumulated by the Buffalo Field Office of the Wyoming BLM were used for this project. The WGFD prioritized the field offices by amount of energy development in the area and the PRB was determined to be the region to collect wildlife monitoring reports related to energy development. WGFD made the initial contact with the supervisory wildlife biologist at the Buffalo Field Office and they agreed to participate in this study. I made several visits to the Buffalo Field Office to collect the data over a period of four weeks in the winter of 2010.

Set-up

At the Buffalo Field Office, wildlife monitoring reports were filed in both paper and digital format. The majority of the reports are in paper format. The supervisory wildlife biologist provided a compact disk with all of the digital wildlife reports available and a printed list of those reports. I used this printed list to compare with the paper reports to avoid duplications. The paper reports were filed in a binder with other documents related to that Plan-of Development (POD). These binders are labeled by the name of the POD and the proponent and are then filed alphabetically in a POD room at the field office.

Due to security protocol, non-BLM individuals must be accompanied by a BLM employee in the POD room. One option was to have a BLM employee in that room at all times while the reports are being collected. Because this would have been a very time consuming and inefficient process, it was decided to move the reports into a public room of the BLM office to scan them . The lead supervisory wildlife biologist loaded as many binders as possible onto a cart and took them from the POD room to the public room. This allowed me to have access to the reports without impeding the work of the BLM employees assisting with the collection. A telephone was available in the public room. When I scanned all of the reports, I called the assisting BLM employee to take the POD binders back to the POD room and re-stock the cart with the next set of binders.

Scanning Process

A portable duplex scanner was connected to a laptop computer in the public room. I sorted through each binder to locate the wildlife documents. Usually, the documents were separated with labeled tabs and the wildlife documents could be found after the “Wildlife” tab. However, not all binders contained tabs and the wildlife reports could be found anywhere within them.

After I located the wildlife documents, I took each report out of the binder and placed it in the scanner. The duplex scanner allowed for both sides of each page to be scanned at once, which was critical for efficiency in this process. I had to monitor the scanning process because many of the documents had creases or tears in them, which caused the scanner to jam. Once a document was scanned onto the computer, it needed to be checked to ensure that no pages were missing and that the final content was readable. If not, I rescanned that document. This did not include how the page was oriented, since that could be edited at a later time. While skimming through each report for scanning mistakes, I recorded the basic information and wildlife species that were included in the report to later inform me of potential categories to consider in the database design.

Once the digital document was acceptable, I converted it to a PDF file and saved it into the appropriate folder. When saving the reports, I gave them descriptive names, so they could later be easily identified. The names consisted of the proponent, the POD name, abbreviated survey type and the year. If there were multiple reports within a year, then the month was included, as well (e.g., AnadarkoBeta_COA2003, DevonHouseCkN_BERS1_2006). I backed up all new files on an external hard-drive after each day of scanning to protect from corruption or deletion. Some surveys contained information on multiple PODs and had copies in each POD's binder. Keeping unique file names corresponding with the survey prevented scanning duplicates of those surveys. After the survey was scanned and saved, then I placed it back in its original place in the binder and scanned the next survey.

I scanned most of the wildlife surveys and included them in the database. These surveys consisted of general wildlife monitoring reports, annual conditions of approval, raptor monitoring, bald eagle (*Haliaeetus leucocephalus*) roost surveys and various other report types. However, if a report could be found in a NEPA (National Environmental Policy Act) document, then it was excluded from scanning and the database because it is already accessible on the BLM website (Bureau of Land Management 2012). These NEPA documents included reviews of PODs by the U.S. Fish and Wildlife Service (USFWS) and threatened and endangered species biological assessments.

Shapefile Data

Each BLM field office has spatial boundary data, or a shapefile, for every approved POD in their region. The Geographic Information System (GIS) specialist at the Buffalo Field Office had access to that data and was able to send it to me via email to be included in the database. Since the PODs are approved, they are treated as public information and can be included. These shapefiles allowed me to combine the digital reports with their corresponding spatial data. However, there were some difficulties when it came to matching each report to a shapefile. The POD names for some shapefiles differed from the names included in the report. This discrepancy was due to the proponents submitting a map with a different POD name than the wildlife monitoring report, which then caused the shapefile to be labeled with a different name. For example, a map may be submitted under the name “Bear Draw Alpha,” while the report is titled “Bear Draw 1.” Another issue I found was that some PODs may have the same name, but different proponents, since the PODs are typically named after some geographical feature and multiple proponents could be developing in the same area. So, when combining the reports with the shapefile data, I thoroughly monitored the operators and names included in the shapefile attribute table. If a POD was in “pending” status, then it was not included in the shapefile bundle. Some of the wildlife monitoring reports were conducted for pending PODs, so they were included in the database without spatial boundary information.

Data Organization

Editing

Once I had scanned all of the reports, they needed to be edited a second time. I used a PDF editing software called CutePDF (AcroSoftware Inc.) for this process. Many times, the duplex scanner would invert pages in a document and they would need to be rotated to the correct position. Some pages were duplicated in the digital copy, so the extra pages needed to be deleted. The title pages of some reports were too dark in the scanned copy and also needed to be deleted. This second round of editing was done to catch any mistakes that were missed or postponed. I postponed any editing that could be done later to save time at the BLM field office. At this time, the digital files that were provided by the BLM office were primarily saved as Microsoft Word documents and needed to be converted to PDF files. I converted and combined them with the scanned documents.

After I edited all of the reports, I reduced their file size. Although PDF files are relatively small in size, space is always something to consider when populating a database. Therefore I reduced the file size as much as possible will prevent future space issues. Using PDF editing software from Adobe, I reduced the file size of all of the reports. It is important to note that during the editing phase, I kept the original copies of all reports on an external hard drive, in case an editing procedure failed and corrupted or deleted files.

Documentation

I met with the WGFD, BLM, WYNDD, U.S. Geological Survey (USGS) and the University of Wyoming to explain what I found in the Buffalo BLM Field Office wildlife monitoring reports and determine what should be included in the database. My focus was on wildlife species or groups that are of special concern for the state of Wyoming and may be impacted by energy development. Due to time restrictions and the amount of data needing to be searched, I categorized most of the wildlife data found into groups. These groups included a variety of species. However, a particular species can only be determined by reading the report itself. For example, if a report contained information on a raptor species it was filed under the "raptor" category. There were 19 raptor species included in the reports in the PRB and creating separate tables and relationships for each one in the database would have been extremely time consuming and may not be necessary for the majority of the searches done. WGFD, BLM, WYNDD and USGS expressed they would be more interested in knowing the general raptor information in an area, rather than focusing on a specific species.

After meeting with the interested parties, I created a list of the wildlife species and groups to include in the database. I read through each report and included a wildlife species or group if the report contained information on its presence or absence, locations, habitat, habitat suitability, sightings or sign. I initially copied the report information into a Microsoft Excel file, which allowed me to document all of the reports' information before creating the database. This ensured that all of the necessary information was accounted for and the database was designed correctly the first time through.

For each report, I recorded general information regarding the survey area and who generated the report. I created a "Region" category in the database, which specified the general area the information was collected. This varied among agencies. For instance, the BLM Buffalo Field Office reports were located in the PRB region. I created an “Agency/Field Office” category, which included the organization and the specific office housing the reports. I made a “POD” category including the name of the surveyed area. Each report included the company developing the area, which I entered into the “Proponent” category of the database. The reports also included the companies contracted to monitor the site and write the report. I created a “Contractor” category for this information. If the report mentioned it, I recorded the type of development that was proposed or occurring in the survey area and listed it in the category “Development Type.” Most reports included the date the report was submitted, thus I created a category called “Report Date.” I entered the date as mm/dd/yyyy, although some reports did not have all of that information. If the date was not specified on the report, then the stamp date of submission was entered. If the exact day was not specified, then the last day of the month was entered. Finally, I recorded the type of survey that the report fell under in the “Report Type” category. This was a general classification that I formed based on the main groups of reports from the PRB. This classification may change as the database progresses. All of this information regarding production of the report allows the user to search the database by categories other than wildlife species.

I formed a category for raptors, which included the following species: American kestrel (*Falco sparvarius*), barn owl (*Tyto alba*), burrowing owl (*Athene cunicularia*), common raven (*Corvus corax*), Cooper’s hawk (*Accipiter cooperii*), ferruginous hawk (*Buteo regalis*), golden eagle (*Aquila chrysaeotus*), great horned owl (*Bubo virginianus*), long-eared owl (*Asio otus*), merlin (*Falco columbarius*), northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), red-tailed hawk (*Buteo jamaicensis*), short-eared owl (*Asio flammeus*), Swainson's hawk (*Buteo swainsoni*) and turkey vulture (*Cathartes aura*). Although not raptors, black-billed magpie (*Pica hudsonia*) and Canada goose (*Branta canadensis*) were recorded since they tended to occupy raptor nests in many instances. The reports also contained information on nests that the species could not be identified, so they were categorized as "unknown." Raptor information was found in its own section of the reports and usually contained nest site data.

I also created an "Eagle" category, which included bald and golden eagles (*Aquila chrysaetos*). Bald eagle information was generally included in its own section of the report and sometimes had a separate survey done for winter roosting because they are a species of greatest conservation need (WGFD 2010). Golden eagle information was found in the raptor section of the reports. I developed a separate category for ferruginous hawks due to their susceptibility to impacts from energy development and WGFD's interest in their population trends (WGFD 2010). Ferruginous hawk information was also found in the raptor section of reports.

Greater sage-grouse (*Centrocercus urophasianus*) had their own group in the database because they are a Candidate Species and of great concern in Wyoming (Endangered Species Act; USFWS 2010). I usually found sage-grouse information in its own section in the reports. However, sometimes I found it in a section for grouse species, which also included information on sharp-tailed grouse (*Tympanuchus phasianellus*). Sharp-tailed grouse had a category of their own in the database and their information was located in the "Grouse Species" section of the reports.

I created a group for black-tailed prairie dog (*Cynomys ludovicianus*). Although black-tailed prairie dogs were removed as a Candidate Species from the Endangered Species List in

2004, they are labeled a species of special concern by WGFD as a result of their declining populations and importance to other species (WGFD 2005). Their information was found in its own section of the reports, usually labeled “Prairie Dog Survey.”

Mountain plover (*Charadrius montanus*) are a species of greatest conservation need and were given their own category in the database (WGFD 2010). The mountain plover is very sensitive to human activity and loss of nesting habitat. Information on this species can be found in its own section of monitoring reports under “Mountain Plover Surveys.”

I included a category for black-footed ferrets (*Mustela nigripes*). The WGFD is interested in black-footed ferrets and their habitat since efforts to eradicate prairie dogs led to near extinction of the species. Recent breeding programs and reintroductions have led to a slow recovery (Jachowski and Lockhart 2009). Any information included in a report concerning habitat suitability could be valuable in their recovery. It is important to note, that although some reports did include information on black-footed ferret habitat, most did not have surveys conducted for the ferrets after 2003. This was due to the U.S. Fish and Wildlife Service issuing a “block clearance” in February of 2004 stating black-footed ferret surveys were no longer required in black-tailed prairie dog and most white-tailed prairie dog (*Cynomys leucurus*) colonies in Wyoming (BLM 2005). Their information can be found under the section “Black-footed Ferret Surveys.”

There was no specific canid species requiring its own listing in the database, so I created a general “Canine” category. If there was a survey performed for a canid species, it was usually for swift fox (*Vulpes velox*). However, some reports included coyote (*Canis latrans*) and red fox (*Vulpes vulpes*) sightings in the “Other Wildlife” section.

Although the collected wildlife reports did not contain any surveys for feline species, I created a “Feline”category in case future reports did. A few reports contained information on habitat suitability for threatened and endangered species. Those reports included habitat suitability for Canada lynx (*Lynx canadensis*) in the surveyed area. A handful of reports documented sightings of bobcat (*Lynx rufus*) in the “Other Wildlife” section.

Due to their importance for WGFD, I included big game species in the database, even though there were limited surveys done for those species in the PRB. I placed the big game species into three main categories in the database, “Elk,”“Deer” and “Pronghorn.” The “Deer” category includes information on both white-tailed (*Odocoileus virginianus*) and mule deer. If the reports included big game species data, they were usually in the form of sightings found in the “Big Game” or “Other Wildlife” section.

Amphibian data were prominent in the reports, so I created a category labeled “Amphibian.” Usually, the reports contained amphibian sightings or habitat suitability in the “Other Wildlife” section. However, in the Cutler Draw POD, there were three surveys performed for northern leopard frogs (*Rana pipiens*) in relation to discharged CBM water. Other common amphibian species documented in the other reports included the spotted frog (*Rana luteiventris*) and the western toad (*Bufo baxteri*).

I included a general “Reptile” category because reports would often include sightings of reptile species in the “Other Wildlife” section. Some common reptile species that were documented are the Great Basin gophersnake (*Pituofis catenifer deserticola*), western painted turtle (*Chrysemys picta belli*), plains garter snake (*Thamnophis radix*) and the desert horned lizard (*Phrynosoma platyrhinos*).

Although there was very limited data on fish species, I included a general "Fish" category in anticipation that there may be more data available in other areas around the state. The only fish data that I found in the PRB reports were habitat suitability presence/absence for Yellowstone cutthroat trout (*Oncoryhynchus clarkii bouvieri*). This information could be found in the "Sensitive Species" section of some reports.

There were several wildlife species that did not fall in the above categories, but were mentioned in the "Other Wildlife" or "Sensitive Species" sections of the reports. To include those species into the database, I created a very broad "Other" category. As the database progresses, some of these species may have their own category created, but for now this is the only method to search for them. Examples of species that can be found in the "Other" category include: Brewer's sparrow (*Spizella breweri*), loggerhead shrike (*Lanius ludovicianus*), sage thrasher (*Oreoscoptes montanus*), fringed myotis (*Myotis thysanodes*) and lagomorphs (hares and rabbits).

Although wildlife information was the focus of this database, there was other data included in some reports that may prove useful for users who are interested in habitat or general information about the survey area. Many of the reports included a project area description, which often included data on species of shrubs, grasses, forbs, cacti, legumes and trees found on site. I created a "Vegetation" category for that data. The habitat descriptions often included major drainages and watersheds in the area, so I created a "Hydrology" category. This category includes data on major drainages/watersheds, surface water, groundwater or water quality in an area.

Several of the reports included surveys that had been performed for special status plants, such as the Ute ladies'-tresses orchid (*Spiranthes diluvialis*) and blowout penstemon

(*Penstemon haydenii*). If the report held information on presence or absence, locations and/or habitat suitability of these plants, then I recorded this in the database. Plant surveys often included soil information, so I created a "Soil" category, as well. If the report had data on soil classification, composition or chemical properties in area, then it was recorded in the database.

