BENEFICIAL USES OF WATER PRODUCED BY COAL BED NATURAL GAS DEVELOPMENT: MORE SURFACE WATER CAN BE GOOD FOR FROGS AND OTHER WILDLIFE[1]

William E. Vetter, and Kimberley Brown[2]

Abstract. The potential effects of surface-discharged coal bed natural gas (CBNG) water on local wildlife populations are not yet fully understood, but the Powder River Basin Final Environmental Impact Statement (FEIS), Biological Opinion (BO), and Biological Assessment (BA) acknowledge the potential for both benefits and negative impacts. A myriad of vertebrate species would likely benefit from the increased availability of aquatic habitats, particularly within this arid landscape. Wetland obligates such as fish, amphibians, turtles, muskrats, and mink would likely increase. Other benefits could include the increased availability of drinking water for big game, brood rearing habitat for waterfowl, and foraging habitat for shorebirds. The potential value however, is largely dependent on the type, quality, and temporal availability of these created and supplemented wetlands. One CBNG operator has initiated a study to investigate northern leopard frog use of wetlands on a development area in northern Campbell County, Wyoming. That ongoing project has included two years of spring and summer surveys for amphibians at seven to eight wetlands. Leopard frogs and several other species of amphibians were documented using both natural and CBNG-supplemented wetlands. Results to date have provided some insight regarding the site characteristics that are valuable for leopard frogs at different times of year. That information can influence impoundment design, construction practices, water management strategies, and final reclamation to benefit frogs and other wildlife.

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[2] William Vetter, CBNG Project Manager/Wildlife Biologist, and Kimberley Brown, respectively, CBNG Project Director/Wildlife Biologist, Thunderbird – Jones & Stokes, 1901Energy Court, Gillette, WY 82718

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Introduction

It has been well established that both anthropogenic and natural disturbances affect animal populations at both a local and landscape level (e.g., Hockin et al. 1992, Underhill and Angold 2000, Guilfyole et al. 2000, Gill et al. 2001, Jones et al. 2001, and Hansen et al. 2005). Numerous studies (Sauvajot et al. 1998, Carney and Sydeman 1999, Frid and Dill 2002, Driscoll and Weir 2005, Fernández-Juricic et al. 2005, Sawyer et al. 2006) have addressed both positive and negative implications for wildlife across various spatial and temporal scales of disturbance regimes. Although several provide evidence of detrimental impacts to wildlife (e.g., loss of habitat, population decline, increased competition, etc.), others demonstrate examples of species that thrived in altered habitats. Furthermore, many cases have shown that reclamation of disturbed habitats can be successful in restoring native wildlife communities (Whitmore 1980, Hingtgen and Clark 1984, Bajema et al. 2001, DeVault et al. 2002, Fletcher and Koford 2002, Vetter 2004).

Numerous development and reclamation practices emphasize incorporating wetlands and other aquatic habitats (i.e., streams, ponds, and reservoirs) because of water's vitality to all wildlife. Increased occurrence, movements to, and frequent use of created water features by big game (Boroski and Mossman 1996, Rosenstock et al. 1999, Turner et al. 2004, Oehler et al. 2005, Morgart et al. 2005), other large mammals (O'Brien et al. 2006), and birds (Vetter 2004, White and Main 2005, Lynn et al. 2006) have all been cited as evidence of the benefits to local wildlife. Although the potential value from increases in aquatic habitat is largely dependent on their quality and temporal availability (Bleich et al. 2006 and Krausman et al. 2006), the benefit is especially significant in arid and semi-arid landscapes, where for instance, one study (Olson and Gerhart 1982) estimated that eighty percent of the native species used the approximate one percent of riparian habitat believed to exist in Wyoming.

One area of development currently altering the abundance of surface water and wetland habitat throughout portions of the western United States (including Wyoming) is the production of coal bed natural gas (CBNG). During the extraction process, large volumes of ground water are brought to the surface as a primary byproduct. Water is especially prevalent during the early stages of production, requiring the construction of additional facilities for storage, treatment and release into larger watercourses, re-injection to restore ground water, or other creative measures of dispersion such as irrigation or misting. As gas production continues, the water in the coal seam decreases and less is discharged to the surface. The water production from CBNG projects is highly variable depending on how the wells are brought on-line (e.g., all at once vs. phased-in), but initial production is generally expected to be approximately 12-25 gallons of water per minute (gpm) (Bryner 2002 and Likwartz 2002). Water production likely decreases afterward to an average of approximately 4 gpm over an average operating life of 7 to 10 years (Bryner 2002 and Cook 2002).

The effects on wildlife from CBNG ground water discharge have yet to be fully investigated, but the potential benefits from enhancement and/or creation of aquatic and wetland habitats are likely similar to those observed for more permanent reclamation practices, except that they are semi-permanent. Although the potential benefits could influence a variety of wildlife taxa, aquatic species are likely to benefit the most from the influences of CBNG water production.

A look at one case study in the northwestern Campbell County, Wyoming has provided some insight as to the influences of CBNG water discharge on several amphibian species in the area.

