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Policy comparison of lead hunting ammunition bans and voluntary nonlead programs for California condors

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Abstract

The endangered California condor (*Gymnogyps californianus*) is negatively affected by lead poisoning from spent lead-based hunting ammunition. Because lead poisoning is the primary mortality factor affecting condors, the California Fish and Game Commission banned lead hunting ammunition during 2008 in the southern California condor range followed by a statewide ban implemented in 2019. In contrast, the Arizona Game and Fish Department instituted an outreach and awareness program encouraging voluntary use of nonlead hunting ammunition in the northern portion of the state during 2005 and a similar program was launched in Utah during 2012. The juxtaposition of policy tools provided a unique opportunity to evaluate the intended efforts to mitigate lead exposure in condors and their respective positive and negative effects. Herein we reflect upon the effectiveness of lead policy actions in the 3-state region on the basis of condor blood-lead levels, population status, and hunter awareness of the issue and use of nonlead hunting ammunition.

KEYWORDS

Arizona, California, California condor, *Gymnogyps californianus*, lead, lead poisoning, nonlead ammunition, policy, Utah

BACKGROUND ON LEAD ISSUE

Lead is an important industrial metal, and simultaneously, a dangerous environmental poison (Eisler 1988, Markowitz and Rosner 2013) with the potential to negatively affect wildlife and humans (Rattner et al. 2008, Watson et al. 2009). In waterfowl, lead poisoning was first reported near Galveston Bay, Texas (Grinnell 1894) where exposure was linked to ingestion of lead shotgun pellets (Wetmore 1919). Further documenting lead related problems in waterfowl, additional research was conducted in central portions of the United States (Bellrose 1959, Sanderson and Bellrose 1986, Havera et al. 1994). During the 1970s and 1980s several states enacted lead ammunition bans for waterfowl hunting, but these laws were nullified by the Stevens Amendment of 1978 (U.S. Fish and Wildlife Service [USFWS] 1988, Belanger and Kinnane 2002). These preceding actions were followed by a Supplemental Environmental Impact Statement [USFWS 1986]), and finally a lawsuit between National Wildlife Federation and the U.S. Fish and Wildlife Service (USFWS) over the death of endangered bald eagles (*Haliaeetus leucocephalus*) resulting from eating lead poisoned waterfowl (Belanger and Kinnane 2002). Eventually, state agencies and the USFWS agreed to a national 5-year (1987–1991), phased-in nontoxic-shot regulation for all waterfowl hunting (USFWS 1988, Schulz et al. 2006).

CURRENT SITUATION

Although lead poisoning has been substantially reduced for North American waterfowl because of the national lead ammunition ban, the problem of lead poisoning in wildlife persists due to continued use of lead ammunition for other hunted species. For example, a substantial amount of data demonstrates the negative effects of lead in mourning doves (*Zenaida macroura*), common ravens (*Corvus corax*), and California condors (*Gymnogyps californianus*) from the ingestion of lead pellets or bullet fragments resulting from spent hunting ammunition (Schulz et al. 2002, Craighead and Bedrosian 2008, Finkelstein et al. 2010, Plautz et al. 2011, Kelly et al. 2016). Progress in elevating the wildlife lead poisoning issue in the U.S. policy agenda has been made (Schulz et al. 2012, Stake 2019, White 2020), but stakeholders believe stronger regulatory action is needed for the endangered California condor with populations around 500 birds (Bellinger et al. 2013, Thomas 2019). A decision was made in 1987 to trap the remaining 27 wild condors and establish a captive breeding program (D'Elia and Haig 2013); this was the first step in an incremental policy process. Although condors are still classified as endangered in 2022 under the Endangered Species Act (ESA; Public Law 93-205 1973), the captive breeding program has allowed condor populations to be reintroduced in northern California, northern Arizona, southern Utah, and prompted proposals for reintroductions along the Oregon coast (D'Elia and Haig 2013).

Within the context of natural resource management, a market failure occurs when the full costs and benefits of an activity are not borne entirely by the party performing the activity, but rather are externalized to society at large (Cubbage et al. 2017). In the case of California condors, continued use of lead ammunition by hunters and related costs of managing endangered condor populations are externalized to society at large. Some scholars have posited an externality occurs because property rights have not been assigned in such a manner that hunters value condors (Sterner and Coria 2012, Cubbage et al. 2017). In other words, hunters do not have a financial incentive concerning condors. State natural resource management agencies, ammunition manufacturers and retailers, and big-game hunters have benefited from the big-game resource without a mechanism that compensates society for wildlife damages caused by lead ammunition.