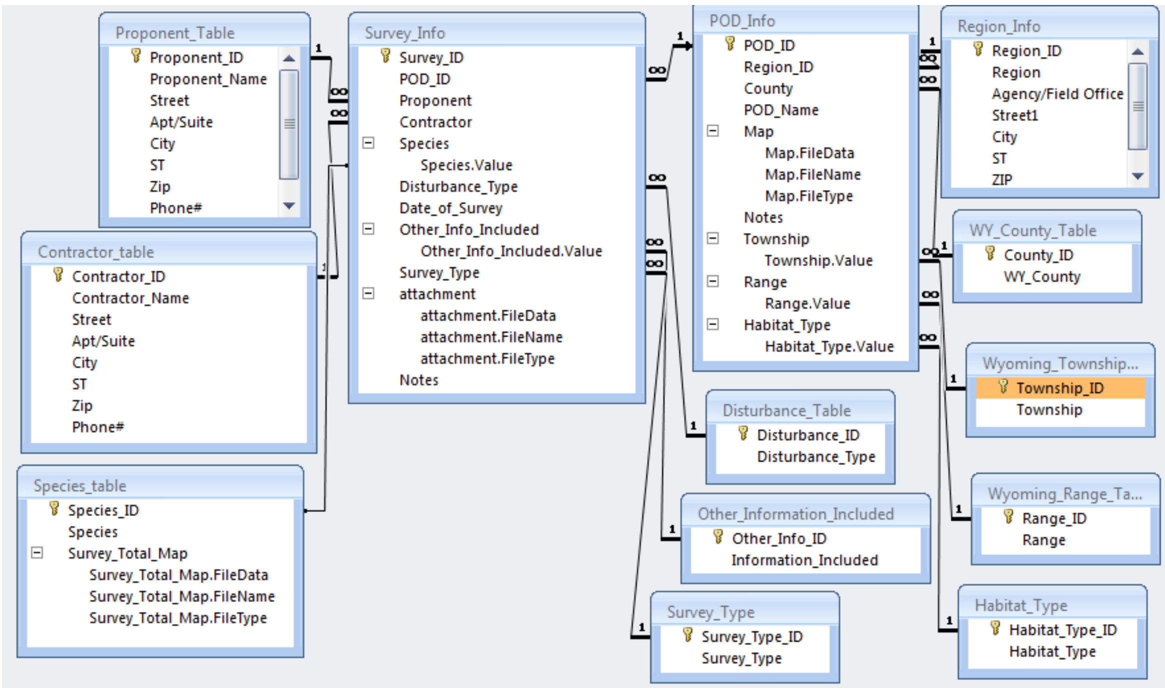
The project area descriptions often included the average climate and social uses of the area. If a report contained data on weather conditions, precipitation or temperature, then it was included in the "Climate" category. Some reports recorded major land uses in the area, so they were included in the "Social/Economic" category. I also created a "Spatial Data" category, which was used if the report contained spatially explicit coordinates, the township(s), range(s) and section(s) or a map of the project area.

Since this was a pilot project that had a limited dataset, categories in this database were created based on the PRB reports. However, as this database expands, there may be other information managers will want included. In anticipation of this, I created some other categories current reports did not have in them. One is a "Historic/Cultural" category. Some reports may include historic or cultural land uses in the project area description, such as a Native American burial ground. This information may not be pertinent to wildlife managers, but could be useful to others. I also created an "Ecological Site Description" category. Ecological site descriptions (ESD) are useful for managers interested in interactions among vegetation, soils and land management (NRCS 2011). ESDs are available for many areas in the state of Wyoming and could be documented in future wildlife monitoring reports. Including a category for this information provides another source of valuable habitat information in a project area.

Database Design

During meetings with the WGFD, BLM, WYNDD, USGS and the University of Wyoming, we discussed how the database should be designed based on types of searches users would be performing. WGFD, BLM and WYNDD all expressed that searching by wildlife species included in the reports and location of the surveys would be their primary method. WYNDD and the USGS wanted to also be able to search for plant and habitat information. In an attempt to make the database as comprehensive as possible, I made the database searchable by all of the categories included in the "Documentation" section. This allows the database to meet the needs of a variety of users. I met with the University of Wyoming's Information Technology Specialist to compose the database design (Figure 1).

Figure 1. Database table design, table population information and their corresponding relationships.



Database Construction

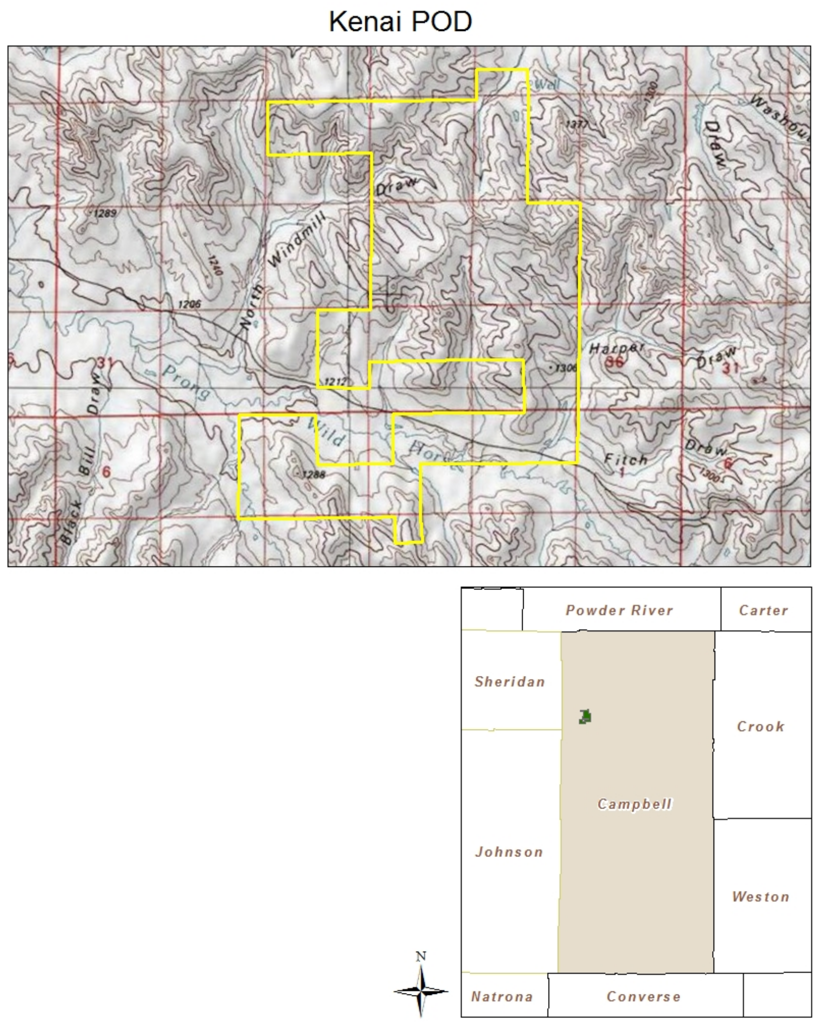
The first step in creating the database was to develop the main tables and populate them with the appropriate information. To begin this process, I started with the broadest and worked towards the more specific search topics. The region in which reports were collected resulted in the most panoptic results. In the "Region" table, I included fields for the basic information of that region: region ID, region name, agency/field office, street name, city, state and zip code. A unique identification number was assigned to every table entry so the database can keep track of records and ensure no duplications occur. This was done for every table and its corresponding entries. The region will vary among agencies because field offices will differ in their number throughout the state and therefore their coverage of authority. For the collected reports, the BLM Buffalo Field Office monitors the entire PRB, so that is their region. This will enable the user to search for wildlife data in large sections of the state and by the agency housing the reports.

The next scale down to search is by the area surveyed, the POD. The "POD Information" table included as much spatial information as possible. The POD table includes the following information: POD ID, region ID, POD name, county, township, range, a JPEG map and the habitat types found in the area. The region ID was included in the table so a relationship could be assigned to the region table. A POD is designated by the BLM and the oil and gas industry, so unless the user is familiar with that process, they may not know where the "Albatross" POD is located. To minimize confusion, I included the county, township and range in the table. To determine the county a POD was located in, I had to use ArcMap10 (Environmental Systems Research Institute). I uploaded the POD shapefiles and created a spatial join to the USA county layer provided by Environmental Systems Research Institute

(ESRI) through ArcGIS online. I used this same method to determine which townships and ranges a POD was located within. I created a spatial join between the POD shapefiles and the township and range layer provided by the Wyoming Public Land Survey System (PLSS), also found through ArcGIS online.

One of the major limitations encountered using Microsoft Access is difficulties providing spatial data to the user, especially if the user does not have access to ArcGIS. To address this issue, I created JPEG maps of each POD and provided them in the POD table. Each map, in layout view, displayed the POD and its immediate geographic features in one data frame and an inset map of where it was located in its corresponding county in another data frame. I overlaid the POD of interest with the USA Topographic Map layer provided by the National Geographic Society through ArcGIS online. I used a 1:60,000+ scale because a larger scale resulted in poor resolution when the JPEG was resized. This map allows the user to identify major land features in the area. In order to have the desired county highlighted, I used the "erase" tool in ArcMap to create a layer from all other counties. This gives the user a quick and easy reference to identify POD locations in the state (Figure 2).

Figure 2. A JPEG map created for the Kenai POD in Campbell County, Wyoming, USA.



I generated a map for every POD with an available shapefile, which resulted in over 500 JPEG maps available in the database. This large amount of data took up space in the database, therefore I used Adobe Photoshop to reduce their file size. I resized each map's resolution to 72 pixels/inch and chose an image size of 6 x 7.76 inches. These specifications resulted in a picture clear enough to discern the topographical features in each POD but took up as little space as possible. To save time, I used the "Automate Batch" function to repeat sizing steps for every POD map.

I made tables for township and range data. I populated these tables with the all of the townships and ranges found in Wyoming. After I executed the spatial join of the township and range layer with the POD layer in ArcMap, I was able to record in the database the township(s) and range(s) each POD overlapped. This will allow the user to either search by POD to determine the township(s) and range(s) to which it relates or search by the township and range if the POD name is unknown. I also created a "County" table to enable the database to search by county. I used the same spatial join method to determine the county each POD occupied.

Some users may be more interested in the general cover types of an area, rather than a specific wildlife species. To accommodate this possibility, I created a table for the cover type(s) found in each POD. After consulting the WGFD, BLM and USGS, we determined the best cover type to use would be the USGS SageMap. This method defines land cover based on its relation to sagebrush because its primary use is to determine sage-grouse habitat suitability (USGS 2012). Using the SageMap shapefile in ArcMap, I created a spatial join with the POD layer to determine what cover types could be found in each POD. I populated the "Cover Type" table with this information. SageMap breaks land cover into five main cover types:

sagebrush, perennial grass with sagebrush loss, annual grasses, conifer encroachment and non-sagebrush.

The next main table I developed was the “Report Information” table. This table allows the user to search based on material found within the report. This table includes the following fields: report identification number, POD name, proponent, contractor, development type, report type, report date, wildlife species included in report, other information included in the report, a PDF attachment of the report and notes. Most of these categories have their own table linked to the “Report Information” table. This enabled me to create combination boxes in the “Report Information” table providing the user with a list of options to select from when entering data. Giving the user these options, rather than allowing them to type it in themselves, keeps the database consistent and accurate. Including the POD name in this table provides a link the POD’s spatial information with each survey record. When a report record comes up in the database, it also pulls up all of the spatial information for that POD. This gives the user all information available for that record and eliminates having to do another search.

I produced a “Proponent” table to link to the “Report Information” table. The proponent is the organization planning, is currently or has developed the POD (e.g., Lance Oil and Gas Company, Incorporated). The “Proponent” table includes: a proponent identification number, proponent name, address of the proponent and its phone number. Only the proponent name is connected to the “Report Information” table. However, contact information is available if needed and keeps the proponent information as accurate as possible.

I created a "Contractor" table to connect to the "Report Information" table. The contractor is the company hired to monitor the site and write the report (e.g., Big Horn Environmental Consultants, Sheridan, WY). The "Contractor" table contains a contractor identification number, contractor name, contractor's address and phone number. As with the "Proponent" table, a search will only produce the name of the contractor that wrote the report, but other information is available if needed.

I created a "Development Type" table listing the different types of disturbances occurring throughout the state. This table includes: coal bed natural gas, oil, oil/gas, coal, power line, water pipeline, carbon dioxide pipeline, wind and other. Most reports listed the type of disturbance occurring on the site in the first paragraph or in the "Project Area Description" section of the report. However, some did not specify, but it could be inferred in the report that it was some sort of oil or gas development, so they were labeled in the general oil/gas category.

The WGFD expressed a need to possibly search the database by the type of report. To accommodate this need, I documented the description or purpose of the report when I went through it. I developed the following types of reports: multiple wildlife species, single wildlife species, conditions of approval, raptor nest occupancy, bald eagle roost, bald eagle nest, special status wildlife species, special status plants, reclamation wildlife, mitigation/exception request, update, amendment, alternative analysis, map and other. Many of the reports did not specify their purpose and just included several wildlife surveys. These reports were categorized under "Multiple Wildlife Species." If only one species was surveyed, it was categorized under the "Single Wildlife Species" type. All of the other report types were clearly stated in the title or introductory paragraph of the report.

The main purpose of this database was to house wildlife data, so the user needed to be able to search by wildlife species included in each report. I created a “Wildlife Species” table that contained all 17 wildlife groups described in the above “Documentation” section (raptor, ferruginous hawk, eagles, sage-grouse, etc.). It also contained an ID for each species and a map of the PODs that have reports with information regarding that species. This table allows users to search for a certain species, but also view other species included in each report.

I generated an “Other Information” table containing miscellaneous information categories. As mentioned in the above “Documentation” section, many of the reports included habitat or land use data. Those 10 main groups are listed in this table (vegetation, special status plants, soil, etc.). This allows the user to search by and view all of the other information that may be included in a report.

After the main tables were in place and populated with the appropriate information, I created relationships between them. A relationship is “a connection established between a pair of tables (Hernandez 1997).” This connection permits the database to pull up information from multiple tables and reduces redundant data. For example, when users enter data into the “Report Information” table, they are given a list of the different wildlife species to select. This list, or combination box, is a result of the connection between the “Report Information” and “Wildlife Species” table. When the user selects a species from this list, the database retrieves that information from the “Wildlife Species” table and displays it in the “Report Information” table. If the database did not have this relationship, then the user would have to type in each species, which would take up a lot of text space in the database and result in a large amount of redundant data. The relationship saves time and space. Figure 2 displays the relationships between the tables.

This database has two primary tables to which all other tables are related; the "POD Information" and "Report Information" tables. Each related table has a one-to-many relationship set between it and a primary table. This simply means a single record in the related table can be connected to one or more records in the primary table (Hernandez 1997). For example, a type of development from the "Development Type" (related) table can be applied to multiple report records in the "Report Information" (primary) table. The "POD Information" primary table has many-to-one relationships with five related tables: region information, Wyoming counties, Wyoming townships, Wyoming ranges and habitat types. The "Report Information" primary table has many-to-one relationships with seven related tables: POD information, proponent, contractor, development type, report type, wildlife species and other information.