One CBNG operator, the J.M. Huber Corporation, has initiated a five-year monitoring plan for northern leopard frog (*Rana pipiens*) populations and other local amphibians within one of their development areas receiving CBNG water discharge. The northern leopard frog is a Bureau of Land Management special status species, and is of particular interest because, like many other amphibian species, there have been documented declines over much of its range and throughout many of the western states (Wagner 1997), including notabledeclines in Wyoming over the last 10 to 20 years (Baxter and Stone 1980, Corn et al. 1989). Anthropogenic factors such as alteration of hydrological regimes/flow and introduced contaminants have been postulated as two possible causes of decline (Wagner 1997), but habitat loss from human disturbance has also negatively influenced leopard frog populations in many western states (Koch et al. 1996). Although optimal breeding habitats for most amphibians require specific water levels (Wershler 1991 and Gilbert et al. 1994) and water quality (Nace et al. 1996 and Wagner 1997), the creation of CBNG reservoirs may help mitigate negative impacts from other local influences if water levels are adequately maintained and sufficient water qualities are ensured. In that regard, CBNG water discharge may provide new, temporary breeding habitats that could potentially benefit many populations of amphibian species in the region, including the northern leopard frog.

Objectives

Several studies have addressed the impacts to wildlife from disturbances caused by a variety of anthropogenic sources, but the potential influences on wildlife from localized increases in artificial sources of surface water are still being examined. Specifically, introducing significant amounts of CBNG water discharge into a semi-arid landscape like northeastern Wyoming may have many benefits for local wildlife populations. Recently, however, biologists have been tasked with demonstrating a clear benefit to the increase of anthropogenic water sources in arid regions. It is important, and the first goal of this paper, to ascertain the current status of scientific work investigating the potential benefits to wildlife from increases in anthropogenic sources of surface water. Secondly, the objective is to explore the potential influence to wildlife from discharged CBNG water by considering preliminary results from a case study monitoring amphibian species within a development area in northeast Wyoming. Specifically, an investigation of amphibian populations in areas receiving and not receiving water from CBNG development may help define potential benefits of CBNG water discharge. The results of the study may help provide biological information worth considering during CBNG impoundment design, construction practices, and water management strategies.

Methods

Current literature was reviewed to include studies that focused on scientific documentation of wildlife use at naturally occurring and anthropogenic sources of water, including reservoirs, ponds, catchments, impoundments, tanks, and guzzlers. Manuscripts referencing studies in the semi-arid and arid climates of the western United States were specifically targeted.

Case Study

The J.M. Huber Corporation's Cutler Draw plan-of-development (POD) includes approximately 42 wells for extraction of federally owned CBNG resources within approximately 7.9 mi^2 of T57N:R74-75W in northwest Campbell County, Wyoming (Fig. 1). The regional climate is semi-arid, and terrain within the Cutler Draw area varies from high ridges and rough breaks with exposed clinker outcrops to the open valley of the Bitter Creek drainage. Major habitats within the project area included agricultural fields, grasslands, and sparse riparian woodlands surrounded by upland sagebrush-grasslands and ponderosa pine (*Pinus ponderosa*)/juniper (*Juniperus* sp.) breaks. Only a small section of Bitter Creek, the most significant drainage in the area, is included in the Cutler Draw project. However, several primarily dry tributaries drain to the creek from the smaller northeast portion and larger southwest portion of the project. Aside from the central Bitter Creek drainage, water sources present in the area before CBNG was established were likely limited to only minimal flow along one tributary in the southern portion of the project and one spring-fed historic impoundment (the only known location of leopard frogs prior to 2005) located in the far northeastern extent.

The Cutler Draw POD includes 19 total discharge points, use of seven existing and seven proposed reservoirs, and numerous constructed low-water and culvert crossings. Amphibian monitoring began in 2005 when the construction of the POD was still on going, and will continue through 2009. As construction was under way and several wells were on-line in the first year of monitoring, CBNG water discharge was present at many locations within the project throughout the first two years of monitoring. Although monitoring conducted in 2006 also occurred during on-going construction, the vast majority of construction on the POD was completed by the end of that summer. The monitoring program has included spring and summer anuran surveys at seven wetlands over two years and one additional wetland in 2006. Of the eight total survey sites/wetlands, three were impoundments constructed or improved to contain CBNG water discharge (i.e., infiltration/evaporation ponds), three were historic impoundments primarily fed by precipitation runoff or a natural spring, and two were located along a flowing creek supplemented by CBNG discharge. No attempt was made to delineate or designate wetlands based on Army Corps of Engineer standards.

In both years of monitoring, two nocturnal call surveys were conducted during each period of spring emergence (approximately 10º C water temperature) between one-half hour and three hours after sunset in late April and early May. A simplified call index was used to measure the relative abundance of all calling male anurans by recording either the estimated number of individuals determined from non-overlapping calls, or the estimated number of individuals from distinguishable but overlapping calls, or an undetermined amount of individuals from a continuous chorus of overlapping and indistinguishable calls.