In addition to wildlife effects, human health can be impacted through ingestion of lead bullet fragments in ground venison (Hunt et al. 2009, Iqbal et al. 2009, Totoni 2020). At a broader societal level, individuals eating game meat shot with lead ammunition are in danger of lead exposure and the externality of society dealing with individuals affected by chronic lead exposure (Rosen 1995, Lidsky and Schneider 2006, Jones et al. 2009, Knott et al. 2010). Human exposure to lead bullet fragments in game meat can occur when state agencies partner with local food banks and distribute lead-tainted venison (Congressional Sportsmen's Foundation 2020, Totoni et al. 2022). Because the U.S. Food and Drug Administration (FDA) does not provide guidance regarding venison donations, most states and localities have not addressed the potential for lead contamination in their donated venison safety regulations (Leib et al. 2018, Totoni et al. 2022).

There are multiple stakeholders in the policy arena of California condors given their endangered status. The USFWS has primary statutory responsibility for implementing the ESA, whereas the U.S. Forest Service (USFS) and U.S. Bureau of Land Management (USBLM) have substantial public land holdings with the potential to affect hunting regulations. State natural resource management agencies in California, Arizona, and Utah are also key stakeholders because they have authority over big-game hunting, and receive funds from permit sales and excise taxes on hunting ammunition and firearms under the Federal Aid in Wildlife Restoration Act, commonly known as the Pittman-Robertson Act (Public Law 50-917 1937). Big-game hunters in the region are also primary stakeholders because they could be directly impacted by hunting ammunition policies. Secondary stakeholders include ammunition manufacturers, outdoor retailers, and nonprofit groups such as the National Rifle Association, National Shooting Sports Foundation, Center for Biological Diversity, Peregrine Fund, and professional or scientific societies (e.g., The Wildlife Society). Other stakeholders could include family members eating game meat killed with lead ammunition and individuals eating that meat donated to food banks (Totoni et al. 2022). The on-going policy actions related to lead exposure from spent hunting ammunition provide a unique opportunity to explore the positive and negative factors related to different policies. Our objective was to examine and compare the impacts of different policy options as they specifically affect California condors.

EXISTING POLICIES

Although multiple wildlife species are impacted by lead exposure, California condors provide a unique situation for examining the effectiveness of different policies. The aims and objectives of existing policies are to sufficiently increase condor populations to facilitate removal from the endangered species list, restore populations to their historic range across most of western North America, conduct restoration management while not negatively impacting hunting activity, and improve environmental quality and human health by reducing the use of lead hunting ammunition on the landscape (Kelly et al. 2014, Smith et al. 2017). To achieve the desired outcomes, there are 3 primary policy types being used: regulatory, self-regulatory (or voluntary), and constituent (Table 1).

A regulatory policy approach banning lead hunting ammunition aims to reduce condor mortality directly related to ingestion of spent hunting ammunition in animal gut piles and carcasses and increase population growth rates (λ) in the wild southern California population, and in the reestablished populations in northern California. Other states have chosen a self-regulatory or voluntary approach with outcomes related to increasing awareness of lead poisoning in condors and potential human health risks among big-game hunters, encouraging big-game hunters to use nonlead ammunition, bury gut piles, or remove animal carcasses from the field (Chase and Rabe 2015, Smith et al. 2017). The voluntary policy works to diminish potential legal and political conflicts with 2nd Amendment advocates, the ammunition and gun industry lobby, and outdoor retailers.

The use of either regulatory or voluntary policies among states is explained by the application of the constituent policy approach based on the experimental-nonessential 10(j) designations of the ESA (Public Law 93-205 1973). This provision under the ESA allows for prohibited activities (e.g., accidental condor poisoning from ingestion of spent lead ammunition) given special designation by the Secretary of the U.S. Department of Interior (DOI). Based on the best available information, the USFWS recommends to the DOI whether an experimental and reestablished population is essential or nonessential to the continued existence of the species, especially populations outside its current range but within its historical range. A 10(j) exemption is a constituent policy (Table 1) and provides states the opportunity to participate in a recovery program without negatively impacting local interests related to existing activities like big-game hunting. Policy outcomes are measured by monitoring

TABLE 1 Summary of 3 policy instruments that have been implemented to mitigate lead poisoning in California condor populations living in northern Arizona, southern California, and southern Utah, USA (Seng 2005, Smith et al. 2017).

State, agency, or organization	Policy type	Policy activity	Policy status
California	Regulatory	Southern California lead ammunition ban	Implemented 2008
		Statewide ban	Adopted in 2013 and phased-in fully in 2019
Arizona	Self-regulatory	Outreach and education	Initiated in 2003
		Nonlead ammunition vouchers	Implemented 2005
		Gut pile raffles	Initiated in 2011
Utah	Self-regulatory	Outreach and education	Initiated in 2009, expanded region wide 2012
		Nonlead ammunition vouchers	2012
		Participation raffles	2012
U.S. Fish and Wildlife Service	Constituent	Enactment of 10(j) Designation Endangered Species Act regulations.	1996–2016
Partnering Organizations and Groups[a]	Self-regulatory		1996–2016

[a]Organizations and groups not previously listed providing administrative or funding support for the Southwest Condor Working Group, e.g., U.S. Bureau of Land Management, U.S. National Park Service, U.S. Forest Service, The Peregrine Fund, Kaibab Band of Paiute Indians, Navajo Nation, Arizona Center for Nature Conservation/Phoenix Zoo, and Coalition of County and Local Governments of Utah and Arizona.

changes in hunter awareness and behavior, acknowledgement of potential human health risks by stakeholders, monitoring condor population status and movements, and monitoring changes in condor blood-lead levels (Chase and Rabe 2015, Kelly et al. 2016, Bakker et al. 2017, Smith et al. 2017, Glucs et al. 2020).

