

Implementing a One Health Approach to Rabies in
Wyoming

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Abstract

One Health is an approach that addresses the interrelation between animal, human, and environment health. One Health seeks to unite efforts at solving health issues by providing a more holistic approach to public health. A One Health approach to the prevention of rabies transmission from bats to humans has received little attention, but, could have great benefits. This project seeks, by providing a One Health recommendation to governmental entities in Wyoming including the Wyoming Department of Health (WDH), to lower the incidence of rabies exposure. Methods utilized in this paper were a literature review, analysis of other state public health programs, and collaboration with WDH. Primary recommendations include bat vaccination research, an increase in inter-departmental communication and collaboration, and an education program to alert the public to the risk of rabies. Recommendations for next steps include a pilot study to determine general knowledge of rabies recommendations and protocols among professionals, pilot research on a rabies vaccine in bats, and implementation of a communication flow and an education program on rabies risk mitigation.

Introduction

Rabies is a nearly completely fatal viral disease. This zoonotic disease is caused from viral exposure from wound contact with saliva from infected animals. Rabies is a preventable disease yet is still the cause of over 59,000 deaths per year (WHO, 2018). Even though there are few cases of rabies in the United States with only 23 cases being reported from 2008-2017, rabies is still a major concern as the possibility for spillover is ever-present, especially in rural areas where domestic animals and people are more likely to come into contact with the natural reservoirs of rabies or in areas where humans have taken over the habitat and displacing the animals that live there (Harrist et. al, 2016). The 2015 rabies case in Wyoming which was the first reported fatal case of rabies in Wyoming has stimulated interest in implementation of programs to raise rabies awareness to prevent further rabies infections. Considering the recent fatality in November due to a rabies infection contracted from a bat in Utah (Utah Department of Health, 2018), it is imperative that states implement effective strategies to decrease the incidence of rabies as this disease is nearly universally fatal. As many cases that have occurred in the United States in the past ten years are due to exposure via bat, and the rabies case from Wyoming was due to a bat, this report will focus on mitigating rabies risk from exposure to bat rabies. It is also important to note that there are many programs in place to mitigate the risk from other sources of rabies such as vaccination programs and well-known knowledge about the other sources of this disease.

One Health is an approach to disease prevention that focuses on interagency collaboration. This approach has been utilized in countries such as Tanzania through the HALI project (HALI Project, 2009) and China (Tan et. al, 2017). They have been working to implement control strategies that focus on a One Health approach to zoonotic diseases endemic

to the areas and have seen some success. A One Health approach to rabies has promise since it includes numerous officials in the solution, is cost effective, and includes all facets of health (Environment, Animal, and Human). There are a variety of One Health tactics that can be utilized to help stop the spread of rabies. Those deemed most pertinent to Wyoming shall be discussed in further detail. The main approaches that will be covered are research into bat vaccinations, increasing inter-departmental communication and collaboration, and implementation of a wide-spread education campaign.

Rabies

Rabies has many reservoir hosts as well including, bats, skunks, foxes, and racoons in the United States (CDC, 2018). Though there are few cases in the United States due to canine vaccination programs, rabies is an important emerging zoonotic disease in third-world countries. Annually, the over 59,000 human deaths due to rabies is likely highly underestimated due to the lack of reporting ability or unwillingness to report in some countries (WHO, 2018). The cases that occur in the United States are often due to interaction with wildlife and lack of proper protective equipment or animal handling knowledge to decrease the risk of exposure to rabies. Clinical symptoms of rabies include, but are not limited to, inappetence, excessive saliva production, abnormal behavior, paralysis, and seizures (Brown et. al., 2016). Rabies is spread through contact with an infected animal's saliva. This is most often from an animal's bite. From the site of infection, the virus infects neuronal cells, replicates, and moves to the next via the synaptic terminal. An important thing to note is that rabies moves opposite the signaling route that neurons use and forces the neurons to allow backwards movement (Gluska et. al., 2014). Rabies viral replication is tightly regulated to prevent apoptosis of the neuron cells to prevent detection by the immune system (Murray, 2018). This virus also refrains from causing apoptosis