Once the relationships were established and tested, I then designed the queries for the database. A "query" is a method of extracting data from tables and displaying the desired information in another table, form or report (GKNI 2007). I created a query for every table's category in the database using the query wizard function in Access. Each query was designed to produce the same results. Every query generated the reports that matched the search criteria and included all information found in those reports. That information includes: report ID, POD name, proponent, contractor, wildlife species included, development type, date of report, report type, PDF attachment of the report, notes about the report, county the POD is located in, map of the POD, township(s) and range(s) the POD occupies, cover type(s), region and any notes about the POD. Thus, a query or search done on raptors would result in all of the reports including raptor data as well as all of the other information found in each report. I changed the "record set type" of the query results to "snapshot." This restricts the user from making any changes to the results and prevents data corruption. Providing all of this data should minimize the number of searches needed and provides the user with as much information as possible.

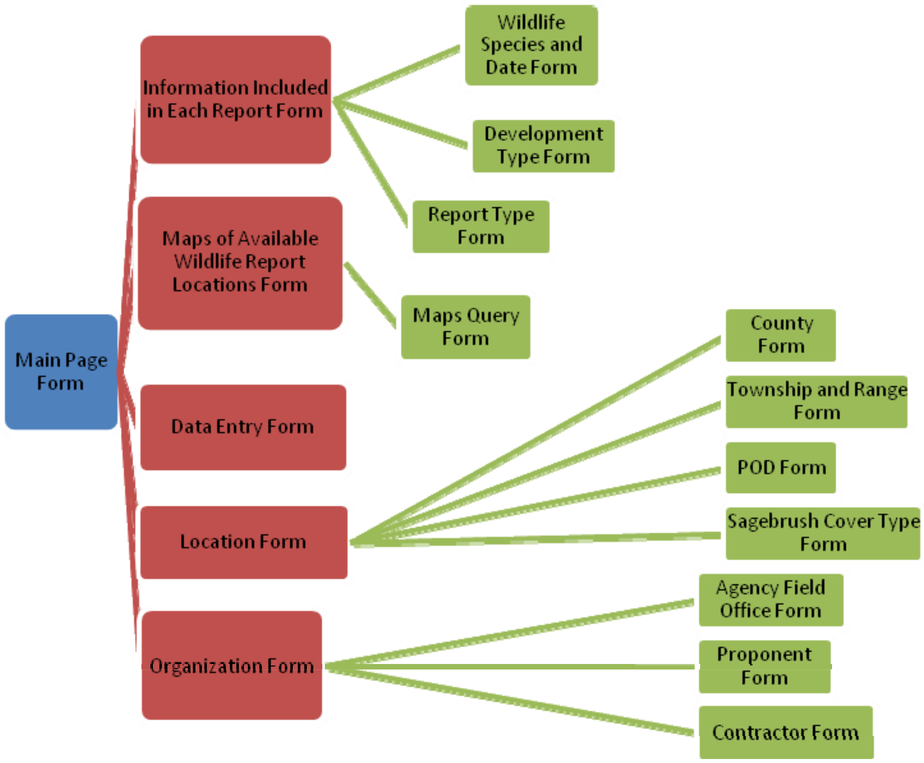
Although queries provide all of the necessary information to the user, they can be confusing to operate if the user is not familiar with the Access set-up. To make this database as user-friendly as possible, I created forms providing a straight-forward and easy to navigate format that basically hides the mechanics in the background. These forms can be thought of as the “pages” of the database. Figure 3 shows how each form is connected. I first created the “Main Page” form to give the user a brief overview of the database and allow them to choose a general method to search. I created a button for each option and programmed them to open up another form once they were selected. These different searches can be done based on information included in each report, location, organization or maps of available wildlife report locations. I also provided a button for users who want to upload their report and its information into the database.

If the user wants to search by the information included in each report, the database will pull up a second form enabling the user to refine a search. I placed four buttons on this form allowing the user to search by wildlife species, miscellaneous information, development type or report type. Again, I programmed these buttons to pull up a third form once selected. For this set of forms, I labeled them with instructions and an overview of the source of their search results. I then added combination boxes and connected them to their corresponding query. A combination box provides the user with a drop down box including all of the categories by which the user can search. The user selects one and the database will display the search results in tabular form. The “Wildlife Species” form was programmed to further refine search results by the start and end date entered in by the user.

If the user wants to search by a report’s location, the database will pull up a second form allowing the user to search by county, township and range, plan-of-development or sagebrush cover type. I programmed each of those buttons to display a third form with a combination box for its search.

If the user wants to search by any organization involved in production of the report, the database will pull up a second form that allows the user to search by the agency/field office housing the report, the proponent paying to have the surveys conducted or the contractor responsible for the surveys and writing the report. I programmed each button on this second form to pull up a third form with a combination box connected to the corresponding query.

Figure 3. Database form labels and connections.



Once the database construction was complete, I entered each report's information. I used the Excel document containing all of the information I had recorded after reading each report. Each report has its own record in the "Report Information" table. I went through and populated all of the fields in a record for every report. The PDF file was then uploaded into the record.

Database Housing

After I completed the database and had it edited by interested parties, it was ready to be transferred to a secure and permanent location. During the initial meetings with WGFD, BLM, USGS and WYNDD, we determined housing it with WYNDD would be the best option at that time because WYNDD has wildlife data and the two could complement each other. It will also benefit users to have one location to search for wildlife data in Wyoming. However, WGFD recently had another wildlife monitoring database constructed that houses spatial data, called the Wyoming Interagency Spatial Database & Online Management System (WISDOM). Currently, the plan is to house the database with WYNDD, as WISDOM is still under construction, however, it may be linked to WISDOM at a later date, which will allow the user to access this database online.

Analyses

For this database, I created maps in ArcMap 10 displaying all of the PODs in the PRB that have wildlife monitoring reports available for them. These maps have gradient colors to reflect how many reports are available as well. I generated a map for every species and uploaded it into the database. I made them accessible through the "Maps of Available Wildlife Report Locations" button and form. This gives the user a reference if they are interested in where and the number of reports available for a particular wildlife species.

To produce these maps, I overlapped the PRB POD,USA county and National Geographic topography shapefiles. The counties provide the user with a general knowledge of where PODs are located. I then created a new field in the POD shapefile attribute table and labeled it after the species of interest, e.g., “Amphibian.” I used the database to perform a query for that species, which resulted in all of the PODs having matching reports. I found each POD’s record in the shapefile attribute table and populated the species field with the number of reports the database pulled up for each POD. This was repeated for all the PODs in the search results for that species. I repeated this process for every wildlife species or group included in the database.

After I populated the POD shapefile attribute table with all of the report totals, I opened up its symbology table. In the field section, I selected the species field and chose color gradient for its representation. If the report totals for each POD ranged from 0 to 10, I did a manual classification, which provided a distinct color for all 10 classes. If the report totals exceeded 10, I used the natural jenk classification, which broke the classes up by groups inherent to the data. I used this classification method to keep the class number lower and the color for each class distinguishable from the next.

RESULTS

In the PRB BLM Buffalo field office, I scanned 1,617 reports and uploaded them to the database. Some reports contained surveys done on multiple PODs and each POD was assigned its own record. The database had a total of 1,776 records. The dates of these reports ranged from year 2001 to 2010, though one map had bald eagle locations from 1980. The database included information for 618 PODs in the PRB. There were at least 56 different proponents who have developed in the PRB. There were 30 contractors that have submitted reports to the Buffalo BLM field office. The tables below display the total number of reports that contain information on the following categories. The database generated these totals from each category's search.

Table 1. Total number of reports containing data for categories included in "Wildlife Species."

Wildlife Category	**Total Number Of Reports From All PODs**	**Wildlife Category**	**Total Number Of Reports From All PODs**
Raptor	1,593	Pronghorn	204
Eagle	1,358	Canine	178
Sage-grouse	1,162	Black-footed Ferret	154
Mountain Plover	1,097	Elk	100
Prairie Dog	1,007	Amphibian	99
Sharp-tailed Grouse	785	Feline	74
Ferruginous Hawk	595	Reptile	68
Other Species	517	Fish	27
Deer	211		

Table 2. Total number of reports containing data for categories included in "Miscellaneous Information."

Miscellaneous Information	**Total Number Of Reports From All PODs**
Spatial	1,024
Hydrology	752
Vegetation	740
Special Status Vegetation	508
Social/Economic	504
Climate	332
Soil	233

Table 3. Total number of reports containing data for categories included in "Survey Type."

Report Type	**Total Number Of Reports From All PODs**	**Report Type**	**Total Number Of Reports From All PODs**
Multiple Wildlife Species	892	Reclamation	22
Conditions of Approval	428	Alternative Analysis	11
Raptor Nest Occupancy	205	Special Status Plants	11
Bald Eagle Roost	85	Other	4
Single Wildlife Species	35	Special Status Wildlife	3
Update	30	Map	2
Mitigation/Exception Request	26	Bald Eagle Nest Occupancy	0
Amendment	22		

Table 4. Total number of reports containing data for categories included in "Development Type."

Development Type	**Total Number Of Reports From All PODs**
Coal Bed Natural Gas	1,716
Oil/Gas	46
Oil	7
Power Line	4
Coal	1
Water Pipeline	1
Carbon Dioxide Pipeline	1

Table 5. Total number of reports containing data for Wyoming counties.

Wyoming County	**Total Number Of Reports From All PODs**
Campbell	884
Johnson	687
Sheridan	167

The following figures display the total number of reports available and the POD from which their surveys were conducted for every wildlife species or group included in the database.

Figure 4. PODs populated with the total number of wildlife reports available for each, Powder River Basin, Wyoming, USA.

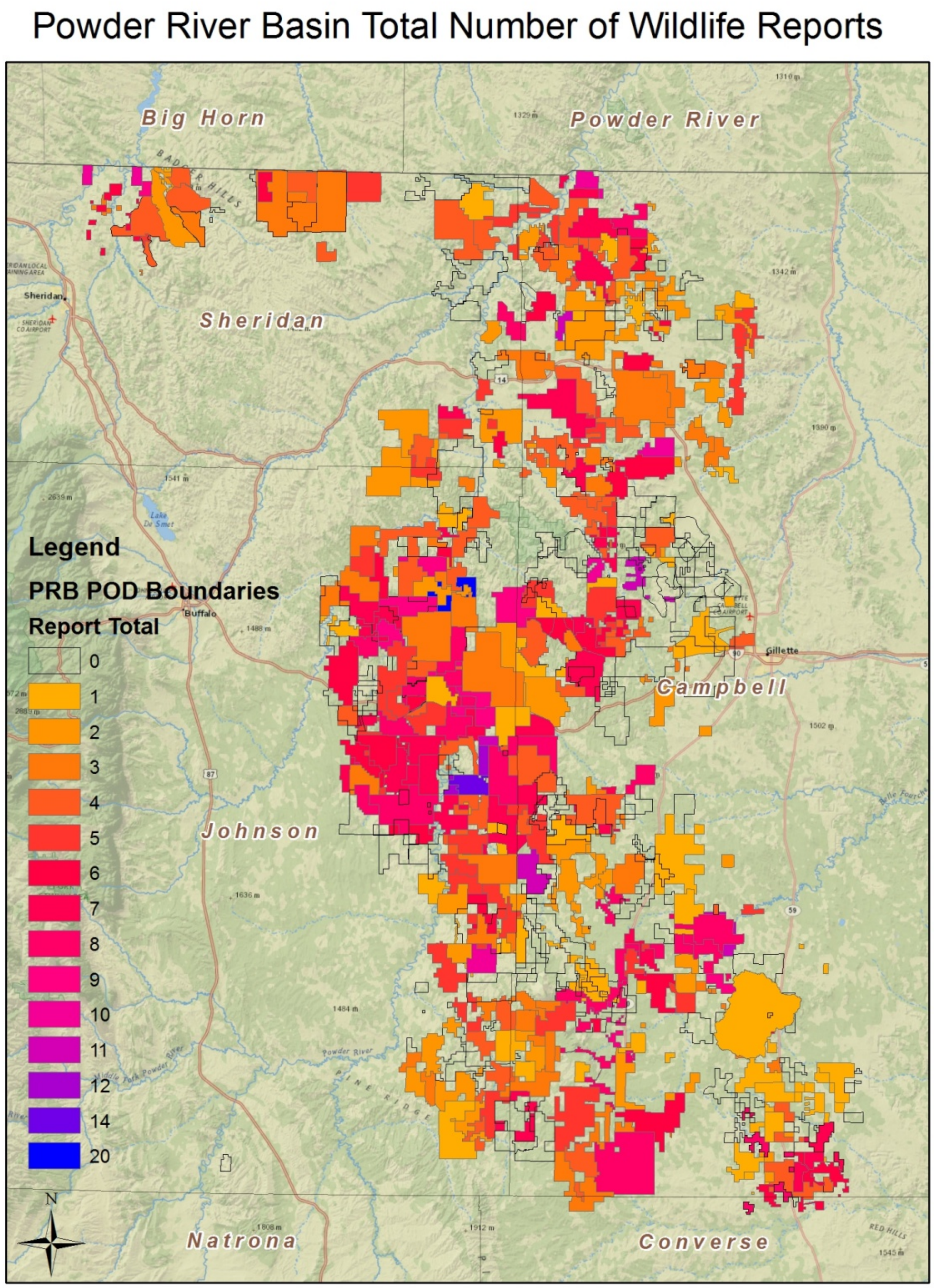


Figure 5. PODs populated with the total number of reports with amphibian data available for each, Powder River Basin, Wyoming, USA.