REGULATORY VS VOLUNTARY

Regulatory policy

Because lead poisoning from hunting ammunition is the primary factor contributing to California condor mortality (Church et al. 2006, Finkelstein et al. 2010, Finkelstein et al. 2012, Kelly et al. 2014), the California Fish and Game Commission established a regulatory policy by modifying methods of take (i.e., a command-and-control approach) during 2008 prohibiting the use of lead hunting ammunition for big-game hunting within the primary condor range of southern California (California Department of Fish and Wildlife 2017). Several environmental nonprofit organizations (e.g., Center for Biological Diversity and San Diego Zoo) attempted to get the issue moved from the general policy agenda (i.e., an informal list of problems or issues requiring attention) to the formal policy agenda (i.e., an explicit recognition of an issue requiring action from a specific authority), but little progress was made towards increasing public awareness. Despite the 2008 regulation, condor blood-lead levels remained high because condors traveled extensively and scavenged on animal carcasses and gut piles outside the nonlead ammunition zone

(Bakker et al. 2017, Smith et al. 2017, Glucs et al. 2020). During 2012, California Audubon joined the advocacy coalition by mobilizing their local chapters to affect the legislative process by moving the issue to the formal policy agenda. Given limited response by condor populations to the original policy in southern California, a more extensive and inclusive statewide lead ban was adopted in 2013 for all big-game and small-game hunting (California Assembly Bill 711 2013) that was phased-in fully by 2019 (California Department of Fish and Wildlife 2017).

The statewide ban on lead hunting ammunition in California was implemented in 3 phases. The first phase began in 2015 and required nonlead ammunition when hunting on all California Department of Fish and Wildlife (CDFW) properties and for all bighorn sheep (*Ovis canadensis*) hunts. Effective 2016, hunters using shotguns were required to use certified nonlead ammunition for upland game hunting (except dove, quail, snipe, and any species taken on licensed game bird clubs), furbearing and nongame species, and any species taken with a depredation permit. Shotgun ammunition must be composed of materials approved as nontoxic by the USFWS. Effective 2019, certified nonlead ammunition was required statewide when taking any wildlife. It is currently too early to fully evaluate the outcomes of the 2019 regulatory policy approach. However, existing evaluation programs tracking condor blood-lead levels, condor reproduction and recruitment, and individual movements have been in place since the late 1990s (Smith et al. 2017) and will be useful for monitoring policy outcomes. In addition to measurable policy outcomes related to condor population response, other unique issues have been identified.

Limited tools are available for law enforcement to determine if hunters obey the nonlead regulation, especially for rifle ammunition. Several commercial devices are available to determine if shotgun shells are made of nonlead materials (Stream Systems 2005, USFWS 2020*a*); however, there is no equivalent field-test for hunter compliance with the regulation for rifle ammunition. In some cases, if a wildlife officer suspects a hunter is in possession of lead ammunition, a cartridge or bullet may be collected for further laboratory analysis. Hunters are informally encouraged by law enforcement officials to assist in confirming compliance by retaining ammunition boxes or other packaging while hunting. Further complicating the issue is that lead ammunition for nonhunting uses is legal to possess in the field (e.g., ranchers dispatching injured or sick livestock).

Self-regulatory policy

In the face of accumulating scientific information linking California condor mortality to ingestion of lead bullet fragments in areas outside of California, environmental nonprofit groups filed petitions against the U.S. Environmental Protection Agency, USFS, and USBLM during 2010–2012 to expand the prohibition of lead hunting ammunition on all federal public lands (Hunt For Truth Association 2017*a*). Although federal courts ruled against the petitioners' requests, calls for expanded regulatory policies on public lands continued (Finkelstein et al. 2012, Bellinger et al. 2013).

The regulatory policy approach adopted in California motivated stakeholders in Arizona and Utah to adopt a self-regulatory or voluntary policy instrument in an attempt to avoid a ban on lead hunting ammunition, fearing it would decrease hunting opportunities due primarily to increased ammunition costs, accompanied by corresponding declines in hunting permit revenues, hunting guide services, and retail equipment sales. In contrast to the nonhunting stakeholders dominating the policy discussions in California (e.g., California Audubon, Center for Biological Diversity), stakeholders in Arizona and Utah were primarily hunting groups and associated business interests related to outdoor equipment retailers, and ammunition and firearms manufacturers.