in cells that host rabies which is thought to aid in its pathogenicity (Dietzschold et. al., 2009). The rabies virus causes inflammation in the brain and has been found to bind receptors like the nicotinic acetylcholine receptor that is bound by a rabies viral protein on its coat that has a toxin-like effect (Hueffer et.al., 2017). This is thought to aid in pathogenicity and host behavior modification to promote its transmission (Hooper et. al., 2011). Post-exposure prophylaxis (PEP) works in a multi-part process. The 4 doses of a killed viral vaccine to stimulate antibody production and immunoglobulin treatment to provide protection for 2 to 3 weeks until the body has produced sufficient antibody to provide protection against rabies. This treatment stimulates and boosts the immune response to the rabies viral presence (Minnesota Department of Health, 2018).

The negative-sense single-stranded RNA rabies virus is classified in the order Mononegavirales and family Rhabdoviridae. This virus is part of the genus Lyssavirus which is also home to Mokola virus, Lagos bat virus, and European bat virus 1 and 2 (CDC, 2018). Rabies virus replicates in the cytoplasm of infected cells like many other viruses, but only has 5 major structural protein genes to replicate named N, P, M, G, L as well as a long 3'-untranslated region directly following the G protein (ICTV, 2018). The N gene encodes for the nucleoprotein, P encodes the phosphoprotein, M encodes the matrix protein, G encodes glycoprotein, and L encodes an RNA-dependent RNA polymerase that the virus packages into its envelope (Luo et. al, 2012). The glycoprotein gene G is important in the pathogenicity of rabies virus as it is used in several different mechanisms that contribute to pathogenicity such as interaction with the RNA-NP-M complex for more competent viral budding (Faber et. al, 2005). These major genes as well as its ability to be spread through saliva are what give rabies its ability to easily adapt to new species and infect them.

Rabies in Wyoming

In Wyoming, dogs and cats are vaccinated around 3 months of age against rabies by licensed veterinarians so domestic animals are rarely a source of rabies exposure (AVMA, 2017). Those suspected of rabies exposure are given a rabies booster and watched in confinement for up to 4 months. Samples produced for rabies testing are sent to the Wyoming State Vet Lab. The Wyoming State Vet Lab keeps track of the number of animals submitted for testing and how many of those submitted test positive for rabies virus. The most common submission for rabies testing is skunks with 29 positive skunks in 2018 as of October 31 (University of Wyoming State Vet Lab, 2018). Positive bats are also relatively common with 64 bats testing positive for rabies from 2009-2017. Comparatively, the number of skunks testing positive for rabies was 170 animals (Wyoming Animal Damage Management Board, 2018).

While a very small portion of the bat population contracts the disease, less than 1%, some species of bats are an important reservoir of rabies. All infected animals can transmit the rabies virus not only to humans, but, to other wildlife and domestic animals as well (Bat World, 2012). The animals that contract rabies can pass rabies along to humans as well. This poses a threat to domestic animal and human health as domestic animals that contract rabies can spread the infection as well as contract the disease and die. While most rabies exposure cases have resulted in PEP being used to prevent contraction of the disease, there was a recent case of exposure that resulted in an unfortunate contraction of rabies. On August 22, 2015, a woman from Wyoming awoke with a bat on her neck, removed the bat, and did not seek medical care. She was later admitted to a Utah hospital with progressing symptoms of respiratory failure and encephalitis. The family recalled that she had found a bat on her around a month before symptoms began but had only called a local authority about the incident. The local authority had not advised that she

seek PEP so nothing was done about this incident other than removing the bat from the home. The CDC confirmed on October 2 that the woman had contracted a bat rabies variant and she passed away shortly after (Harrist et. al., 2016). This case gained widespread attention in the media as the first confirmed human case of rabies in Wyoming (CBS, 2015).