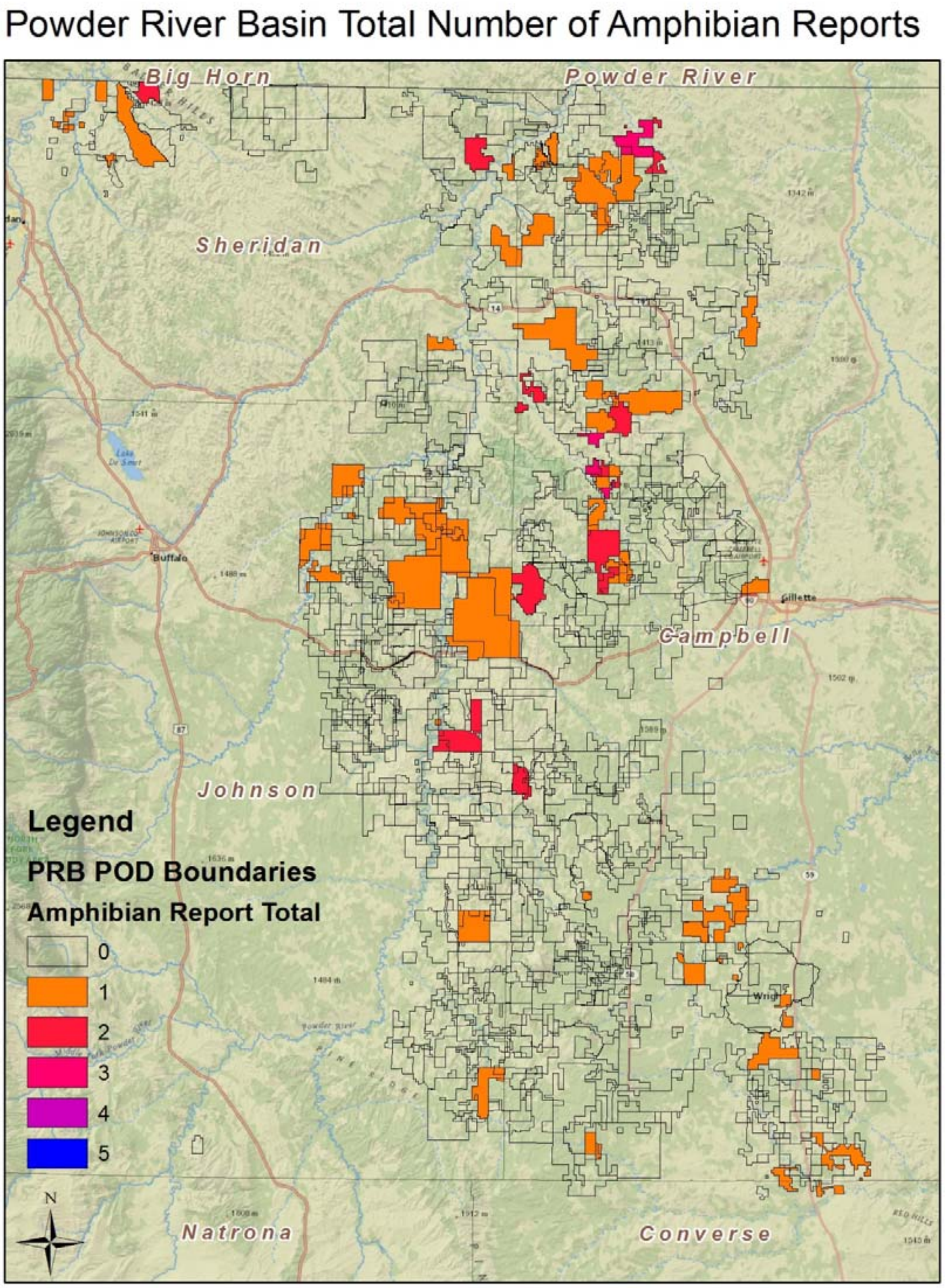


Figure 6. PODs populated with the total number of reports with black-footed ferret data available for each, Powder River Basin, Wyoming, USA.

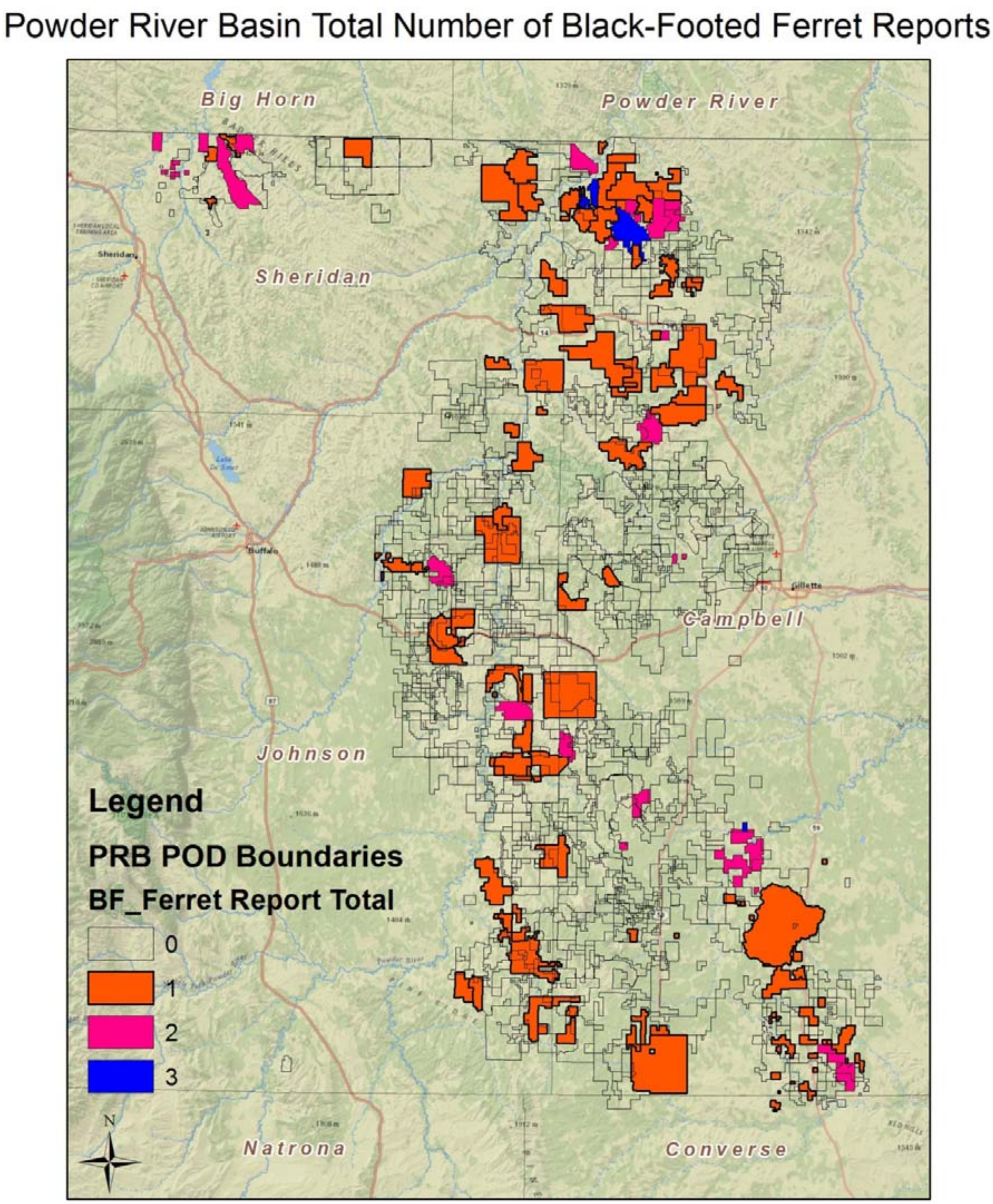


Figure 7. PODs populated with the total number of reports with canine data available for each, Powder River Basin, Wyoming, USA.

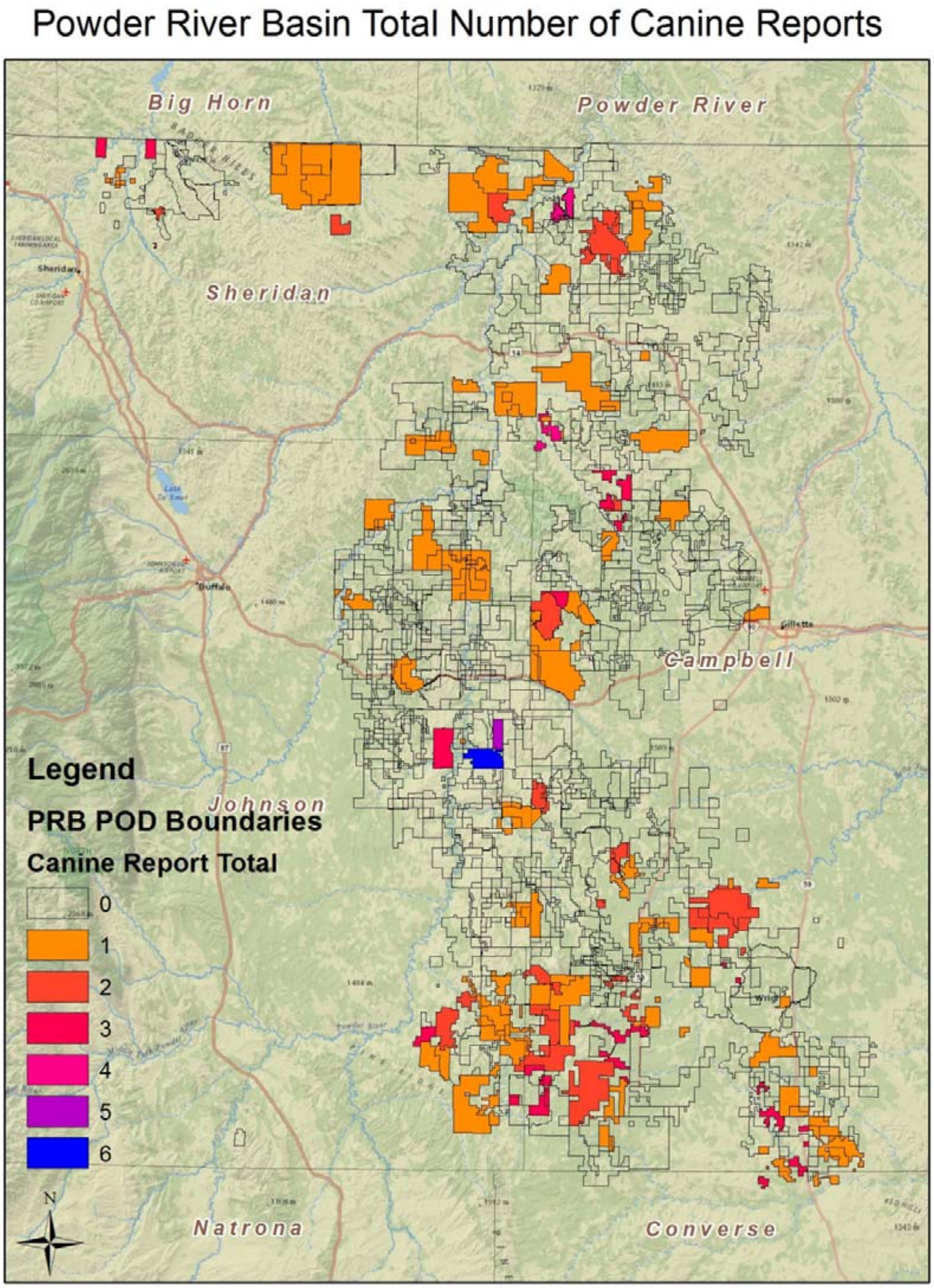


Figure 8. PODs populated with the total number of reports with white-tailed or mule deer data available for each, Powder River Basin, Wyoming, USA.

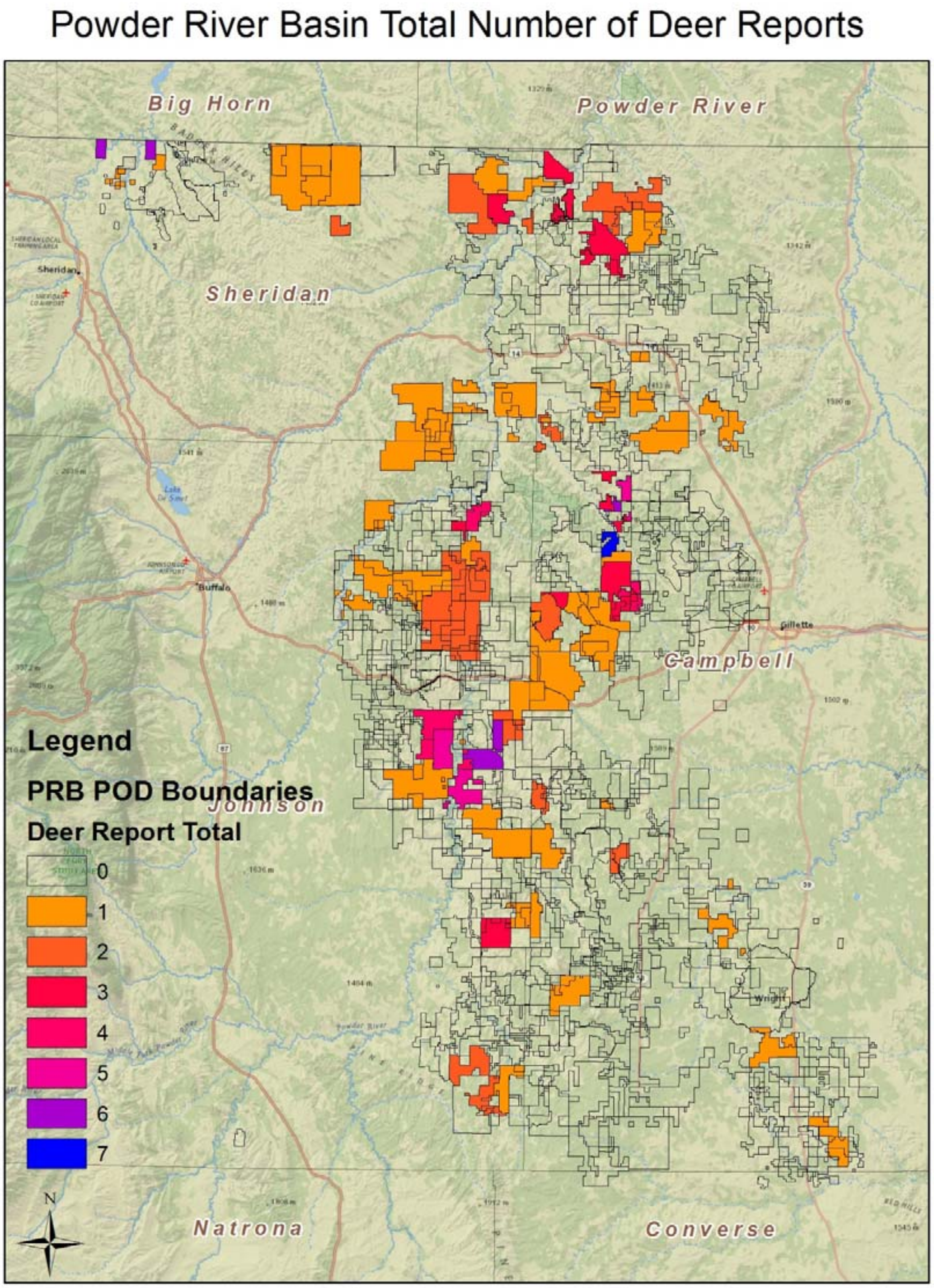


Figure 9. PODs populated with the total number of reports with bald or golden eagle data available for each, Powder River Basin, Wyoming, USA.