Relying on a self-regulatory or voluntary policy approach, Arizona Game and Fish Department (AGFD) instituted a voluntary nonlead ammunition program in the northern portion of the state during 2005 using a combination of informational materials, shooting demonstrations, and free nonlead hunting ammunition vouchers (Seng 2005, Chase and Rabe 2015). A similar voluntary reduction and awareness program about lead poisoning in condors was established in southern Utah by the Division of Wildlife Resources (UDWR) during 2013. Both Arizona and Utah additionally used gut-pile raffles as an incentive with limited success. For each gut pile from an animal shot with lead ammunition and brought to a check station, the hunter would be eligible for a drawing for a new hunting rifle or other outdoor related equipment (Long 2021). The voluntary approach used focus groups to test outreach messages and establish baseline issue awareness among hunters (Seng 2005). Mail surveys and hunter interviews were also conducted to periodically monitor program effectiveness (Chase and Rabe 2015, Smith et al. 2017).

Efforts to address potential human health risks from lead bullet fragments in donated ground meat remain problematic due to jurisdictional differences among natural resource agencies and human health agencies; i.e., in many states each agency says it is the other's responsibility to address human health issues related to lead exposure from eating meat harvested with lead hunting ammunition (Totoni et al. 2022). From a public health standpoint a self-regulatory approach is problematic considering that an epidemic of lead poisoning continues to put children at risk of lifelong neurobehavioral impairment, and scientists have cited an urgent need to eliminate all avoidable sources of lead exposure from children's environments and ban nonessential uses of this element that pose a threat to human health (Lanphear 2007, Landrigan and Bellinger 2021). Data show lead is a zero-threshold neurotoxin (i.e., there is no safe level of exposure), especially in young children (Bellinger et al. 1991, Lanphear et al. 2016). People ingesting lead-tainted venison are susceptible to chronic and acute effects of lead exposure leading to impaired cognition, and cardiovascular and kidney disease (Bellinger et al. 1991, Earl et al. 2016, Gerofke et al. 2018, Harari et al. 2018, Lanphear et al. 2018). In addition, low-level lead exposure represents a disproportionate risk to women of childbearing age by increasing spontaneous abortion, preeclampsia, intrauterine growth restriction, premature delivery, stillbirths, pregnancy hypertension, and low birth weights (Kumar 2018, León and Salas Pacheco 2020). Alternatively, many stakeholders falsely claim small amounts are acceptable for human consumption due to a lack of acute poisoning symptoms (Hunt For Truth Association 2017*b*).

POLICY EVALUATION

Despite adoption of regulatory policies in California and voluntary programs in Arizona and Utah, lead poisoning remains the primary cause of mortality in California condors (Church et al. 2006, Finkelstein et al. 2010, Finkelstein et al. 2012, Smith et al. 2017). Lead poisoning occurs predominantly during fall and winter associated with big-game hunting (Bedrosian et al. 2012, Cruz-Martinez et al. 2012, Franson and Russell 2014); however, lead exposure in scavenging birds remains present throughout the year (Slabe et al. 2022). In other words, animals shot with lead ammunition whose remains are left in the field present opportunities throughout the year for lead exposure, e.g., prairie dog (*Cynomys spp.*) hunting (Herring et al. 2016, Mctee et al. 2019). Given these policy actions, evaluation and monitoring efforts revolve around testing blood-lead levels in wild condors and associated scavenging birds, and widely varying human dimensions survey activities gauging hunter compliance with policy initiatives.

Due to the relatively small size of the wild condor population, the majority of the birds are captured several times annually and tested for lead exposure in the southern California, northern Arizona, and southern Utah region (Smith et al. 2017). During 2011–2016 the proportion of the condor population tested ranged from 87%–95% with 59%–80% of birds showing recent lead exposure and 20%–42% requiring treatment for lead poisoning (Table 2). Monitoring data has linked condor blood-lead levels with the ingestion of bullet fragments from rifle-killed big game, predators, and livestock shot with lead rifle bullets (Hunt et al. 2006, Finkelstein et al. 2012, Kelly et al. 2014). After ingestion, acids in the condor's gut convert lead fragments to soluble salts absorbed into the blood stream and delivered to soft tissues, organs, bones, and the brain with a blood half-life of roughly 2 weeks (Green et al. 2008, Kelly et al. 2011). Thus, blood-lead scores are a snapshot in time relative to the continuum of a lead exposure event (Finkelstein et al. 2010). Data from throughout the condor's range indicate condors scavenge on a wide variety of food sources outside of hunting season; e.g., coyote (*Canis latrans*) carcasses, dispatched livestock, and ground squirrels. To reduce lead exposure to condor populations, Kelly et al. (2014) and Bingham et al. (2015) have suggested future policy considers effects of lead ammunition

TABLE 2 Percentage of the California condor population tested for lead exposure in the southern California, northern Arizona, and southern Utah regions of USA combined during 2011–2016 and percentage of the birds with various levels of lead exposure and/or treated with chelation therapy (data reproduced in part from Smith et al. 2017).