One Health

One Health is an incredibly old concept and has been known as both One Health and One Medicine. This concept was first written down as One Health by Hippocrates in 400BC (Evans and Leighton, 2014). One Health is likely much older as the ancient Egyptians had papyri with both animal and human health issues written on them. The papyri were used by physicians who cared for humans and animals alike (Zinsstag et.al., 2011). The term ‘One Health’ was coined in 1984 by Schwabe and has been used to describe the convergence of human, animal, and environmental health since (Zinsstag et. al., 2012). Many physicians recommended that veterinary programs and human medical programs contained coursework for both animal and human health to emphasize the interrelatedness of human and animal health as up to 75% of emerging diseases are zoonoses (Webster et. al., 2015). This is important to note as up to 80% of new human diseases are zoonoses (Morens & Fauci, 2013).

A One Health approach requires a firm foundation of knowledge of ecology in an area (Zinsstag et. al., 2012). In addition to understanding the ecology of an area, a One Health approach requires integration of an effective communication strategy for organizations and governments in affected areas (Mazet et. al., 2009). Public education is another important facet to One Health as this gives the public needed information to avoid unnecessary exposure to disease. Education should also target public officials as they are often the first figures that the public looks to during a disease outbreak.

The One World, One Health Symposium in 2004 created 12 principles named the ‘Manhattan Principles’ that outline ideal goals in approaching the issue of emerging diseases and re-emerging diseases as they affect our society today. The principles focus heavily on the interrelatedness of human, animal, and environment health as well as investing in research and increase collaboration between governments, locals, and the private and public sectors to be better prepared for emerging diseases (One World One Health, 2004). An ideal for One Health is to employ an integrated approach that accounts for political, cultural, and ecological factors as well as resources that are available to the governing forces and the organizations involved in mitigation of a disease’s influences. These principles will be modeled in the recommendations for Wyoming’s approach to rabies prevention in the next section.

Integration of A One Health Approach to Rabies in Wyoming

To effectively integrate One Health into Wyoming’s approach to rabies, I recommend the following: creation and implementation of an oral vaccine for bats, an education campaign, and an increase in inter-departmental communication and collaboration. The educational campaign would target youth in schools and use a social media campaign to involve the youth as well as the general populous. An increase in inter-departmental communication would allow for more information to be disseminated to lower branches and pertinent data to be more easily passed to the higher branches of the system.

Currently there are no bat rabies vaccines for commercial use; however, several vaccines are being researched for use in bats using a variety of delivery methods to determine the most effective at providing protection against rabies infection. One such vaccine was being tested against vampire bats is being tested to determine if intramuscular (IM), scarification, oral, or aerosol delivery is most effective at providing protection against future challenges to rabies

(Aguilar-Setién et. al., 2002). The results from this experiment showed promising results for each of the delivery methods. The IM and scarification methods were shown to be the most effective for widespread use while the oral and aerosol methods were more effective to prevent the spread of rabies from one species to the next or between infected and non-infected bats when in close proximity. A more recent study focused on IM and orinasal (ON) options for a recombinant rabies vaccine. This study used poxvirus as a vector for rabies virus genes to create a vaccine for rabies in bats with some success (Stading et. al., 2016). This experiment showed promising results in using a virus vector to create protection against rabies via ON vaccination. Mass vaccination programs have proven to be very effective for other species such as dogs, foxes, and racoons. Tanzania has had great success with a dog vaccination program that not only decreased the incidence of canine rabies, but, also decreased the incidence of dog bites in the vaccination zones (Lavan et. al., 2017).

Many states in America orally vaccinate wild racoons against rabies and Texas even orally vaccinates foxes and coyotes against rabies infection (APHIS, 2015). These programs show that a vaccination program in bats could limit the spread of this disease even further. In Wyoming, a mix of ON and IM methods would likely be the most efficient. An ON method would be useful in areas where there are high populations of bats around rural towns as this method is easiest to vaccinate large populations at the same time. IM could be useful in bats that have been caught in homes or for other research purposes. It would be helpful to vaccinate during peak breeding times when bats are producing young to stop the transmission of rabies to the new generation of bats. It could also be good to vaccinate during times that bats are coming out of hibernation and becoming active again or migrating for the winter and summer (National Park Service, 2016).