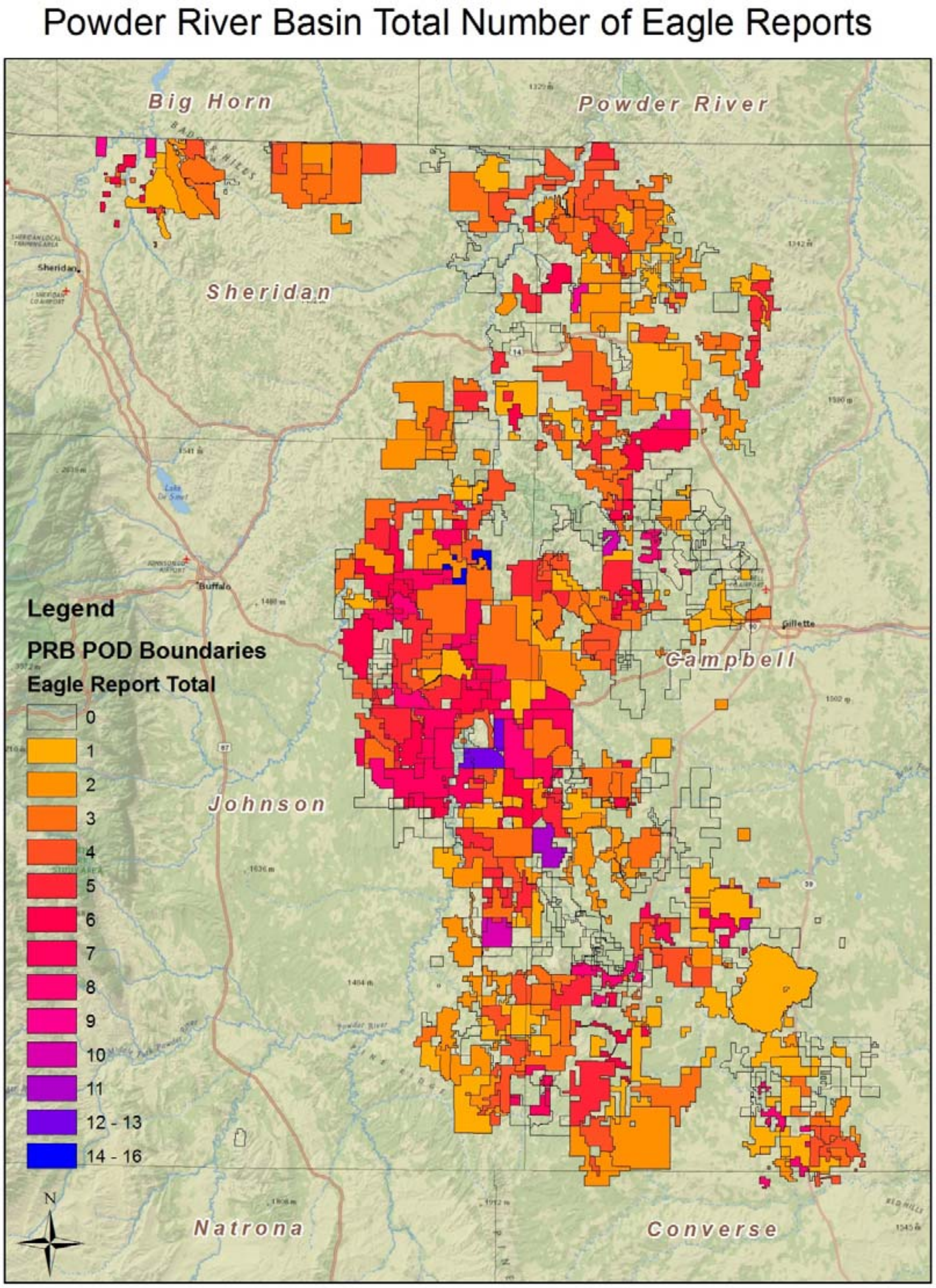


Figure 10. PODs populated with the total number of reports with elk data available for each, Powder River Basin, Wyoming, USA.

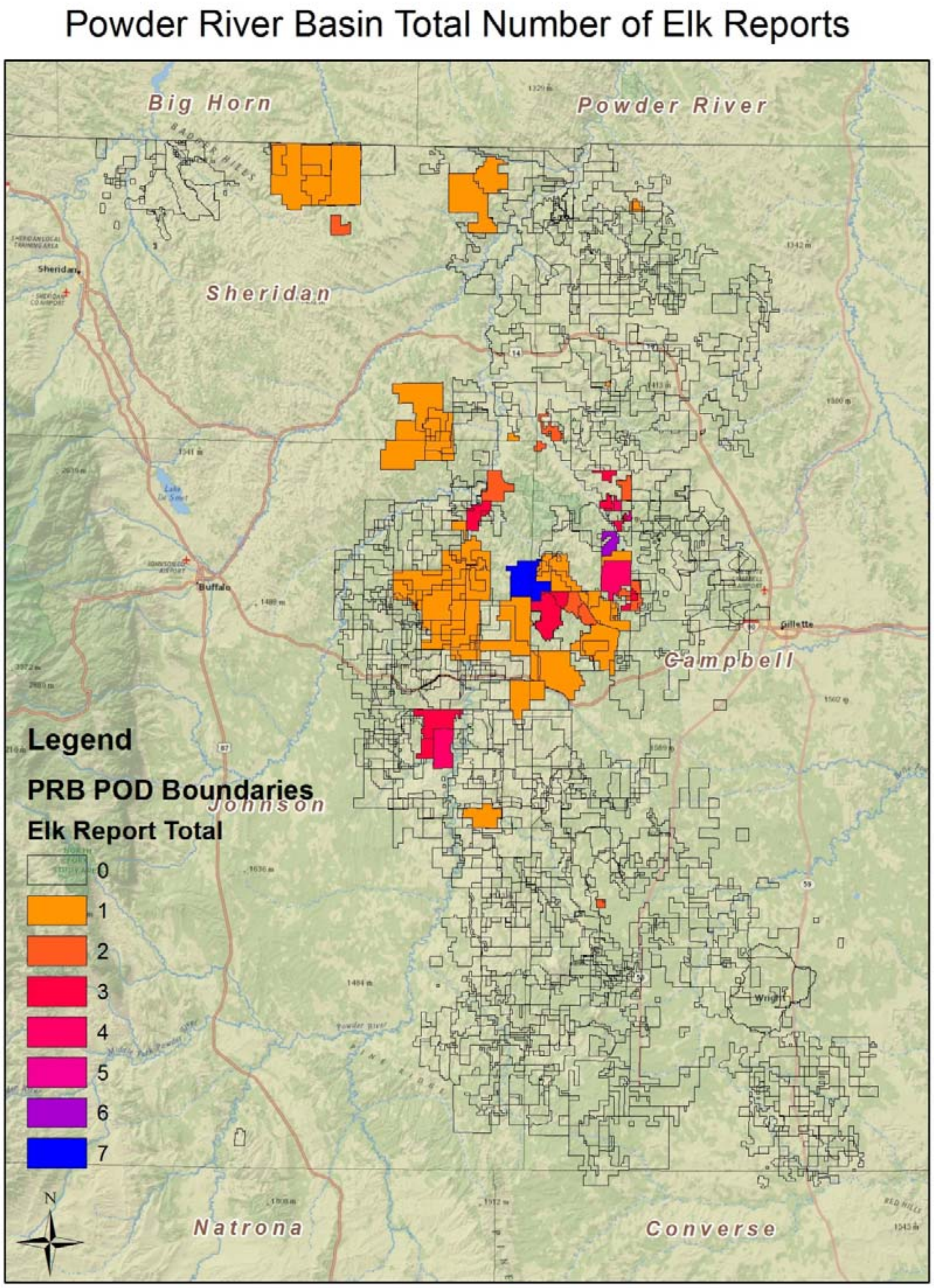


Figure 11. PODs populated with the total number of reports with ferruginous hawk data available for each, Powder River Basin, Wyoming, USA.

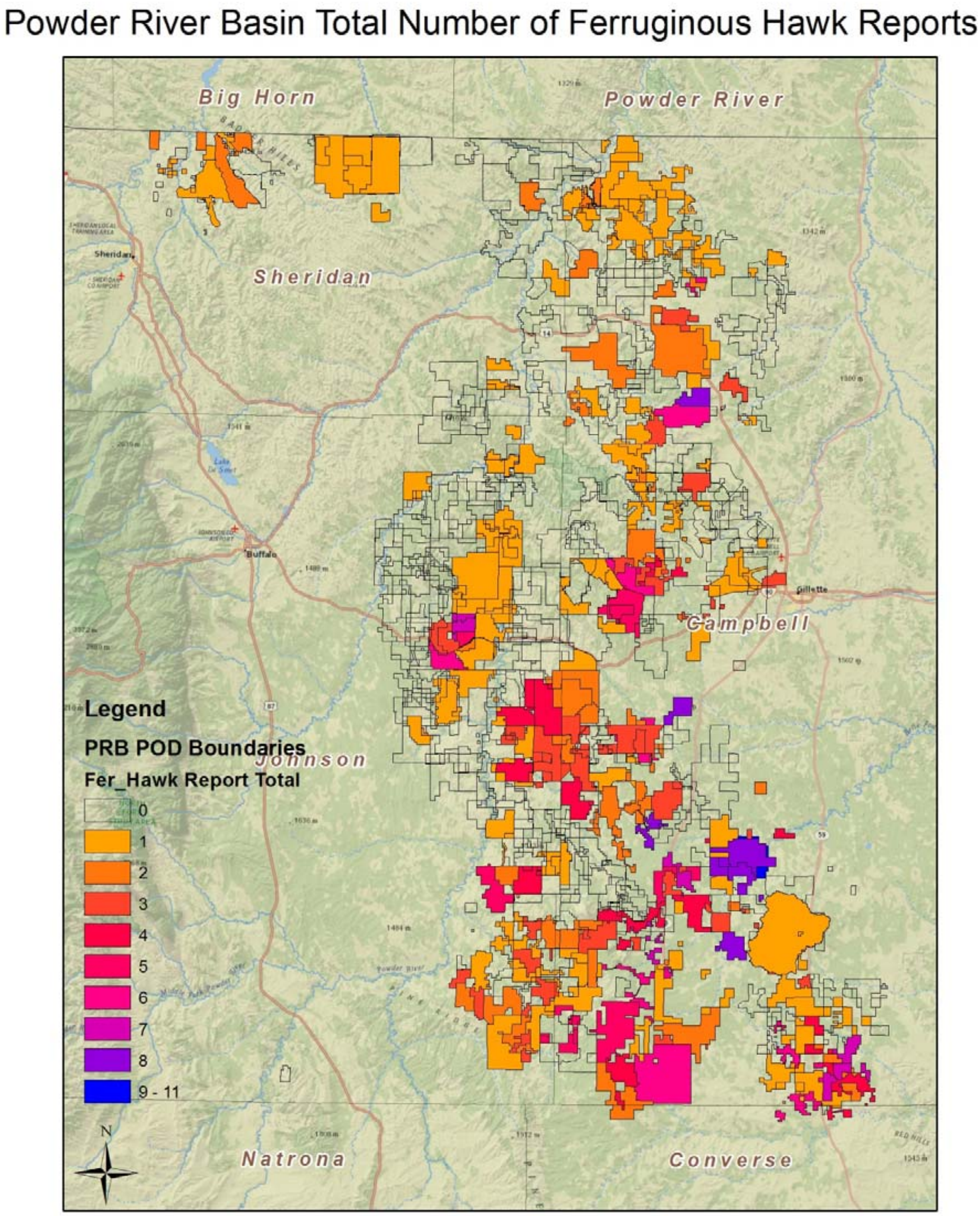


Figure 12. PODs populated with the total number of reports with feline data available for each, Powder River Basin, Wyoming, USA.

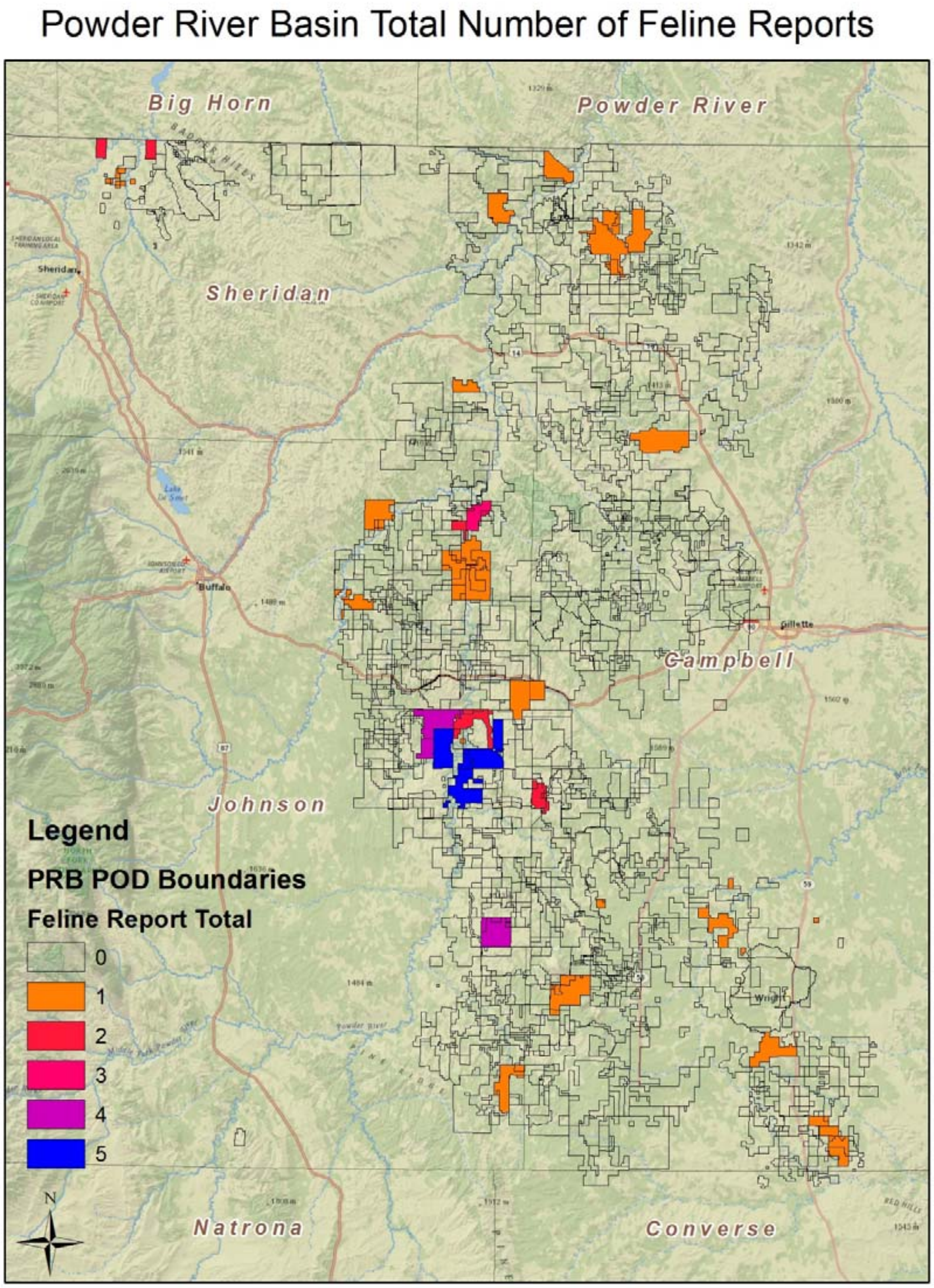


Figure 13. PODs populated with the total number of reports with fish data available for each, Powder River Basin, Wyoming, USA.