Two diurnal visual surveys occurred from one-half hour to six and one-half hours after sunrise during late May and early August in each survey year. Visual surveys were also conducted during mild weather conditions (i.e., light to moderate winds and no precipitation) and consisted of a careful pedestrian search around the perimeter of each wetland to search for mature frogs, tadpoles, and egg masses. Survey sites along the creek were inventoried by walking 50 m in both directions of the survey point along the creek bank. Search effort was standardized, but total survey time varied for each site due to the size of the wetland and the attributes of the habitat.

Not all sites were suitable for surveys during each visit in 2005 or 2006 due to fluctuations in surface water levels throughout the area. Four sites (two historic impoundments and two creek sites) were surveyed on nearly every date ($\geq$ 7 surveys for each). Three newly constructed CBNG reservoirs were surveyed on nearly every date after completion of the reservoir ($\geq$ 4 surveys for each). Fluctuations in water levels were more variable at the one remaining site (an historic impoundment), and a total of only two surveys were conducted at that location.

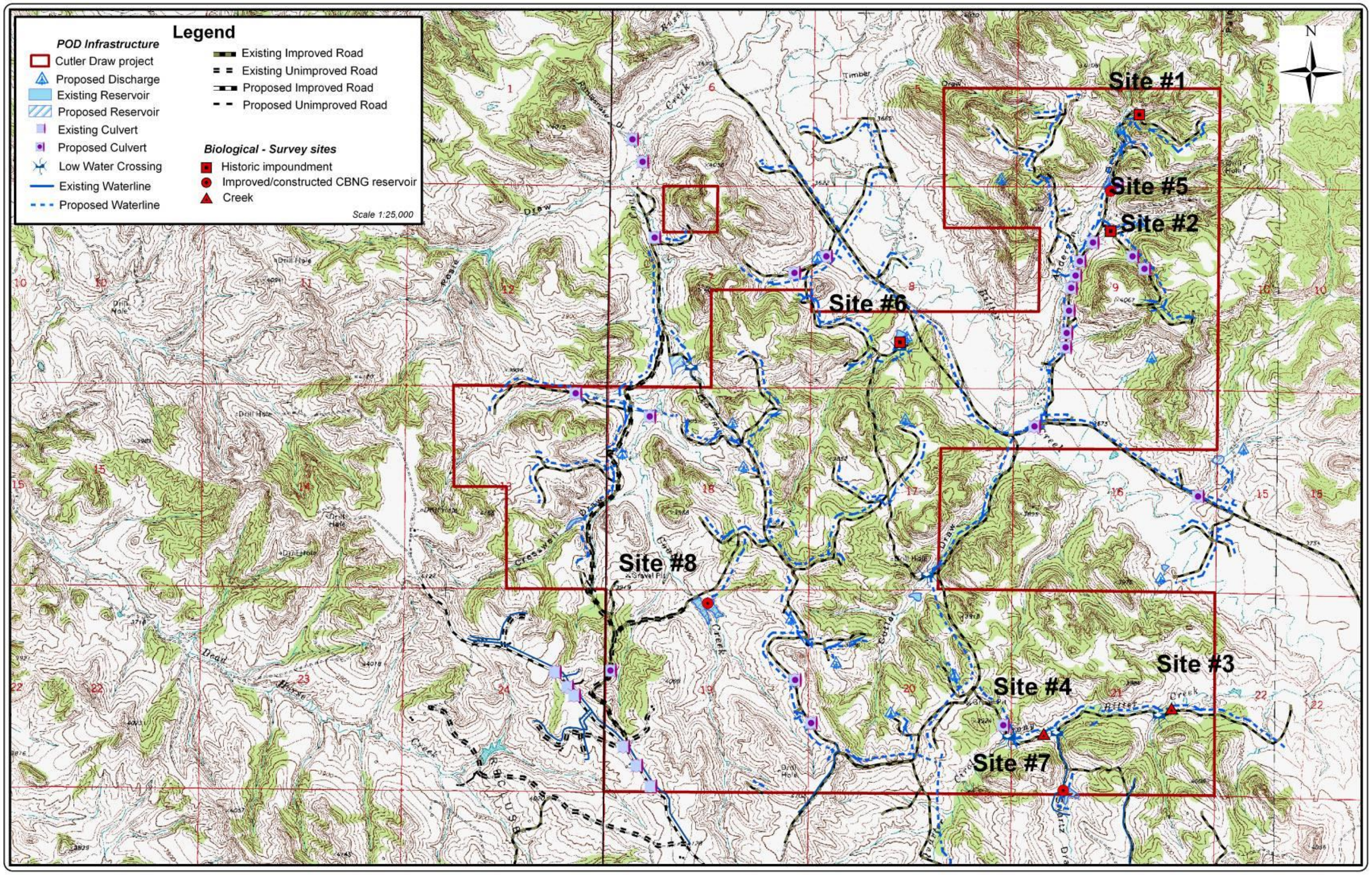

Figure 1. Sites surveyed in 2005-2006 for northern leopard frogs and other amphibians on J.M. Huber Corporation's Cutler Draw CBNG project within T57N:R74-75W in northwestern Campbell County, Wyoming.