Level of lead exposure	2011	2012	2013	2014	2015
Proportion Tested	95%	88%	89%	95%	87%
Exposure Likely (>15 µg/dl)	59%	73%	65%	80%	73%
Treated for lead poisoning	25%	42%	20%	29%	29%
Extreme exposure (>65 µg/dl)	20%	41%	17%	26%	27%

in connection with livestock ranchers dispatching nuisance wildlife, sick or injured livestock, and lead shotgun ammunition used for upland game bird hunting.

Pre- and post-monitoring data from the southern California lead ammunition ban enacted in 2008 were collected from golden eagles (*Aquila chrysaetos*) and turkey vultures (*Cathartes aura*) as representative scavenging birds (Kelly and Johnson 2011, Kelly et al. 2011). First, the relationship of different levels of hunting activities to blood levels in turkey vultures was evaluated (Kelly and Johnson 2011). During 2008–2009, 3 study sites along a gradient of wild pig hunting intensity represented a range of hunting activity in areas with a resident turkey vulture population; low-intensity wild pig hunting area accounted for 1% of the total statewide harvest for wild pig hunting, medium-intensity wild pig hunting area accounted for roughly 3%, and high-intensity hunting area accounted for approximately ≥15% of the total statewide pig harvest. Kelly and Johnson (2011) sampled 34 vultures during the deer hunting season and 39 vultures outside of the hunting season at the high-intensity deer hunting location. The median blood-lead level was 15 µg/dL (min–max = 6–170) during deer hunting season compared to 7 µg/dL (min–max = 6–36 µg/dL) outside of the deer hunting season. At the low-intensity wild pig (*Sus scrofa*) hunting site 52 vultures were sampled, 39 vultures at the medium-intensity site, and 47 at the high-intensity pig hunting site. The median blood-lead level was 4 µg/dL (min–max = 6–38 mg/dL) at the low-intensity pig hunting site, 7 µg/dL (min–max = 6–36 µg/dL) at the medium-intensity pig hunting site, and 14 µg/dL (min–max = 6–76 µg/dL) at the high-intensity pig hunting site. The findings of Kelly and Johnson (2011) showed big-game hunting in California with lead ammunition increased the risk of lead exposure in avian scavengers.

After establishing the relationship between big-game hunting and blood-lead levels in scavenging birds, researchers evaluated whether the ban on lead big-game hunting ammunition would decrease blood levels in golden eagles and turkey vultures (Kelly et al. 2011). Elevated golden eagle blood-lead (>10 µg/dL) decreased 58%, from 76% (13/17, 95% CI = 53%–92%) pre-ban to 32% (12/38, 95% CI = 18%–48%) post-ban (Table 3). In nonmigrant golden eagles, there was a 100% reduction in prevalence from 83% (5/6, 95% CI = 41%–99%) pre-ban to 0% (0/9, 95% CI = 0%–28%) post-ban. Blood-lead concentrations in golden eagles sampled from 1985–1986 were similar to those sampled pre-ban (Table 3). No significant difference was detected in blood-lead between nonmigrant golden eagles and eagles of unknown residency, but during the post-ban period, nonmigrant golden eagles had significantly lower blood-lead compared to eagles of unknown residency ($P = 0.04$). Median blood-lead was not significantly different between subadult golden eagles (8 mg/dL) and adults (12 mg/dL; Kelly et al. 2011), but age was significantly correlated with blood-lead.

Elevated blood lead (≥10 µg/dL) in turkey vultures decreased from 61% (23/38, 95% CI = 45%–75%) pre-ban to 9% (3/33, 95% CI = 2%–23%) post-ban; an 85% decline (Table 4). Recaptured vultures showed a 78% decrease from 60% (9/15, 95% CI = 35%–82%) pre-ban to 13% post-ban (2/15, 95% CI = 5%–45%). Linear mixed effects model demonstrated a significant decline (2.5-fold decrease) in turkey vulture blood lead following the lead ammunition ban ($P < 0.001$). Despite large variation among vultures, there was no significant difference in blood lead by sex and age class. Although the southern California ban was for only big-game hunting (excluding varmint

TABLE 3 Blood lead levels (µg/dL) measured in golden eagles before and after a lead ammunition ban in southern California, USA, implemented during 2008 (data reproduced in part from Kelly et al. 2011).

Period	Sample population	Sample size	Median µg/dL	Range µg/dL	≤10 µg/dL	11–19 µg/dL	20–29 µg/dL	30–49 µg/dL	≥50 µg/dL
Pre-ban (1985–1986)	All eagles	91	18	1–411	60	18	13	23	6
Pre-ban (2007–2008)	All eagles	17	22	6–64	13	4	4	4	1
	Non-migrants only	6	15	8–37	5	3	1	1	0
Post-ban (2008–2009)	All eagles	38	7	6–110	12	5	0	4	3
	Non-migrants only	9	6	6–10	0	0	0	0	0

TABLE 4 Blood lead levels (µg/dL) measured in turkey vultures before and after a lead ammunition ban in central California, USA, during 2008 (data reproduced in part from Kelly et al. 2011).