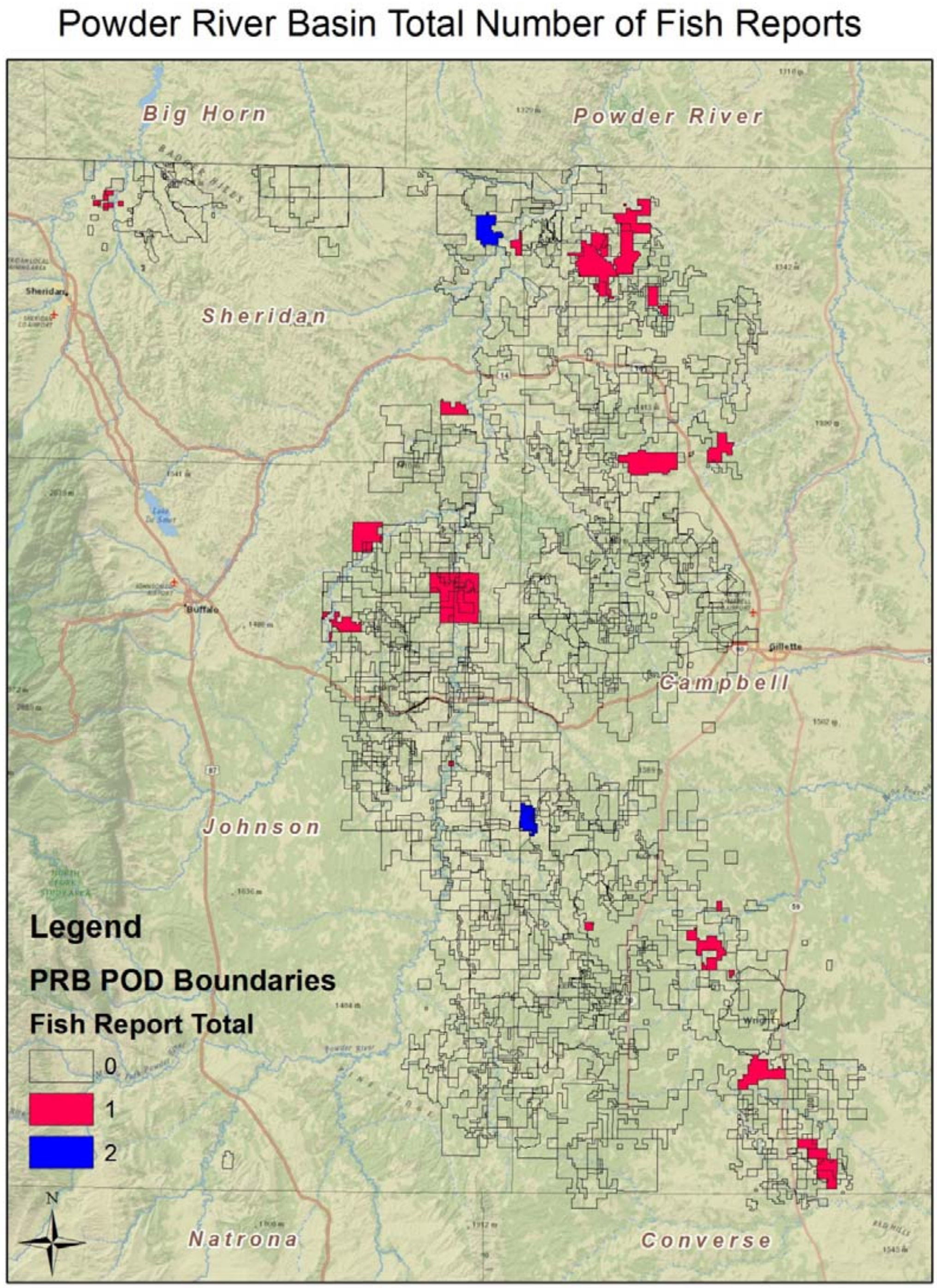


Figure 14. PODs populated with the total number of reports with mountain plover data available for each, Powder River Basin, Wyoming, USA.

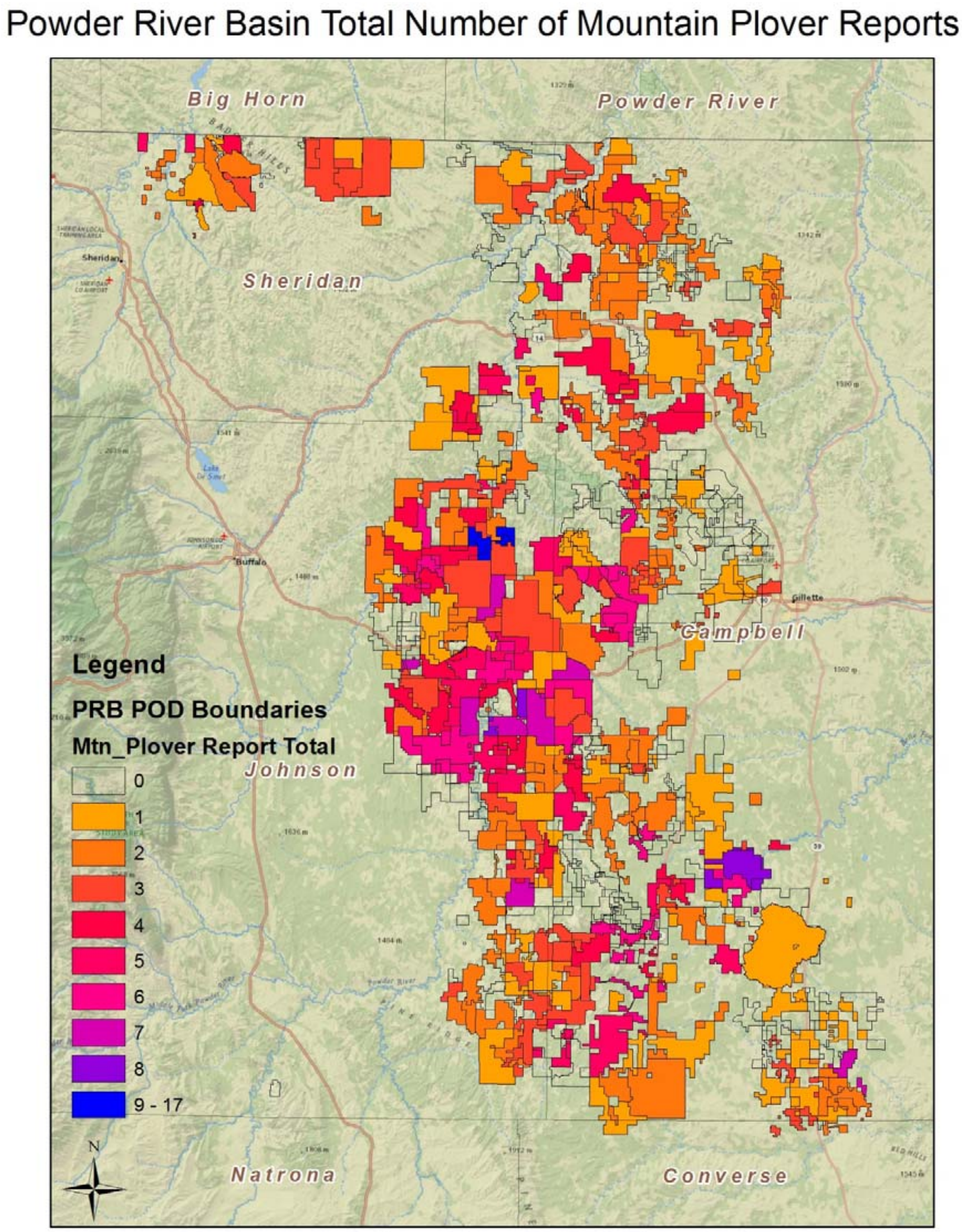


Figure 15. PODs populated with the total number of reports with other species data available for each, Powder River Basin, Wyoming, USA.

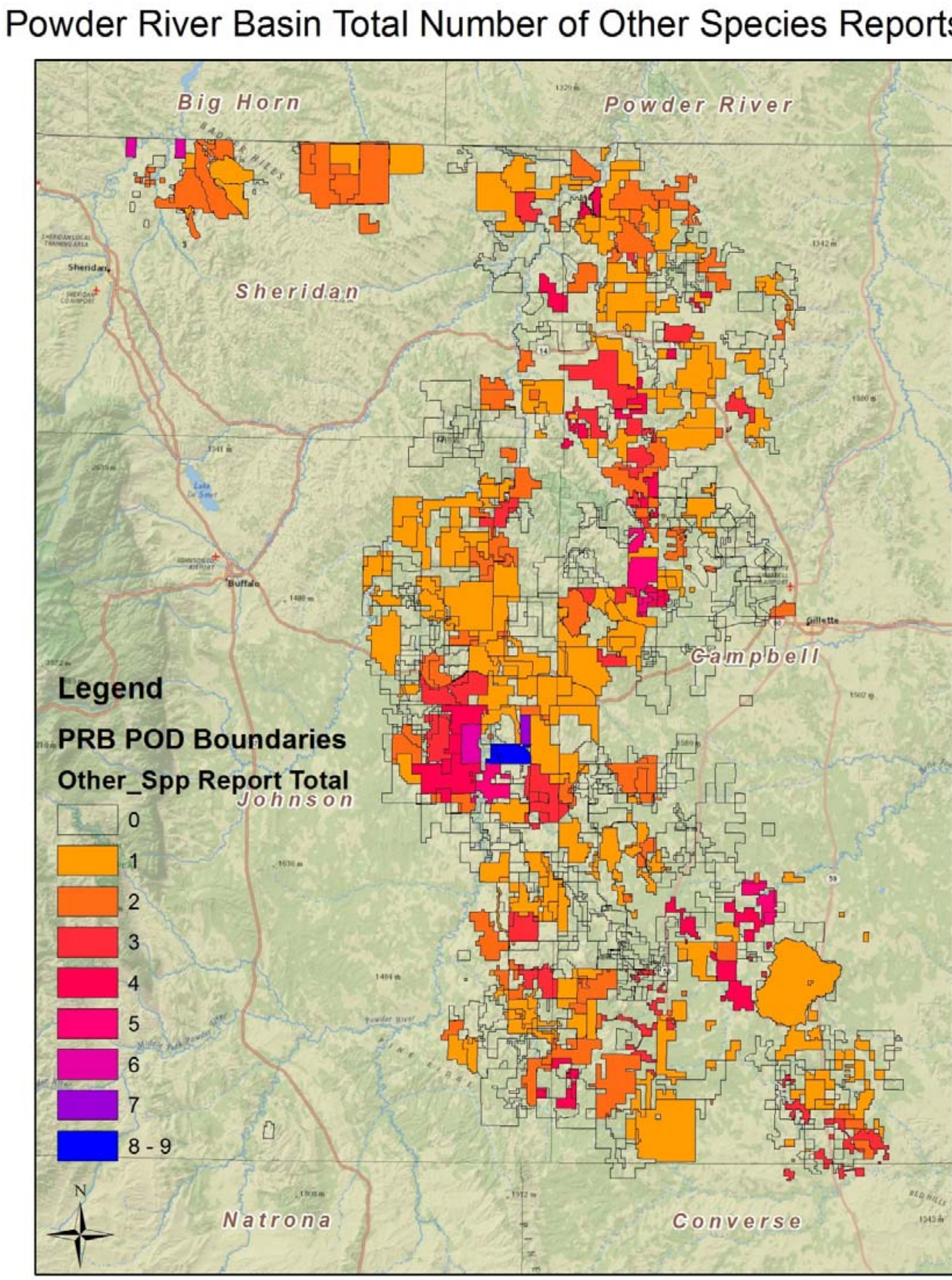


Figure 16. PODs populated with the total number of reports with prairie dog data available for each, Powder River Basin, Wyoming, USA.

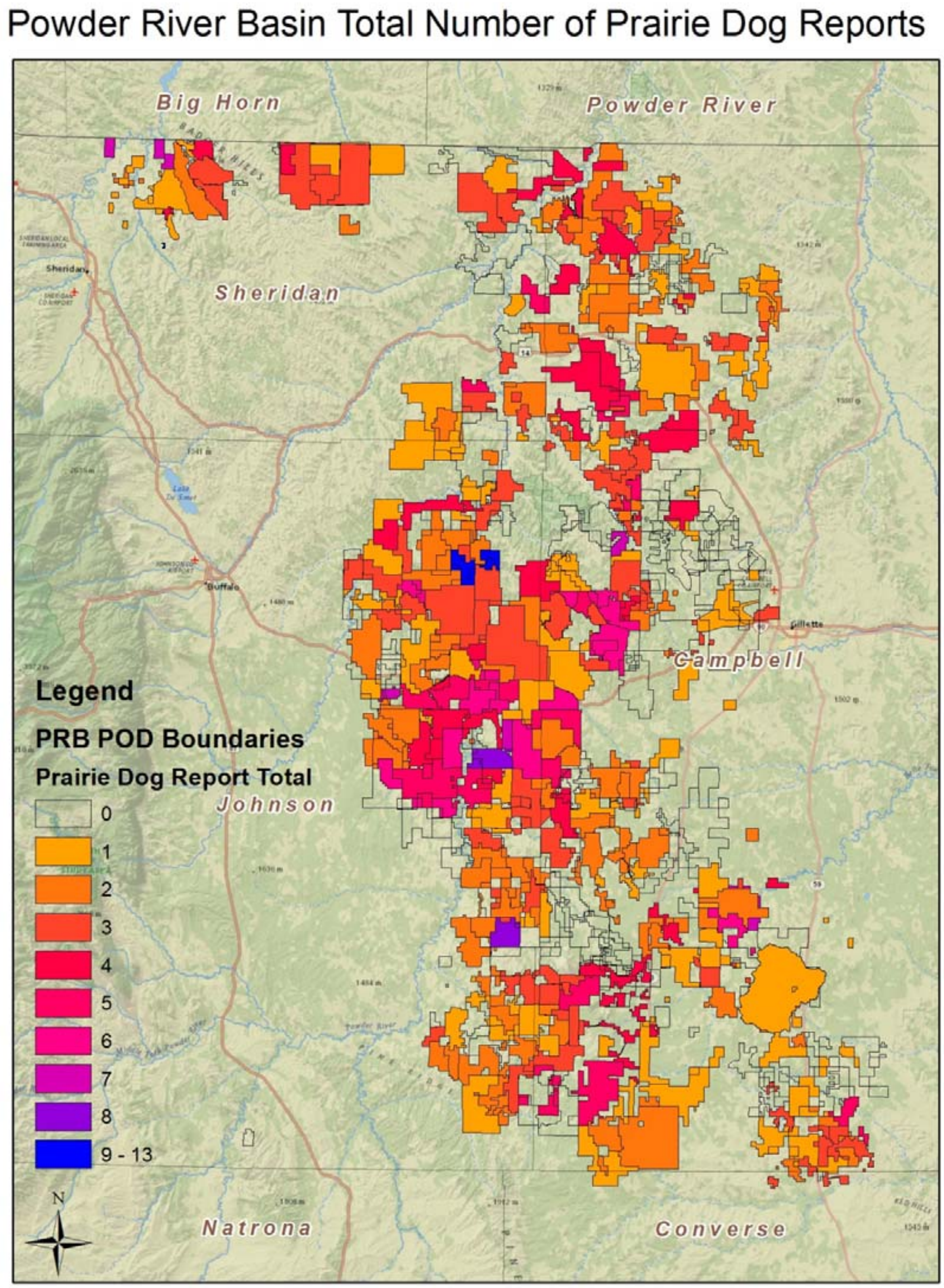


Figure 17. PODs populated with the total number of reports with pronghorn data available for each, Powder River Basin, Wyoming, USA.