Literature Review

Free-standing anthropogenic water sources provide obvious benefits to a variety of wildlife as drinking water and as newly created wetland habitat. Additional indirect benefits, such as enhancement of existing habitats (e.g., improved forage), may also be advantageous for many wildlife species.

The majority of recent studies (within the last two decades) addressing the potential impacts on wildlife from anthropogenic water sources have largely focused on big game utilization, with a thorough investigation centered around the value of artificial water sources in the southwest desert (primarily Arizona and California) to local populations of bighorn sheep (*Ovis Canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and pronghorn (*Antilocapra americana*). Much of that research was prompted because the benefits of artificial free-standing water supplies to big game and other local wildlife were generally accepted without reservation until several (Baber 1983, Kubly 1990, Cunningham and deVos 1992, Krausman and Etchberger 1993, Broyles 1995, Schmidt and DeStefano 1996, Brown 1998, Krausman and Czech 1998, Broyles and Cutler 1999 and 2001, Swift et al. 2000) speculated on a number of potentially adverse effects. The primary basis for those inquiries rested in better determining whether the behavioral framework of habitat selection could become increasingly important in understanding population-level consequences of artificially created water sources. Central to all were source-sink and ideal-despotic distribution theories, which predict that younger, weaker conspecifics of a population are forced to occupy lower quality habitat because the territorial superiority of socially dominant individuals permits them to occupy the high-quality habitats (Fretwell and Lucas, 1970, Pulliam 1988, and Pulliam and Danielson 1991).

Consequently, much of past speculation has led to recent findings that demonstrate the clear benefits of anthropogenic water sources to a variety of wildlife species. Bleich et al. (2006) indicated that wildlife water developments play an important role in the conservation of large herbivores, and Rosenstock et al. (2004) concluded that they are an integral part of wildlife management programs. In addition, O'Brien et al. (2006) and others have documented heavy use of artificially created water sources by ungulates, small mammalian carnivores (e.g., badgers, bobcats, coyotes), bats, and game and non-game birds alike. Krausman et al. (2006) presented a review of studies addressing the importance of free-standing water for >26 species and indicated increased distributions, populations, or movements relative to free-standing water sources for 17 of them, including numerous mammals and birds. Even though most accolades for created water sources come from the benefits to game species, O'Brien et al. (2006) recorded utilization by >34 species and a greater number of visits by non-game species. Although several studies (Boroski and Mossman 1996, Lynn et al. 2006, Marshal et al. 2006) have demonstrated the increased benefits of artificial water sources during drought conditions and drier periods of the year, the same studies have documented utilization throughout the year for numerous species of mammals and birds. Furthermore, Krausman et al. (2006) emphasized that the implication from many of the recent studies is an increased recognition of the year-round conservation value from created water sources; they also noted that results may indicate only an opportunistic use and not an explicit need for water resources.

While the recent focus on artificially created water features has largely pointed to marked benefits for wildlife, the bulk of information collected to date does not fully encompass the wide range of wildlife species that may benefit from their increased distribution. Surprisingly, few studies (AGFD 1997, Rosen and Schwalbe 1998, Sredl and Saylol 1998) have examined the potential benefits for aquatic species, such as fish and amphibians. However, increased awareness of the potential impacts to native fish and amphibian populations from CBNG-created water sources in northeast Wyoming may have much to offer in this regard. The considerable anthropogenic changes and increased surface water availability from CBNG extraction in this region has impelled several multi-agency/private aquatic task groups to acknowledge and implement means for determining the effects of CBNG surface water quality and management on local wildlife. Much of the work has focused on the prominent waterways (e.g., the Powder and Tongue Rivers) within the region, and the potential influences of CBNG water discharge (Davis and Bramblett 2006 and Stagliano 2006). In addition to the vertebrate sampling currently being conducted, data is also being collected on macroinvertebrate communities and the water quality parameters at many of the sites along those rivers. Unfortunately, much of that work has only recently been initiated (primarily 2005 or later), and the majority of the data is still being compiled.

Preliminary results (presented below) from a separate study may provide some of the most current information to date. These results demonstrate some of the apparent benefits from an ongoing case study (two out of five years completed) monitoring anuran species in northwest Campbell County, Wyoming.

Case Study Results & Discussion

Survey Conditions and Sites

Prior to monitoring in 2005, one known location (a spring-fed historic impoundment) in the northeastern extent of the Cutler Draw project hosted a sufficient year-round water supply and leopard frogs. That site also contained dense submersed vegetation along a deep mud substrate suitable for the wintering requirements of leopard frogs. Other water sources and distributions of amphibian species throughout the remainder of the project were unknown prior to monitoring in 2005. In 2005, seven total sites/wetlands were surveyed, including two impoundments constructed or improved to contain CBNG water discharge (i.e., infiltration/evaporation ponds), three historic impoundments primarily fed by precipitation runoff or a natural spring, and two sites located along a creek supplemented by CBNG discharge. In the second year of monitoring, one new CBNG impoundment had been completed and added to the monitoring program to include a total of eight survey sites.

