



U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services

U.S. Government Publication

the country, largely because of the lower energy demands for cooling than heating. With respect to residential and transportation energy use, El Paso, Tucson, Las Vegas, and Phoenix all recently ranked among the 25 US metro areas with the lowest emissions out of the 100 largest metropolitan areas in the US (Brookings Institution 2008).

While these cities continue to grow and thrive by many metrics, new investments must be used to help resolve historical inequities: socioeconomically marginalized people often face higher heat exposure, rely on lower-quality infrastructure, have less access to private means of adaptation, and are more excluded from governance processes (eg Harlan *et al.* in press). The path forward must involve processes and strategies that enable all urban residents to meaningfully participate in decision-making structures, avoid dangerous heat exposure, and access clean water.

We invite and encourage continued scrutiny of the experiences of southwestern cities, as their successes and failures in climate adaptation will be instructive for others around the world in the coming decades. While predictions of doom for cities of the American Southwest make for tempting headlines, efforts to highlight the experience of southwestern cities as vital testbeds for urban resilience may prove more beneficial to the global community preparing for future heat and water challenges.

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The conundrum of agenda-driven science in conservation

Conservation biology is a value-laden discipline predicated on conserving biodiversity (Soulé 1985), a mission that does not always sit easily with objective science (Lackey 2007; Pielke 2007; Scott *et al.* 2007). While some encourage scientists to be responsible advocates for conservation (Garrard *et al.* 2016), others worry that objectivity in conservation research may suffer (Lackey 2007). At this time, we believe advocacy by scientists is essential for environmental conservation and, indeed, humanity. It is difficult to envision the state of our environment had scientists failed to encourage policy makers and the public to address emerging conservation problems. Nevertheless, conservation scientists must avoid misusing the scientific process to promote specific conservation outcomes (Wilholt 2009); doing so erodes the credibility of science and can produce undesirable consequences (Thomas 1992; Mills 2000; Rohr and McCoy 2010). We consider intentionally engaging in activities outside of professional norms to promote desired outcomes, as part of either the production or dissemination of science, to constitute “agenda-driven science”. The issue of advocacy-related bias in conservation science merits renewed discussion because conservation conflicts in an increasingly polarized world might tempt some to engage in agenda-driven science to “win” a conflict (Redpath *et al.* 2015; Kareiva *et al.* 2018).

Agenda-driven science can take many forms (Table 1). Concealing conflicts of interest when publishing may indicate that scientists are beholden to parties with a vested interest in results (Rohr and McCoy 2010). The intentional misuse of data, misrepresentation of literature, and misinterpretation of results in a manner favorable to one’s conservation objectives are also clear manifestations of agenda-driven science (Wilhere 2012). While peer review is the bedrock of science, it can be imperfect and does not always purge poor-quality, agenda-driven science from

Table 1. Elements of agenda-driven science and some examples of activities outside of scientific norms that may be symptomatic of agenda-driven science

Elements of agenda-driven science	Activities symptomatic of agenda-driven science
Undeclared conflicts of interest	Failure to disclose funding sources that might benefit from a specific scientific result Failure to disclose involvement in litigation related to a study
Inappropriate use of data and literature	Selective use of data in support of hypotheses Publishing incomplete or unvetted data Selectively referencing literature to support hypotheses
Drawing unsupported conclusions	Emphasizing certainty and simplicity over uncertainty and complexity
Inappropriate use of social media and reliance on quasi-scientific outlets	Publishing in journals with lax peer review Conducting scientific reviews of papers outside of the peer-review process
Inappropriate professional behavior	Pressuring other scientists to retract published papers Conducting biased reviews of articles Obtaining other scientists' data through the Freedom of Information Act without seeking collaboration

publication and public-policy debates. Further, biased peer review can lead to papers being accepted or rejected because of their perceived conservation implications rather than their scientific merit (Hilborn 2006; Kareiva *et al.* 2018), such as when Vellend *et al.* (2013) demonstrated no net biodiversity loss at local scales but a reviewer recommended the paper be rejected over fears that its results could undercut conservation (see Vellend [2018] for details). Importantly, the proliferation of journals with less rigorous peer review increases opportunities to disseminate agenda-driven science (Bohannon 2013). Intimidation or pressuring of scientists, particularly junior scientists, to suppress research is symptomatic of agenda-driven science – as occurred when senior colleagues of Donato *et al.* (2006) attempted to suppress their study showing negative environmental impacts of salvage logging (Donato *et al.* 2006; see Harden [2006] for details).