Sample population	Time period	Sample size	Median µg/dL	Range µg/dL	≤10 µg/dL	11–19 µg/dL	20–29 µg/dL	30–49 µg/dL	≥50 µg/dL
All vultures	Pre-ban (2008)	38	14	6–21	23	16	2	5	0
	Post-ban (2009)	33	6	6–44	3	2	1	0	0
Recaptured vultures	Pre-ban (2008)	15	14	6–21	9	4	2	3	0
	Post-ban (2009)	15	6	6–44	2	1	1	0	0

hunting and small game hunting with shotguns), a measurable decline in blood lead was detected in scavenging birds.

Awareness and outreach programs encouraging big-game hunters to use nonlead ammunition were conducted by AGFD and UDWR using a variety of surveys and sampling frames. On average, 88% of Arizona's Kaibab deer hunters and 80% of southern Utah deer hunters participated in some aspect of lead reduction efforts during 2012–2016 (Smith et al. 2017). Many of the partner agencies and organizations also provided substantial outreach related to condor management and efforts to reduce lead exposure. Using funds from a variety of sources, AGFD administered a free nonlead ammunition program for big game hunters within northern big-game management units incorporating areas used most frequently by condors during the fall with outreach describing risks of lead poisoning in condors (Seng 2005, Chase and Rabe 2015). Approximately 1,500 hunters were eligible for free ammunition annually, dependent upon the number of hunting tags (Smith et al. 2017). During 2012–2016, 3,279 of 3,702 (88.6%) big-game hunters participated in lead reduction actions related to the AGFD outreach program. Qualifying actions included shooting with nonlead bullets, packing out the gut pile, taking a head or neck shot, or electing to use archery or a crossbow during the rifle hunt.

The UDWR's voluntary nonlead, big-game ammunition program mimicked AGFD's program. Hunters participating in managed deer hunts received an informational letter about lead poisoning in condors and a voucher for one free box (up to USD $50 value) of nonlead ammunition. Additionally, elk hunters in the southern portions of the state were also sent letters explaining the voluntary nonlead program but did not receive a nonlead ammunition voucher. The UDWR requested hunters voluntarily stop at check stations to show they were using nonlead ammunition or deposit a gut pile from an animal harvested with lead ammunition to be eligible for prize drawing. Based on post-season telephone surveys, 88–94% of Zion Hunt Unit hunters indicated they received a voucher, 55%–72% redeemed the voucher, and >60% used nonlead ammunition (Smith et al. 2017). Additionally, 26%–52% of hunters using lead ammunition reported removing a gut pile from the field, and 22%–32% reported registering for the prize drawing. Responses to the post-season surveys indicated deer hunters had removed 106–181 gut piles from the field, even though ≤18 were brought to a UDWR facility (Smith et al. 2017). Measurable progress occurred during 2012–2016 with roughly 80% of deer hunters being aware of the voluntary nonlead program in the southern Utah condor range (Smith et al. 2017). Unlike AGFD survey data with a known population of hunters applying for special permits, UDWR's evaluation survey data come from an unknown population of hunters in the affected area, and the high participation rates could be positively skewed.

The ADFG evaluated the efficacy of their voucher program encouraging hunters to voluntarily use nonlead ammunition (Chase and Rabe 2015). The study compared a group of hunters within the northern Arizona portion of the condor range receiving only educational materials to a group receiving educational materials plus a voucher for free nonlead ammunition. Nearly half of the control group (49%) used nonlead ammunition, compared to 75% of the treatment group. Barriers to adoption of nonlead ammunition included difficulty of obtaining it, obtaining it in the desired caliber, and increased cost. Motivations for using nonlead ammunition included positive encouragement by ADFG, and the desire to aid California Condor conservation recovery (Chase and Rabe 2015).

There were at least 2 unintended consequences of the 2008 lead ammunition ban in southern California, and the fully implemented statewide ban in 2019. First, the statewide regulation has provided the hunting ammunition industry a guaranteed market. The California hunting and fishing economy generates >USD $813.2 million annually, with >3.4 million total hunters and >1.8 million big-game hunters (USFWS 2018). The large size of California's hunter population provides ammunition manufacturers with a market signal indicating capital spent on scaling-up production with new manufacturing machinery will pay for itself over time with the guaranteed market of nonlead ammunition. Correspondingly, this also signaled the need for the increased availability of nonlead rifle ammunition in a wider variety of calibers (California Department of Fish and Wildlife 2017). Voluntary programs, although politically attractive by reducing conflict, do not provide the guaranteed market incentives to ammunition manufacturers.