A summary of the surveys conducted, the qualitative habitat data collected at each of the eight sites, and the changes in the wetland habitats (water depth and percent vegetation cover) over the first two years of monitoring are provided in Table 1. No quantitative water quality data was collected at any of the sites during surveys. Surface water levels fluctuated slightly more in the first year than in the second, and an overall increase in water availability was recorded in year two at all of the previous sites except the two historic impoundments. The percent of wetland vegetative cover remained relatively consistent at most survey sites in both years, but was noticeably greater in the second year of monitoring at one of the historic impoundments and one creek site.

Table 1. Preliminary summary (2 out of 5 years) of surveys conducted and habitat data collected at eight survey sites on the J.M Huber Corporation's Cutler Draw CBNG project in northwestern Campbell County, Wyoming.

Survey Sites	**Water feature/source**	**Wetland persistence**	**Call surveys**	**Visual surveys**	**Estimated range/average water depth in 2006**	**Change in average water depth from year one**	**Water quality**	**Estimated range/average vegetation cover in 2006**	**Change in average % vegetation cover from year one**
1	Impoundment, fed by spring	Permanent	2	2	62 to 67 inches, 63 inches	+ 5 inches	Clean and clear	1-10%, 6%	+ 1%
2	Impoundment, fed by runoff	Ephemeral	2	1	0 to 14 inches, 7 inches	- 2 inches	Clear and stained	50-85%, 71%	+ 45%
3	Creek, supplemented by CBNG discharge	Permanent	2	2	14 to 19 inches, 15 inches	+ 2 inches	Clear to cloudy and stained	5-70%, 49%	+ 26%
4	Creek, supplemented by CBNG discharge	Permanent	2	2	12 to 24 inches, 17 inches	+ 8 inches	Clear to cloudy and clean to stained	10-45%, 31%	+ 1%
5	Impoundment, supplemented by CBNG discharge	Semi-permanent	2	2	5 to 40 inches, 28 inches	+ 21 inches	Clear to cloudy and clean to stained	0-40%, 14%	+ 1%
6	Impoundment, fed by runoff	Ephemeral	1	0	0 to 14 inches, 3 inches	- 4 inches	Clean and clear	0-25%, 9%	- 5%
7	Impoundment, fed by CBNG discharge	Permanent	2	2	66 to 72 inches, 67 inches	+ 13 inches	Clean and clear to cloudy	5-20%, 13%	- 2%
8	Impoundment, fed by CBNG discharge	Permanent	2	2	10 to 66 inches, 46 inches	NA (not established in 2005)	Clear to cloudy and clean to stained	5-35%, 15%	NA (not established in 2005)

Anuran Detections

Northern leopard frogs, the primary anuran species targeted for the monitoring program, were documented within the northeastern extent of the project at a single historic impoundment fed primarily by spring water (site 1), prior to monitoring in 2005. Bovbjerg (1965) demonstrated that adult leopard frogs show a strong affinity for a particular area by returning to their home ranges (161-6,458 ft^2) year after year and, not surprisingly, leopard frogs were again recorded at site 1 during the first year of monitoring. Leopard frogs were also documented at a second historic impoundment fed primarily by precipitation runoff (site 2) and a newly constructed CBNG reservoir (site 7) in 2005. Both historic impoundments hosting leopard frogs in the first year were relatively close (~ 0.6 mile) and within the same drainage. Although Seburn et al. (1997) stated that young frogs were capable of dispersing up to 1 km (0.6 mi) just three weeks after metamorphosis; the CBNG reservoir hosting leopard frogs in 2005 was located considerably farther away from site 1, in a separate drainage, and approximately 3.3 miles to the south. However, Seburn et al. (1997) also found that young frogs had dispersed up to 8 km (5.0 mi) from their natal ponds by their first spring.

Although 18 total leopard frogs were observed or heard at the three sites during the first year of monitoring, 14 of the frogs and the only evidence of breeding (calling males) in year one were recorded at the historic impoundment site (site 1), where leopard frogs were originally recorded in 2004. Again, the dense submersed vegetation, mud substrate, and deep waters represent critical breeding and wintering habitats likely needed to sustain a leopard frog population at that site. The four remaining leopard frogs recorded in the first year of monitoring consisted of three juveniles and only one adult observed during the last survey at the second historic impoundment (site 2) and newly completed CBNG reservoir (site 7), respectively. Although CBNG discharge did occur in the first year of monitoring, the connectivity among aquatic habitats throughout the POD was still highly variable in 2005 due to the natural fluctuation of wet and dry periods and the progression of CBNG surface water discharged from wells brought on-line in that year. The few leopard frogs documented outside of the original occupied site in the first year of monitoring were likely influenced by these factors.