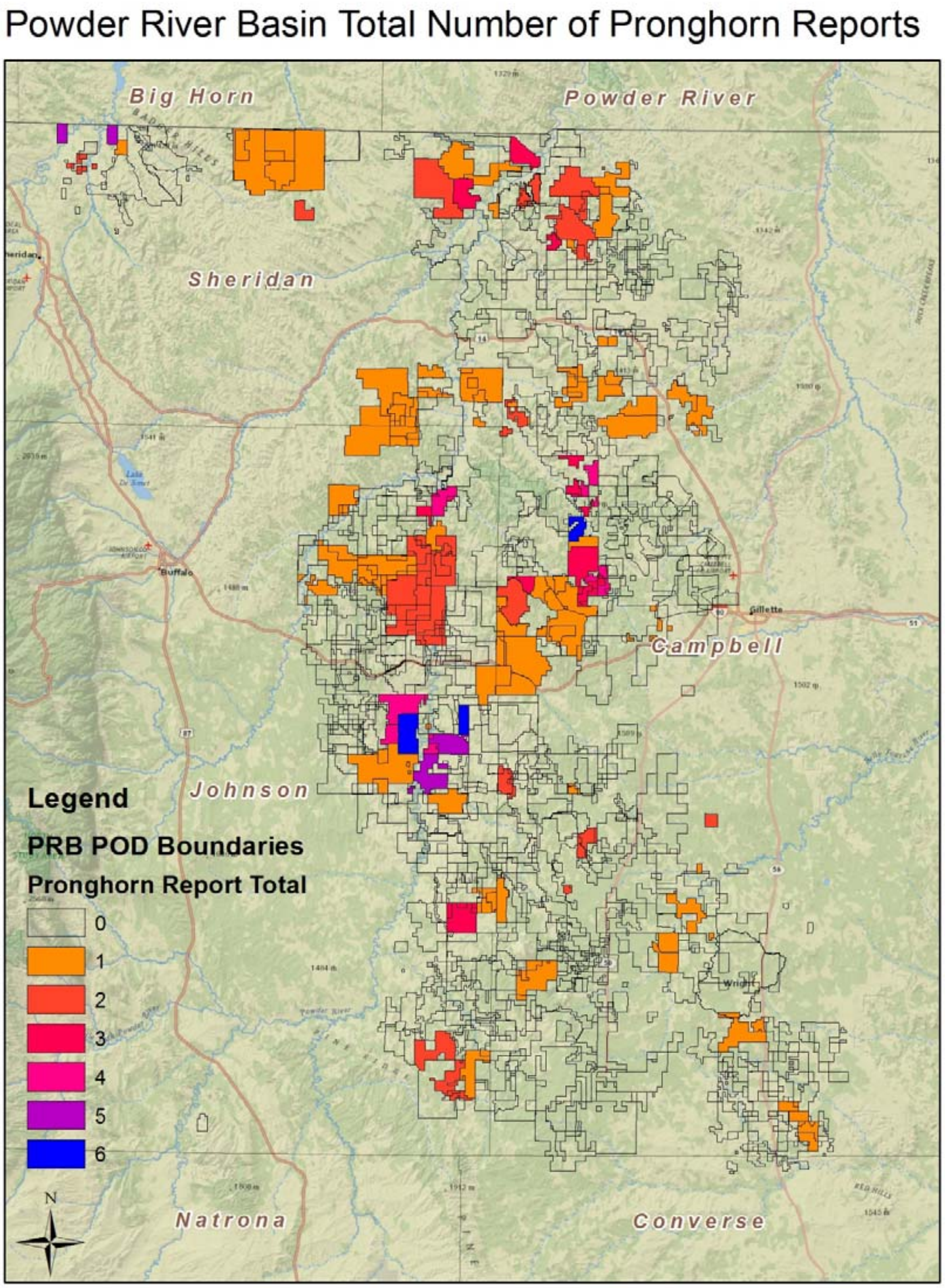


Figure 18. PODs populated with the total number of reports with raptor data available for each, Powder River Basin, Wyoming, USA.

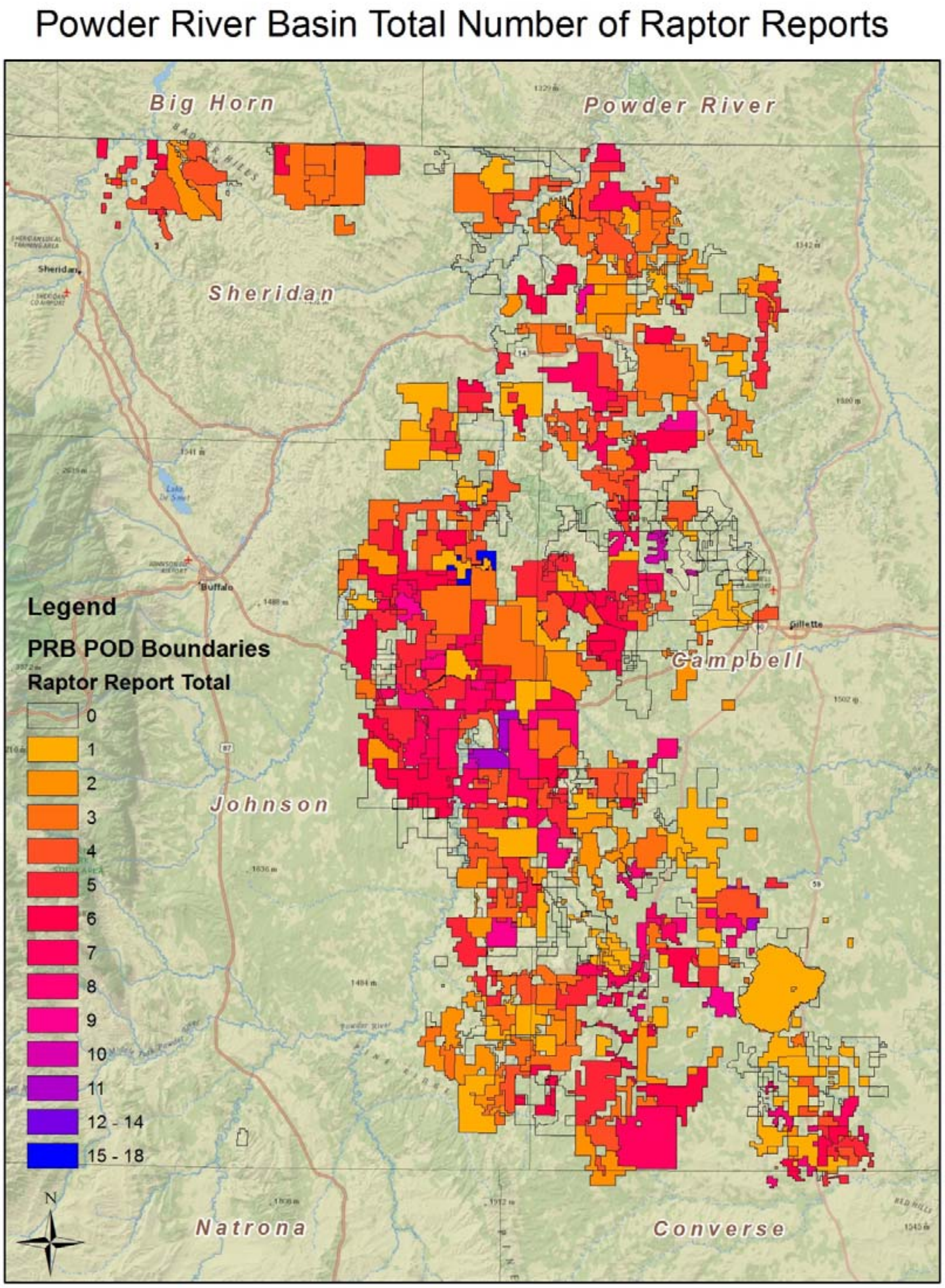


Figure 19. PODs populated with the total number of reports with reptile data available for each, Powder River Basin, Wyoming, USA.

Powder River Basin Total Number of Reptile Reports

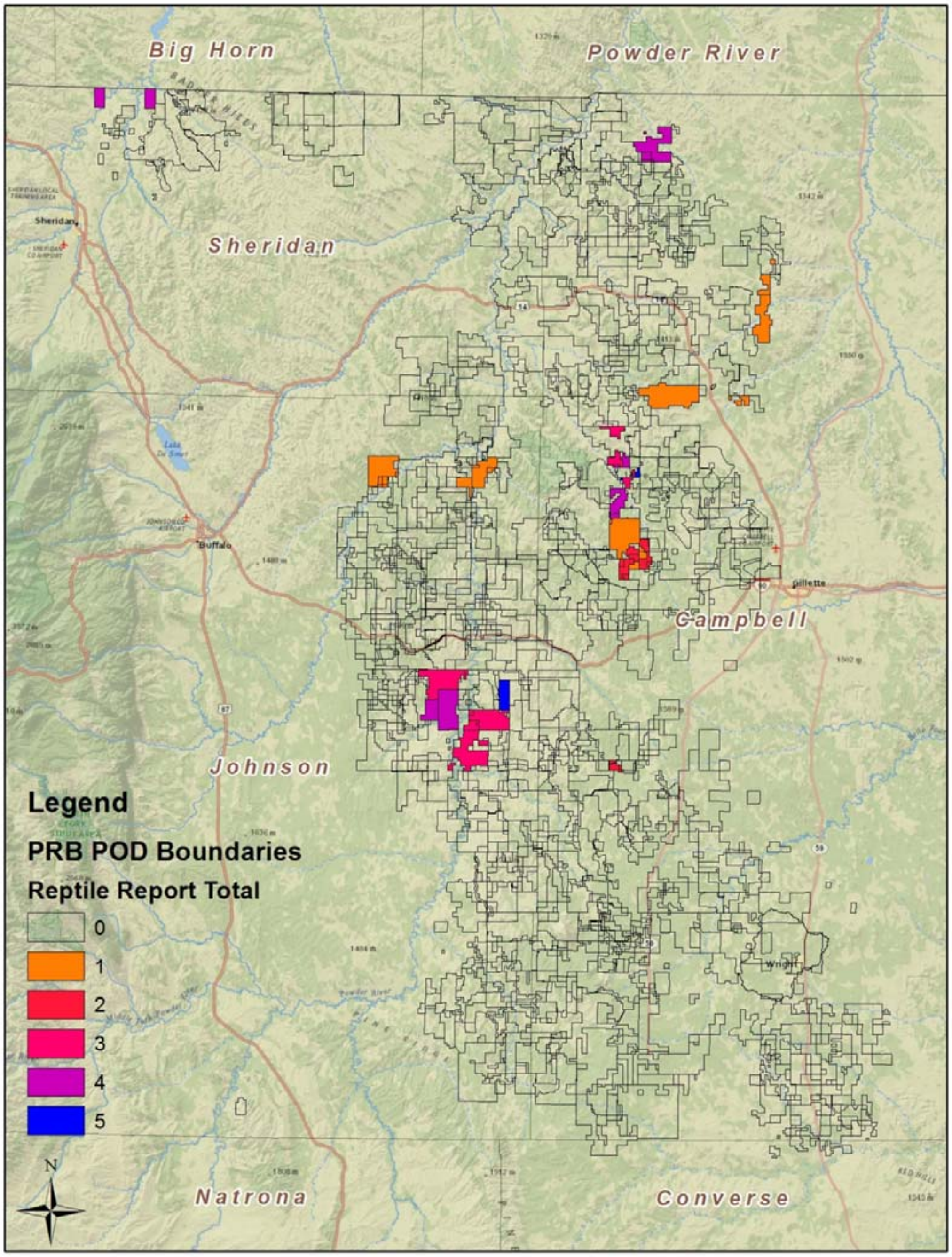


Figure 20. PODs populated with the total number of reports with sage-grouse data available for each, Powder River Basin, Wyoming, USA.