DISCUSSION

Policy objectives for reducing lead poisoning in California condors have been only partially achieved. California lead ammunition bans have proven successful in moving the issue toward the formal agenda on a broader regional or national scale, and have reduced lead exposure in condors and other scavenging birds on a localized scale (Kelly and Johnson 2011). However, lead poisoning continues to be the primary barrier to condor recovery (Finkelstein et al. 2012, Bellinger et al. 2013, Smith et al. 2017). The inability of meeting the regulatory policy objectives is due in part to condors' far-ranging movements and scavenging behavior (Green et al. 2008, Bakker et al. 2017). Thus, the original 2008 policy ban in only southern California was geographically too narrow given the birds easily found contaminated meat outside of the nonlead ammunition hunting zones. To be fully effective, it may be necessary for a regulatory ban on lead ammunition to extend at least to areas of anticipated condor population range expansion.

Voluntary nonlead ammunition outreach programs by AGFD and UDWR had an average of 88% of Arizona's Kaibab deer hunters and 80% of southern Utah deer hunters participating in lead reduction efforts indicating some level of success, but condor blood levels also remained unchanged in that region (Smith et al. 2017, Table 2). Partner agencies and organizations often assist with outreach related to condor management but given the extremely low condor populations it is difficult to assume voluntary outreach programs can be a viable long-term solution. At best, they can be an effective incremental step toward creating a more favorable regulatory environment. Voluntary efforts in Arizona and Utah were also geographically narrow in scope and did not anticipate further expansion of the condor population. In addition, the voluntary programs were likely not financially sustainable with regards to providing vouchers for free nonlead ammunition indefinitely, especially if the condor population expands beyond current boundaries. Economically, voluntary programs provide ammunition manufacturers with an uncertain market for nonlead hunting ammunition due to the uncertainties and sustainability of voluntary compliance.

Proposals are under review to expand the California condor population to areas along the Oregon coast (D'Elia and Haig 2013, Haig et al. 2014) but some stakeholders may be reluctant to use captive-reared birds because of the continued exposure to lead hunting ammunition (Bakker et al. 2017). The primary reason for inaction and reluctance is the considerable cost associated with captive-reared condors, and the act of releasing them into areas where they will be knowingly exposed to lead ammunition. By 2016, the southwestern California population had increased by 79 condors, including 70 captive-reared and 9 wild-hatched birds (Smith et al. 2017). During 1996–2016, 189 captive-raised condors were released in the northern Arizona and southern Utah; 125 of these birds died from lead poisoning or from injuries related to lead exposure (Smith et al. 2017). Therefore, reintroduction efforts to expand the condor range into Oregon will be complicated by unsustainably high mortality from ingestion of lead hunting ammunition, the leading cause of diagnosed mortality (Finkelstein et al. 2012, Bellinger et al. 2013, Bakker et al. 2017, Glucs et al. 2020).

Regulatory actions, although showing measurable benefits of reducing lead exposure in scavenging birds, may have also encouraged some stakeholders to further polarize the issue. Such efforts are consistent with industry tactics to delay regulation of lead containing products including paint and gasoline (Markowitz and Rosner 2013, Snow 2017, Gottesfeld 2022). Specifically, the regulatory lead ammunition policy may have encouraged some gun-rights advocates to use communication tactics similar to discussions surrounding secondhand cigarette smoke or global climate change issues (Oreskes 2004, Oreskes and Conway 2010). Some of these commonly used communication strategies provide a form of selective inattention to potential dangers of well-being (Opotow and Weiss 2000, Cook 2017, 2019). Within the context of nonlead ammunition, the communication strategies include perceptions about gun control legislation, the veracity of the science related to lead poisoning in wildlife and human health, creation of impossible expectations, and cherry-picking data (Hunt For Truth Association 2017*b*). Given the data linking condor mortality to lead ammunition, however, environmental groups repeatedly petitioned several federal agencies to ban lead hunting ammunition on public lands. Federal agencies declined to regulate lead ammunition and federal courts ruled against petitioners' requests (Hunt For Truth Association 2017*a*).

During 2010–2013, Center for Biological Diversity (CBD) et al. v. United States Environmental Protection Agency (EPA) et al. (Hunt For Truth Association 2017*a*) alleged the EPA is obligated to regulate lead hunting ammunition under the Toxic Substances Control Act of 1976 (TSCA; Public Law 94-469 1976). The CBD initiated the lawsuit despite previous attempts being denied based on EPA not having authority to regulate ammunition under TSCA. The National Rifle Association (NRA) and Safari Club International (SCI) obtained permission from the U.S. District Court in Washington, D.C. to intervene. The suit claimed scavenging birds such as California condors, vultures, and eagles were being poisoned from eating lead bullet fragments in carrion left by hunters. The CBD also claimed humans were at risk of lead poisoning by consuming meat containing lead bullet fragments. The U.S. District Court, however, dismissed the case finding EPA acted within its authority with the understanding that TSCA has an exclusion for firearms and ammunitions from the definition of a chemical substance (Hunt For Truth Association 2013).