The second part to this recommendation is to not have large-scale bat reduction programs as this would only increase the risk of people coming into contact with infected bats. This would also likely only reduce the healthy bat population as it is a relatively low percentage of the population that carries the rabies virus. This has been shown to not work effectively in countries such as Bhutan with mass dog culling programs (Lavan et. al., 2017). Culling programs have been shown to be ineffectual as it only reduces the population temporarily and only leads to younger animals becoming more susceptible to rabies. Many of these programs cull dogs indiscriminately and remove vaccinated dogs from the population as well (Taylor et. al., 2017). These factors only confound the problem of rabies transmission. As this method has been shown to not work well in the dog population in several countries that employ a culling technique to control the rabid portion of the population, it is likely that it would not work well in the bat population for many of the same reasons in addition to the fact that this is a wildlife population so only a small portion of the population would actually be culled unless efforts were made to cull a larger portion of the population which would lead to increased risk of exposure. Additionally, bats are an incredibly important part of the ecosystem as they pollinate a wide variety of plants and help to reduce the insect population (Bat Conservation International, 2018). Utilizing a culling program may reduce the possible exposure for a wider portion of the population, but, would increase the risk for those exterminating the bats and of other disease transmission as insects have proven to be a competent disease vector for a wide variety of diseases. Avoiding large-scale reduction programs goes hand-in-hand with supporting ecological health. A healthy environment supports a healthy animal population which in turn benefits human health. This information is most important for animal control and Fish and Game to know as they would likely be the organizations implementing bat culling programs.

Instead of culling programs, wild animal surveillance could be utilized instead to help limit rabies by placing oral vaccines in areas that have higher populations of mammals and to better understand the movement of the animals to help prevent human exposure through decreasing human flow through areas where likely infected animals flow in high volumes. Surveillance could be done through the University of Wyoming as they have many wildlife classes that could benefit from animal surveillance projects. The wildlife program in addition to Game and Fish could spearhead the vaccination program once some bat vaccines are available for commercial use.