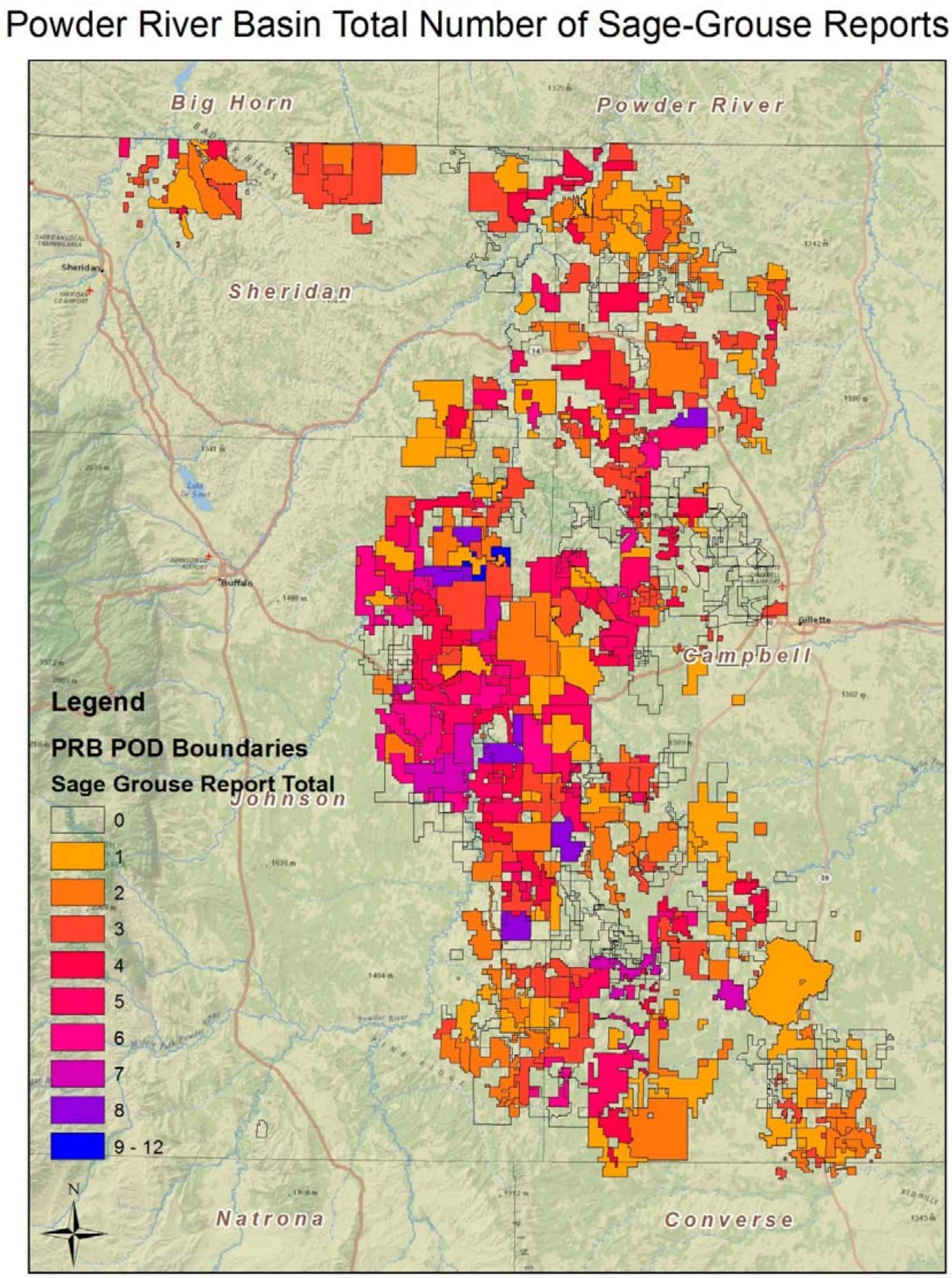
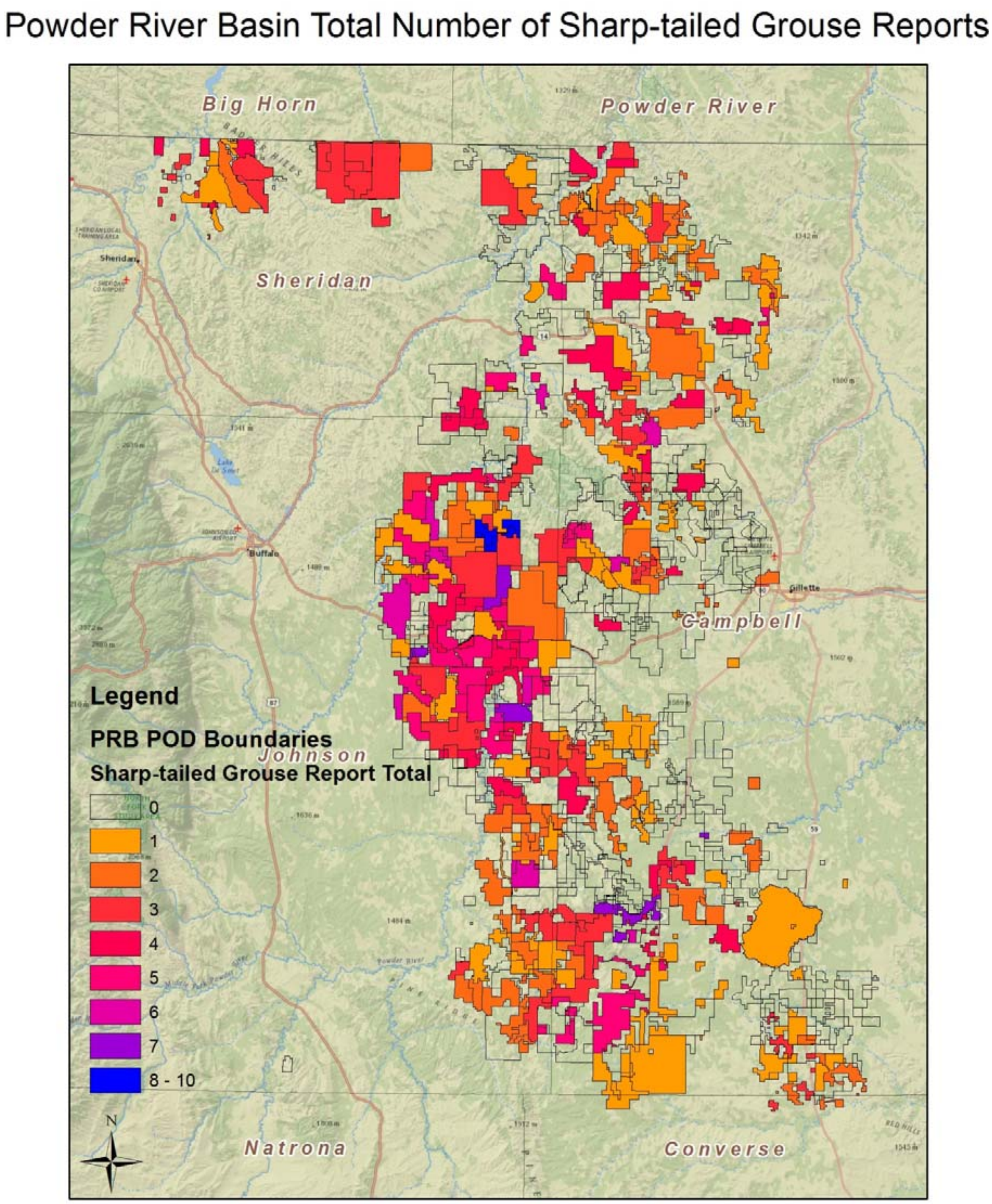


Figure 21. PODs populated with the total number of reports with sharp-tailed grouse data available for each, Powder River Basin, Wyoming, USA.



DISCUSSION

This database can be used for a variety of purposes. It supplies managers with large amounts of data previously unavailable. This "new" information comes from several sources throughout the state and will increase the transfer of knowledge between agencies. Increased coordination and communication will hopefully develop between these agencies as a result of this information being made available to all.

This metadata can fill in current gaps of knowledge in some areas. According to Naugle (2011, p. 44), "anthropogenic development can influence population processes in three interrelated ways: changes in population abundance or distribution, modifications in demography and extirpation." The reports included in this database provide survey results for many wildlife species over the course of several years and can be used to examine these influences. The information also allows the user to look at small (PODs) to large (region) scales. Metadata from these reports can especially benefit large-scale modeling for non-game species, as there is usually not enough information in peer reviewed literature (Karl et al. 1999). Such information can shed light on all of these processes for wildlife species. Some reports provide detailed locations and descriptions for the species in their surveys. If a proponent was required to conduct surveys and submit a report over several years, then these locations and descriptions can be compared to determine any trends.

The reports found within the database can help determine if changes in population abundance or distribution are occurring in the development site. All of the surveys included in each report will make clear whether a species is present or absent at the site. Presence and absence data gives managers a better understanding of species distribution and occurrence, which is fundamental for species conservation (Ferrier 2002). In some instances, this data can be combined with habitat information and used to identify habitats that are of high value for wildlife species (MacKenzie 2005). Population changes can be detected if a survey recorded species occurrence for several years. For example, surveys for mountain plovers recorded whether plovers were present in suitable habitat within a site. If plovers were detected for some years and not others, managers can use this information to help determine species persistence and investigate causes of population change. Some reports include only presence data in the form of species sightings. Although no population trends can be determined from this information, it at least allows managers to decide if a site warrants further surveys. Such presence-only data are useful because they can still provide a method for predicting species' distributions (Elith et al. 2006).

Some of the surveys provide information to determine changes in a wildlife species' productivity through count data (Skalski et al. 2005). The thoroughness of each survey on a specific species will limit the demographic categories determined. For example, most raptor surveys include nest productivity and species composition for a site over a period of several years. Raptor nest occupancy can be used as an indicator of territory quality, so nest occupancy trends could demonstrate how site development affects habitat quality over time (Sergio and Newton 2003). It is also commonly known that a disturbance can lead to changes in species composition. Comparing raptor species composition among various stages of development will give some insight on how this type of disturbance may alter their composition.

For managers to use reports for such purposes, a database must be accessible and searchable. This database was created to focus on wildlife information, but may also include other useful data. I made the database searchable by all of the included categories to make it as user friendly as possible. A familiar navigation format is provided for users by creating buttons that will open up other search pages, similar to web browsing. I included a standard paperclip icon for the upload feature on the “Data Entry” form to make it easy for users to upload their reports. Hopefully, these efforts will promote future use by agency and industry personnel from all over the state. This will make the database the best source for wildlife monitoring reports in Wyoming.

To remain a major resource for wildlife information, this database must be current. In the future, all Wyoming BLM field offices should have their wildlife data gathered and entered into the database. To start, this will be a very time consuming process until managers begin to input the reports themselves. In addition, it took me four weeks to scan all of the 1,617 reports collected at the Buffalo Field Office. It took two weeks to edit those reports. I then spent approximately three months reading through and entering the information from the reports into the database. It took an additional two weeks to create the POD maps and enter them into the database. Now that a database exists, the process of recording the report information into Excel and transferring that into the database can be by-passed. It is unknown exactly how many reports are available in each field office, so the processing times will vary. Other federal and state agencies gathering information on energy development impacts on wildlife, like the U.S. Forest Service, Wyoming Department of Land Quality, Wyoming Oil and Gas Conservation Commission, etc., should be encouraged to place it in this database. Allowing access to each other’s material should facilitate communication between agencies.

As the lead agency for this effort, it will be up to the WGFD to determine how this metadata will be collected and entered into the database. The data collection itself may be done by several people to save time. However, having one person go through the reports and enter the information into the correct categories of the database would likely be the most consistent and accurate method. The WGFD will have to decide who will be responsible for updating and maintaining the database. If the database stays housed with WYNDD, it will not be remotely accessible and a manager will be responsible for data entry. The agencies could send their reports to this database manager who will enter the information and upload each report. If the database becomes remotely accessible through WISDOM, either the agency who houses or the contractor who writes the report can enter the data into the database. This method will be the most time effective, but there will likely be more discrepancies with data entry because there will be multiple sources making different interpretations.

Currently, the only changes users can make to the database are through the data entry option. I implemented several security features to prevent data corruption. I changed the record set type for each query to "snapshot." This disables the user from making changes to the query results. However, it still gives them access to all of the information, including the attachments. I created a code in the database to hide the toolbar and navigation pane. This keeps the user from making changes to the tables, queries and relationships that are set in place. If changes do need to be made, the database manager can simply go into the design view and change the code to show the toolbar and navigation pane.

Continued maintenance of the database is paramount to keeping it current. As the database grows, new categories will need to be programmed, like proponents, contractors and PODs from other areas. While the individual report information can be entered by others, the tables that support the report "Data Entry" form should be managed by one person. I recommend this be the responsibility of a database manager because it will prevent duplicate data and improve the accuracy of the database. Companies interested in contributing to the database will have to contact the manager to have their information entered into the appropriate tables. Once their information is entered, then it will be available to select in the "Data Entry" form.

Another important consideration is the size limit of the database. Currently, the database has a maximum size limit of two gigabytes (GB) (Microsoft 2012). All of the reports, data and POD images from the PRB take up approximately one GB. The two GB limit can be increased slightly if the database is split later on. However, this is only a temporary fix if it is intended to store data for multiple agencies across Wyoming. In order for the database to have plenty of space for this large amount of data, a server will be necessary. A Microsoft SQL server would be the most compatible for this database. If WGFD has access to an SQL server through WISDOM, that would be the best available option for now. If this is not an option, funding should be secured to purchase and develop a server to support this database. Upgrading to a server will still maintain the current database's content and provide enough space for statewide metadata.

Technology and management needs are constantly evolving. The future maintenance of the database must include adapting to those changes. As the database grows, new tables, relationships, queries and forms will be needed. As evident from the report totals, raptors, eagles, sage-grouse, mountain plover and prairie dogs are the wildlife species focused on by past monitoring efforts. In the future, other species may become of greater importance and will need to have their own categories included. General categories like "Reptiles" and "Other Wildlife" may be broken down to specific species later on. Due to timing restrictions, this study did not include whether a survey had positive or negative species data. The database simply acknowledges there is species information in a report. Some agencies have expressed a desire to include whether a species was present or not on a site. This will require a division of each wildlife category. So, when data is entered, the user could select a present or absent category for each species. Another future inclusion may be the designation of whether or not a survey was actually conducted for a species, or if it was just sighted in the POD. The addition of song bird and bat groups in the "Wildlife Species" table will be necessary for surveys conducted in wind development areas. The advantage of using a Microsoft Access database is that these future changes will be fairly easy to incorporate if needed.

One possible benefit arising from availability of this database is more consistency with the reports. The oil and gas industry is required to conduct these surveys at various stages throughout development, depending on the conditions of approval allotted to each POD. These surveys and their reports are required for annual clearance of the development. Some reports have before, during and after development data. However, many reports only include one stage of development. This difference in survey efforts can make the results difficult to analyze. It doesn't allow managers to detect any sort of population trends if there is no before and after data. There is also variation among contractor companies on methods to conduct raptor surveys. The BLM has unique timing and space restrictions on raptors, based on each field office location. For example, no surface disturbing activities can occur within 0.5 miles of an active raptor nest during nesting season (15 April through 15 June) in the PRB. The BLM specifically states which species to include in the surveys (BLM Protocol 2005). However, based on this research, many of the surveys included black-billed magpies and Canada geese, though these are not considered raptor species. Some reports, on the other hand, included black-billed magpies, but did not include their nest status. Based on this finding, I believe some contractors do and some do not include such species in their reports. These differences should be taken into account if managers intend to analyze this data.

Another inconsistency among reports is many of them did not state the stage of development of the POD. This information may be readily accessible for agencies housing that information, like the BLM, but it is difficult to track down otherwise. The BLM grants access to dates PODs were approved for drilling, but this information does not include when construction actually began or was completed (BLM 2012). The Wyoming Oil and Gas Conservation Commission has some information on which PODs are still in production, but their information does not include most PODs no longer in production (WOGCC 2012). Without knowledge of the stage of development, it is impossible to determine any wildlife population trends with relation to the development. Once contractors have access to each other's reports, hopefully these differences will be realized and more details will be included in each report. Agencies could request these details be included to improve analyses, as well.

This project served a dual purpose by creating a source for wildlife metadata input and by providing a model for others. Creating a database involving cooperation among multiple agencies can be a daunting task. However, this thesis gives others a guideline as to what to consider in the design process. This thesis supplies them with the capabilities and limitations of such a database. Hopefully, the most beneficial use of this database will be to demonstrate how the cooperation and sharing of data among multiple agencies can improve our knowledge of wildlife in relation to energy development. The database will promote communication and transfer of knowledge between these agencies. The database makes this information useful for purposes other than what it was intended for. This could prevent unnecessary duplicate surveys and save agencies and managers money in the future. The shared metadata will augment and fill in gaps in our current wildlife knowledge. This, in turn, will give managers a better understanding of how energy development affects wildlife species in Wyoming.

CONCLUSION

For the scope of this graduate project, the Buffalo BLM Field Office had all of its wildlife monitoring data entered into the database. If the project is continued, all of the Wyoming BLM Field Offices' wildlife monitoring data will eventually be entered into the database. In the future, other agencies can participate by entering their data into the database. It is known that there is a large body of wildlife data that agencies, until now, had no method of making available. This database makes these reports accessible, searchable and available to others. Not only will this database transform their paper reports into available digital copies, but it will increase communication and transfer of knowledge between agencies. Managers can use these reports to determine changes in wildlife population abundance and distribution. The organized metadata will be available at WYNDD for examination until a server can be secured to permanently house the database. Combining this information with data already collected by WYNDD provides a central location for agencies to submit and find wildlife information. This project provides a model for others considering the use of a database for data management. As technology and wildlife management needs change, this database is capable of being adapted to meet those needs and continue to be a source for energy-related wildlife monitoring metadata in Wyoming.

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