Dating back to policy discussions for waterfowl nontoxic shot regulations (USFWS 1988), arguments revolved around ballistic performance of nonlead ammunition, lethality or killing effectiveness, and relative cost of nonlead ammunition compared to traditional lead ammunition (Belanger and Kinnane 2002, Schulz et al. 2006). At the time, many hunters said they would discontinue hunting due to increased ammunition costs, increased probability of crippling or wounding birds, and inability to find sufficient quantities of ammunition (USFWS 1988, Belanger and Kinnane 2002). Today, many state natural resource management agency administrators remain sensitive to these concerns and comments regardless of their factual basis (Schulz et al. 2006, Thomas 2013, Pierce et al. 2015). The primary reason for state agency inaction is likely declining number of hunters and participation rates due to multiple shifting demographic factors (Winkler and Warnke 2013, Andersen et al. 2014). Declining hunter numbers (USFWS et al. 2018) could be responsible for many state resource management agencies being risk averse to anything perceived as accelerating these declines and associated declines in permit revenues.

Superficially, a national ban on lead hunting ammunition similar to the waterfowl regulation would appear to be most efficient and effective for reducing lead poisoning in scavenging birds and other wildlife, and reducing the risk of lead exposure to humans (Thomas and Guitart 2003, Haig et al. 2014, Totoni et al. 2022). However, the stark differences evidenced among political leaders and their constituents and jurisdictional complexities among state and federal agencies indicate that option is unlikely (Association of Fish and Wildlife Agencies [AFWA] 2017). A more realistic approach may be a national outreach program encouraging all hunters and anglers to voluntarily use nonlead alternatives based on effective messaging and outcome monitoring (Schulz et al. 2012, Schulz et al. 2019). A strategically coordinated national voluntary outreach program may keep the issue prominent on the national policy agenda in anticipation of more favorable attitudes toward a future regulatory policy instrument and provide a viable market signal to ammunition manufacturers to increase production, e.g., the North American Non-lead Partnership (2021).

CONCLUSIONS

Lead poisoning in condors is only one of many related issues when dealing with lead exposure in wildlife and humans. Ultimately, decisions about policy options for the use of lead-based hunting ammunition require consideration of multiple lead poisoning sub-issues, each having related but unique characteristics, including (1) poisoning of condors; (2) poisoning of bald eagles and other scavenging birds; (3) increases in human blood lead levels and corresponding health effects from eating game meat with lead bullet fragments; (4) poisoning of mourning dove and other surface feeding birds; (5) ingestion of lost fishing tackle by loons (*Gavia spp.*), swans (*Cygnus spp.*), pelicans (*Pelecanus spp.*); and (6) broader environmental impacts of outdoor shooting ranges (Schulz et al. 2019). For California condors, existing policy instruments have been only partially successful in achieving their respective objectives indicating more work is needed to increase condor populations to sustainable levels. As suggested by Thomas and Guitart (2003) and Bellinger et al. (2013), a mandatory regulation for all hunting ammunition and fishing tackle represents the most effective and efficient policy mechanism. However, given the complex and contentious nature of lead poisoning in wildlife and related human health issues, voluntary programs provide a policy instrument for maintaining the issue on the policy agenda pending a more favorable regulatory environment. The current approach of voluntary programs is piecemeal and fragmented with little strategic framework effectively developing and implementing outreach programs at a national scale (Schulz et al. 2019, Schulz et al. 2021*a*); however, the recent North American Non-lead Partnership (2021) shows promise.

The AFWA and their regional affiliates (e.g., the Midwest Association of Fish and Wildlife Agencies; MAFWA) are the likely organizations to spearhead a national voluntary outreach program, similar to their program on humane furbearer trapping standards (AFWA 2018). However, action to date has been incremental with minimal discussions of a comprehensive national voluntary nonlead program (Schulz et al. 2019). The lack of a cohesive approach was highlighted in January 2017 when the outgoing USFWS Director issued an order to phase-in nonlead ammunition over several years for hunting on National Wildlife Refuges, also known as Director's Order 219 (USFWS 2017). Shortly after the installation of the new Secretary of the Department of the Interior on 2 March 2017 the order was rescinded with Secretarial Orders 3346 (U.S. Department of Interior 2017*a*) and 3347 (U.S. Department of Interior 2017*b*). Since that time several outreach programs encouraging the voluntary use of nonlead have emerged (USFWS 2020*b*, North American Non-Lead Partnership 2021, Belanger 2022).

Complex environmental problems are often characterized by a high degree of uncertainty and disagreement about the available scientific information combined with fundamental value differences among stakeholders eventually leading to no single or clear policy option (Balint et al. 2011). Our analysis, therefore, indicates no single simple solution will meaningfully address condors' exposure to spent lead ammunition. In other words, solely relying on a voluntary (Belanger 2022) or regulatory policy approach (Thomas and Guitart 2003, Bellinger et al. 2013) will not effectively address the primary mortality mechanism hampering condor recovery. Rather, our analysis indicates a combination of approaches where voluntary programs share information and build consensus among stakeholders using tools from human dimensions research (Schulz et al. 2021*b*), which may eventually lead towards acceptance and implementation of a possible future regulation on nonlead hunting ammunition.

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The authors declare no conflicts of interest.

ETHICS STATEMENT

No ethical information provided.

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