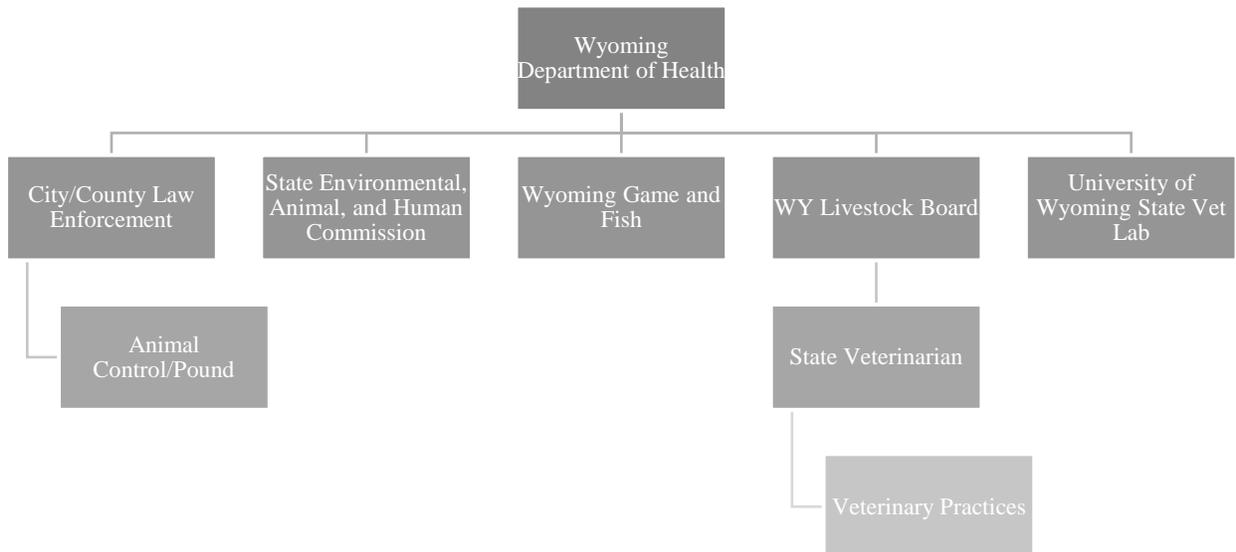


Figure 1: Recommended flow of information from lower entities to the Wyoming Department of Health to allow for the most efficient flow of information. The lowest tier on this figure is not shown as it is the individuals reporting concerns and these entities naturally report up to officials.

The next recommendation would be to increase inter-departmental communication and collaboration for rabies management. This would include not only three larger state entities such as the Wyoming State Health Department and the Wyoming Game and Fish, but, also the community entities such as sheriff's departments, animal control, and local veterinary practices.

It would be ideal to create an information flow so that all rabies data is being sent to where it needs to be sent and all information is being dispersed to all departments so there are fewer information gaps about rabies protocols and recommendations. In addition to this, it would be beneficial to have a reporting service that transfers all data to one central location that can be accessed by all entities in the organizational flow to allow for rabies data to be easily accessed and added to. All of the data would be compiled by the Wyoming Department of Health and then posted to the reporting service area for ease of access, understanding, and reporting. As shown in Figure 1, the Wyoming Department of Health is at the apex of the information flow as it is the highest-ranking entity with the most public health resources. The entities lowest on the flowchart are entities with the fewest public health resources and connections. Following Figure 1 would help to create allow for accountability in rabies reporting that could help stop fatalities from occurring.

Currently, there are many gaps in reporting of rabies information as shown in the 2015 rabies case in Wyoming as the woman was not told about the risk of rabies nor was any follow-up performed by another institution which a communication flow would remedy. As of now, there is little enforcement in rabies reporting as Wyoming is a state with home rule. This means that cities hold the power of determining their laws (Wyoming Association of Municipalities, 2010). Without a set ideal for communication flow, rabies reporting can get glossed over as less important. A communication flow that covers all municipalities in Wyoming could cover these reporting gaps and provide a basis for collaboration between departments.

In addition to having a better flow of information between Wyoming departments and agencies, it is important to educate the population using several methods of communication. Using social media is a very useful way to target a very large majority of the population as most

people have some social media presence. Using their Facebook page or Twitter could be an incredibly effective mode of communication among the younger, tech-savvy generations. Social media platform can garner good attention to topics like rabies and can be a good way to disseminate information quickly as sharing posts on these sites is incredibly easy. Social media accounts could help in not just the general populous education, but, also school education as school-age children will appreciate using a new approach to teach them information.

Utilizing schools is also important as educating the youth on rabies prevention could help limit the amount of post-exposure prophylaxis that is administered to children by educating against actions that would necessitate prophylaxis. The CDC website has a good section for children and creating an education program based off would be useful as the information there is correct and up-to-date (CDC, 2010). The Wyoming Department of Health also has an education course for school-age children that could also be used with some interactive activity additions to make it friendlier for younger school-age children (Wyoming Department of Health, 2018). Both of these programs are very educational and full of helpful information.

Information that should be underscored, especially in areas with a large bat population or one that has endemic rabies, is that residents should use window screens and keep the doors closed and use screens to prevent bats from entering their homes. Additionally, staying inside when bats are most active will help to stop bats from entering homes and prevent unnecessary exposure. As it is unlikely that people will be able to keep bats out of barns or open workshops, it is important that people understand how to use proper protection when entering areas that may have bats to help lower the risk of exposure. A critical part of education is informing both the Wyoming citizens and the officials about who to call in case of exposure or suspected exposure to a bat.