An increase in the relative abundance of northern leopard frogs between the first and second year of monitoring on the Cutler Draw project was notable (a 472% increase in the second year) and likely influenced from the increase in sustained wetlands and a greater hydrological connectivity throughout the project. As an example, leopard frogs were recorded at only three of the seven sites surveyed in the first year, but were documented at five of the eight sites surveyed in the second year and six of the eight sites over both years. Leopard frog detections increased to a total of 85 frogs recorded, but as with year one, breeding northern leopard frogs (calling males) were confirmed only at the original historic impoundment (site 1). Nearly half (41 of 85) of all leopard frogs documented in 2006 occurred at the CBNG reservoir that hosted leopard frogs in the previous year (site 7), and 33 of those were young of the year. In addition, seven or more combined adult and juvenile leopard frogs were also recorded in 2006 at the original historic impoundment, both creek sites, and an additional CBNG reservoir site (sites 1, 3, 4, and 5). Those records demonstrated utilization of the full range of water source features (historic impoundments fed by natural runoff, improved or constructed CBNG impoundments, and sites along a creek) within the Cutler Draw project. The placement of new or improved CBNG impoundments near historic water sources increased the density of wetland habitats in particular areas of the project area and likely influenced movements (voluntary and involuntary) of local leopard frog populations.

The sites where leopard frogs were not recorded in 2006 were notably the remaining two historic impoundments (sites 2 and 6), where dry conditions prevailed during some or most of the surveys, and the most recently established CBNG reservoir (site 8). However, leopard frogs were recorded at one of those historic impoundments (site 2) during the first year of monitoring when surface water was sustained throughout the entire survey period. A summary of northern leopard frog occurrences recorded during call and visual surveys in 2005 and 2006 on the Cutler Draw project is presented in Table 2.

Regardless of connectivity and wetland abundance, the development of sustained, deep-water habitats from CBNG impoundments will likely benefit leopard frogs as well as other amphibians. In particular, leopard frogs are generally associated with moderately deep, still or slow-moving aquatic habitats. Those conditions provide habitat for winter hibernation along underwater substrates that are relatively ice-free and development of tadpoles in waters without strong currents that would otherwise jeopardize tadpole survival (Kendall 2002, Wagner 1997, and Wright and Wright 1995). Many CBNG reservoirs typically meet those requirements, but those at the Cutler Draw project are also designed with a mixture of gradual and moderately sloped banks that provide additional breeding and late summer habitats. Moderately sloped, vegetated shorelines can be especially valuable in late summer for juvenile frogs because they offer a quick escape (from predators) into deeper waters while basking or foraging out of water. Gradually sloped shorelines at many of the reservoirs include flooded vegetation important for egg and tadpole development as well as foraging or refuge for adults and juveniles.

A total of six amphibian species have been recorded during the first two years of monitoring on the Cutler Draw project, and the results at each survey site are detailed in Fig. 2. In addition to northern leopard frogs, four other amphibian species were documented during call and visual surveys conducted in spring/summer 2005. Those species included the boreal chorus frog (*Pseudacris triseriata*), Woodhouse's toad (*Bufo woodhousii*), Great Plains toad (*Bufo cognatus*), and tiger salamander (*Ambystoma tigrinum*). In addition to numerous unidentified tadpoles, several unknown adult frogs or toads were also documented. Four additional species of amphibians were documented during the call and visual surveys conducted in spring/summer 2006, including the boreal chorus frog, Woodhouse's toad, plains spadefoot (*Scaphiopus bombifrons*), and tiger salamander. Unlike the first year of monitoring, Great Plains toads (*Bufo cognatus*) were not documented during surveys in 2006. Numerous unidentified tadpoles, one unknown juvenile frog or toad, and nine unknown adult frogs/toads were also documented during the second year of monitoring.

All sites except one historic impoundment exhibited the same level of species richness or an increase in total species between the first and second year of surveys. The greatest diversity of amphibian species documented within the first two years of monitoring on the Cutler Draw project were recorded among the creek sites, with generally even diversity recorded per site per year (mean = 3.25 species, 3.0 species in 2005 and 3.5 species in 2006). Although the diversity measured at the CBNG reservoirs was among the lowest of all sites in the first year of monitoring (mean = 2.0 species), the amphibian species recorded at CBNG reservoirs in 2006 was much higher (mean = 3.3 species). Because of the diversity documented at the CBNG reservoirs in 2006, the total diversity measured across the first two years of monitoring (mean = 2.8 species) exceeded that measured at the historic impoundment sites (total mean = 2.2 species; 2.3 species in 2005 and 2.0 species in 2006).

The overall relative abundance of amphibians at each survey site (standardized by survey time) in the first two years of monitoring at the Cutler Draw POD is detailed in Table 3. Detection of amphibians from call surveys was greatest at the CBNG reservoirs (mean = 1.9 calling males/minute) during the course of the first two years of monitoring. Although numerous calling males were recorded during particular surveys or years at other sites, the average calling males detected at the historic impoundments (mean = 1.5 calling males/minute) and creek sites (mean = 1.0 calling males/minute) was lower. Detections from visual surveys revealed similar results with the greatest amphibians documented at the CBNG reservoirs (mean = 0.31 amphibians/minute) and slightly fewer recorded at the creek sites (mean = 0.25 amphibians/minute). During the first two years of monitoring, the fewest amphibians recorded per minute during visual surveys occurred at the historic impoundments (mean = 0.19).

Table 2. Northern leopard frog occurrence during spring/summer in first two years of monitoring at eight survey sites on the Cutler Draw CBNG project in northwestern Campbell County, Wyoming.