Discussion

The recommendations for implementing a One Health approach to rabies control in Wyoming- creation of rabies vaccines for bats, increasing already existing inter-departmental communication and collaboration, and education- are useful if carefully implemented in Wyoming and integrated into the Wyoming Department of Health. Each recommendation has benefits and drawbacks. With time, the benefits of implementing each will outweigh the current drawbacks as this will also save valuable resources, treatments, and most importantly, lives. These methods could then be implemented, expanded upon, and tailored to other states and countries to further minimize the possibility of being exposed to rabies.

The creation of rabies vaccine for bats is still in very early development so this recommendation could not be put into use for some time. This is a fair problem considering that there are few strides being made in the area of a rabies vaccine for use in bats. If a group began research on a rabies vaccine, the best-case scenario is that it could be implemented in around 10 years, so this leaves a large gap in time where a vaccine is not increasing the population's protection from being exposed to rabies. In between now and when a rabies vaccine is available for commercial use and implementation in halting the spread of rabies through the bat populations in Wyoming, the use of education and mechanical prevention methods such as window screens, closed doors, and protective equipment will have to be heavily encouraged. If the University of Wyoming were to spearhead the research of a rabies vaccine and its implementation, this could garner good publicity for the state of Wyoming for both important research and use of its university to benefit not only the entire state, but, any area with a major bat population that has endemic rabies.

Increasing communication on all levels of government and private- and public-sector entities is one of the most important facets of One Health as open communication allows for better collaboration on projects so that they are more efficient and are able to approach and reach the goal of lowering the incidence of rabies as a united front. This is likely the most difficult of the suggestions to implement as state organizations and non-state organizations often do not use the same communication systems, so a different system would have to be set up for collaboration. Once set up though, if one organization maintained the server, it would likely be the most efficient way to communicate and share collected data on rabies. This would also be a good place to analyze the collected data and then post both the raw data and the analyzed data in case others are looking for specific motifs in the data.

As mentioned before, in the time between now and implementing a rabies vaccine for bats, education will be imperative as this will begin to mitigate the risk of humans coming into contact with rabies through negligence. Education of the younger generations is the most important part of education as they are generally the population that is being exposed to rabies due to lack of knowledge about avoiding wildlife and stray animals of which the vaccination and infection status are unknown. An education campaign could possibly be difficult to implement as rabies is not currently at the forefront of the Wyoming population's concern. Marketing the education as preventative and interactive could help lower disinterest in an education program as well as requiring schools to have a rabies education day on World Rabies awareness day which is on September 28th.

Utilizing social media could have a great impact on rabies awareness as media tends to garner great awareness over issues that sometimes get glossed over for other topics that are controversial and portrayed as important in the mainstream media sources. Using this in addition

to in-classroom teaching will provide a two-pronged approach that should reach a larger portion of the population. Distilling rabies information down to what is absolutely essential to fit in a social media blog will be difficult as there is a lot of information about rabies to convey to the populous. But, if done correctly, a campaign like this could have a farther reach and educate more than just those living in Wyoming. The existing social media accounts for the Wyoming Department of Health could be used to disseminate the necessary rabies information.

To aid in the education campaign, pilot projects based on data collection that focuses on determining the level of knowledge that the public already has to tailor the education campaign better to Wyoming. Studies like this could be region specific to better tailor the education program to different areas in Wyoming as they may have differing levels of baseline knowledge about rabies. Another pilot study could look at the knowledge of after exposure rabies protocols in professional sects like animal control. Using these studies to tailor education to the needs of the population will likely garner a more positive result as only new information is shared rather than redundant information.

Conclusion

A One Health approach will minimize rabies exposure and transmission. These recommendations together have promise to drastically lower the chance of rabies incidence and prevent further contracts of this fatal disease. Including the economic benefits from not having to perform PEP as often if all the recommendations are integrated into how incidence of rabies is decrease, the decreased chance of infection and thus loss of life, and the potential educational gain from researching a bat vaccine it is obvious that implementing actions against rabies is beneficial in Wyoming. As the human population expands and demands more land, the probability of the human and domestic animal population coming into contact with rabid animals

grows larger every day. The implementation of a One Health approach in Wyoming will lower the risk of human exposure to rabies from bats.

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