Survey sites	Year	1st call survey	2nd call survey	1st visual survey	2nd visual survey	Total leopard frogs
1	2006	1 calling male	0	6 adults	1 adult, 8 juveniles	16
	2005	0	2 calling males	4 adults	2 adults, 2 juveniles	14*
2	2006	0	0	0	No habitat present	0
	2005	0	0	0	3 juveniles	3
3	2006	0	0	0	1 adult, 6 juveniles	7
	2005	0	0	0	0	0
4	2006	0	0	1 adult	2 adults, 7 juveniles	10
	2005	0	0	0	0	0
5	2006	0	No habitat present	0	8 adults, 3 juveniles	11
	2005	No habitat present	0	0	No habitat present	0
6	2006	0	No habitat present	No habitat present	No habitat present	0
	2005	No habitat present	No habitat present	0	No habitat present	0
7	2006	0	0	4 adults	4 adults, 33 juveniles	41
	2005	No habitat present	No habitat present	No habitat present	1 adult	1
8	2006	0	0	0	0	0
	2005	No habitat present	No habitat present	No habitat present	No habitat present	0

* Four additional leopard frogs were documented at site 1 during the habitat inventory in April 2005.

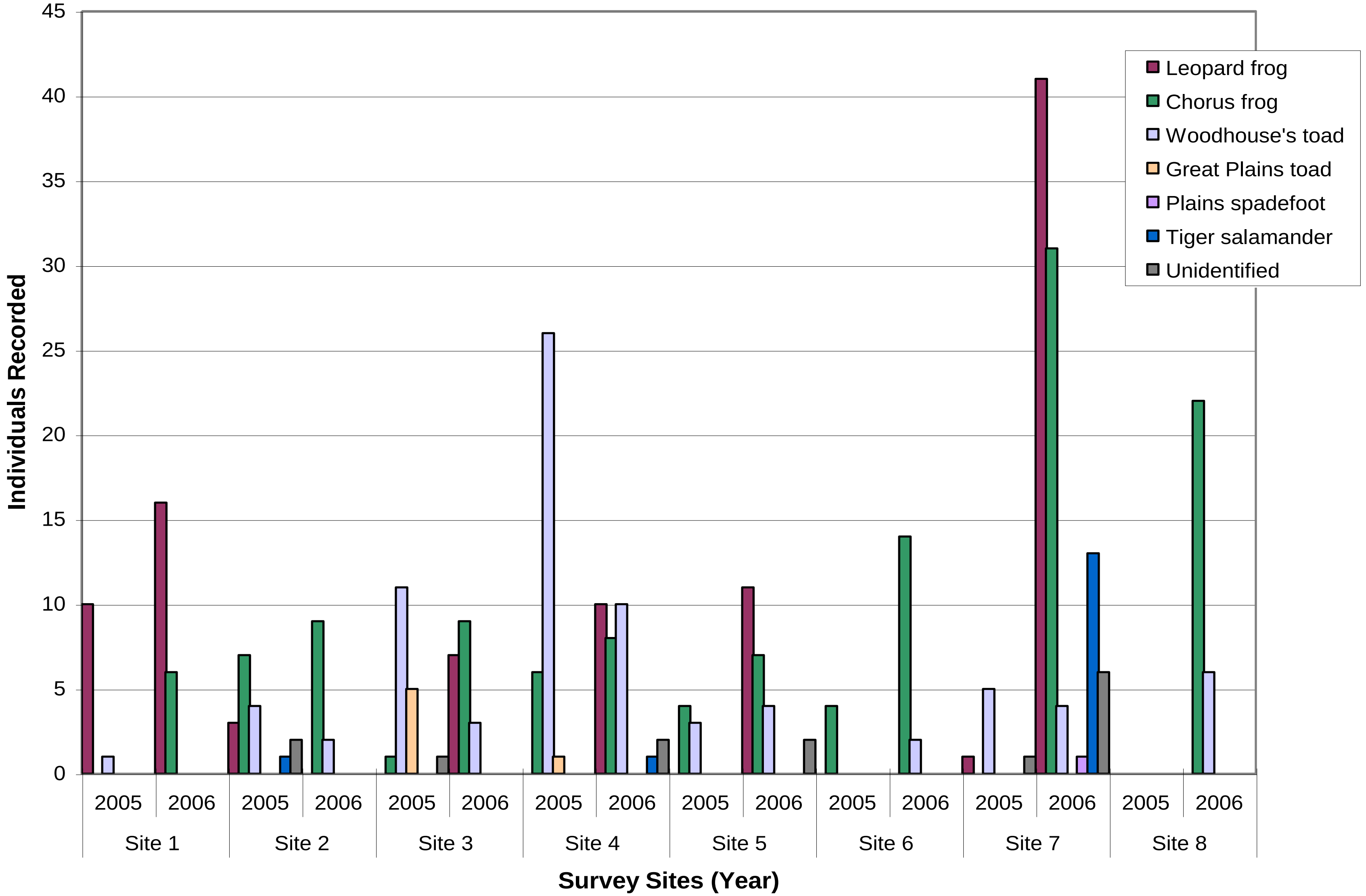

Figure 2. Amphibian species recorded during northern leopard frog monitoring (2005-2006) at eight survey sites at the Cutler Draw POD in northwestern Campbell County, Wyoming.

Table 3. Relative abundance[1] of all amphibians combined in the first two years of monitoring at eight survey sites on the Cutler Draw POD in northwest Campbell County, Wyoming.

		Amphibians recorded per minute of survey time[3]		
Survey site/wetland area	**Type of survey[2]**	**2005**	**2006**	**Total**
1 (0.6 acres – historic impoundment)	Call surveys (4)	0.20	0.70	0.45
	Visual surveys (4)	0.15	0.25	0.20
2 (0.5 acres – historic impoundment)	Call surveys (4)	0.40	1.10	0.75
	Visual surveys (3)	0.26	0	0.20
3 (~ 0.3 acres – creek bank 50m upstream and downstream)	Call surveys (4)	0.70	1.10	0.90
	Visual surveys (4)	0.15	0.19	0.16
4 (~ 0.3 acres – creek bank 50m upstream and downstream)	Call surveys (4)	1.10	1.00	1.05
	Visual surveys (4)	0.34	0.35	0.34
5 (1.1 acres – CBNG reservoir)	Call surveys (2)	1.40	0.30	0.67
	Visual surveys (3)	0	0.31	0.19
6 (2.4 acres – historic impoundment)	Call surveys (1)	---	3.20	3.20
	Visual surveys (1)	0.16	---	0.16
7 (2.3 acres – CBNG reservoir)	Call surveys (2)	---	2.70	2.70
	Visual surveys (3)	0.28	0.78	0.67
8 (2.3 acres – CBNG reservoir)	Call surveys (2)	---	2.20	2.20
	Visual surveys (2)	---	0.07	0.07

1 Tiger salamanders do not vocalize and cannot be detected during call surveys.

2 Due to periodic dry conditions that eliminate suitable wetland habitat and the on-going construction on the project, not all call and visual surveys were conducted at each site in the first two years of monitoring. The numbers in ( ) indicate the combined total surveys conducted to date for each type of survey.

3 Standardized across survey sites by search time. All call surveys included a five-minute listening period, but visual surveys differed in time due to wetland size, shape, and the surrounding habitat.

Conclusions & Recommendations

A literature review of the studies investigating the benefits to wildlife from artificial free-standing water sources indicates that there are clear advantages provided in the form of increased drinking water and greater availability to wetland habitats. In addition, many of the negative impacts that were postulated in the past have not been exhibited in the majority of the recent studies. Numerous examples exist demonstrating the vitality of anthropogenic water sources for a variety of wildlife taxa, including game and non-game species of mammals and birds. A clear example of the benefit to amphibian species has also been demonstrated in the preliminary findings at the J.M. Huber Corporation's Cutler Draw CBNG development area in northeast Wyoming. Albeit a temporary enhancement, the value of artificially created surface water from Cutler Draw CBNG development is evidenced from the fact that numerous amphibians, including some special status species, have utilized newly created wetland habitats in the area during the first two years of a five-year monitoring program. In fact, the diversity over the first two years of monitoring at CBNG reservoirs on one project has exceeded that measured at historic impoundment sites that lack CBNG discharge. Likewise, the relative abundance measured during both call and visual surveys over the first two years of monitoring was greater at CBNG reservoirs than at creek sites or historic impoundments. Although the influence from CBNG discharge water (anticipated discharge life of <10 years in most areas) has yet to be fully understood, preliminary results of this study suggest that CBNG reservoirs placed properly could have substantial benefits for several amphibian species and the overall diversity of aquatic wildlife in the immediate term. In addition to newly created wetland habitats, the improvement of old impoundments and the early levels of moderate CBNG water discharge on the project have helped to supplement and sustain historically ephemeral wetlands during relatively dry years. Again, the immediate effects may, however, warrant particular caution in future years as a decrease in water production is expected after the early stages of CBNG production are surpassed.

Habitat loss and livestock activity (trampling, grazing, increased turbidity, defecation and associated nutrient loading) are often cited as causes for population declines in many amphibian species (Blaustein and Kiesecker 2002, Wagner 1997). As livestock activities are prevalent in the Cutler Draw area, the combined effect of increased wetland availability from CBNG discharge and fencing to restrict livestock trampling could help mitigate those potential impacts. Furthermore, increased stability of the water levels may provide better breeding and wintering habitats to help sustain local populations of several amphibian species. Although several aspects of this study constrain conclusions on particular mechanisms (CBNG-related or otherwise) that may regulate local populations, the early results of this on-going study suggest that there may be significant benefits to wildlife from CBNG water discharge. Additional effects specific to water chemistry, parasite loading, pathogens, and predation are important considerations as well, but the insights gained to date should help in determining CBNG construction practices and water management strategies that can benefit frogs and other wildlife. In that same respect, it may suggest that increased availability of artificial surface water (regardless of its source) and greater landscape connectivity likely benefit many wildlife species in the immediate term by providing opportunities to establish and enhance source populations that can withstand the future stochasticity associated with natural and anthropogenic disturbances.

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