Scientists also play an increasingly important role in communicating conservation issues to the public, with the proliferation of social media, including blogs, and online press outlets expanding opportunities to disseminate science. However, attempts to adjudicate scientific debates in the public sphere by, for example, posting reviews of scientific articles on blogs without the oversight of peer review and customary rebuttals may lead to greater uncertainty and is unlikely to resolve conservation conflicts (Harvey

et al. 2018). Such media outlets greatly influence public opinion and policy, and have been used effectively to stoke doubt about the reality of climate change and the dangers of pesticides (Oreskes and Conway 2010).

Agenda-driven science poses a conundrum to conservation because, as defined here, it implies intent, which is difficult to demonstrate. Each of the potential elements of agenda-driven science described in Table 1 may emerge for reasons other than the intentional misuse of science. A poor analysis that supports a desired conservation outcome may be an honest mistake. Moreover, disagreements about scientific conclusions do not necessarily indicate agenda-driven science; they are both commonplace among well-intentioned scientists and an integral part of the scientific process. However, the specter of agenda-driven science cannot be ignored when such activities co-occur with conflicts of interest and information campaigns intended to marginalize competing studies outside of the peer-review process. We therefore suggest that it is the cumulative frequency and broader patterns of behaviors outside of scientific norms that indicate agenda-driven science. Even so, assessing when scientific activities “cross the line” is subjective and will be open to interpretation. Recently, several authors of this letter have been involved in a scientific controversy involving forest management and the conservation of spotted owls (*Strix occidentalis*) in California, elements of which we

believe provide an example of this conundrum (see WebPanel 1).

How then should scientists handle the conundrum of agenda-driven science and minimize its impacts on conservation outcomes? We suggest that increased discussion among conservation scientists is needed to help understand how values can lead to biases and ensure that we as a community conduct objective research and stay true to findings in communications with the public. For instance, as part of their graduate education, tomorrow's scientists could benefit from improved training in scientific ethics and communication to avoid engaging in agenda-driven science and to assist the public in distinguishing between rigorous peer-reviewed science and unmoderated scientific debates. Also needed are broadly accepted tools and procedures for recognizing and responding to agenda-driven science. Journal editors and peer reviewers play a key role in guarding against bias in published science but increased vigilance for signs of an intention to influence policy is also needed. Greater disclosure of personal values (as is the case in other scientific disciplines) as well as conflicts of interest (such as litigation activities and consulting for litigants) would facilitate enhanced scrutiny and awareness within the peer-review process. We also encourage professional societies to combat proactively the spread of misinformation to ensure that agenda-driven science does

not discredit objective science and negatively influence conservation outcomes. Finally, the fostering of a diverse scientific community with a range of values will help maintain objectivity beyond what is possible for individual scientists (Longino 1990). We hope that strategies such as these will help conservation scientists avoid adopting the tactics of those denying the reality of environmental impacts (Oreskes and Conway 2010) – we must be the gatekeepers of our own integrity.

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■ Supporting Information

Additional, web-only material may be found in the online version of this article at <http://onlinelibrary.wiley.com/doi/10.1002/fee.2006/supinfo>



Principles of translational science education

The influence and acceptance of scientific discoveries and technological advances are linked to the scientific literacy, which

remains an enormous challenge to achieve in the modern era (Hurd 1998; Sturgis and Allum 2004). As scientists, teachers, and parents, we wholeheartedly agree with the growing consensus that a promising solution lies in science education reform (DeBoer 2000; National Research Council 2013). Evidence suggests that authentic learning experiences (those that emphasize applying knowledge in real-life contexts) can improve performance in primary and secondary (ie K–12) STEM education (Michael and Modell 2003; Lombardi 2007). In response, innovative initiatives such as the Next Generation Science Standards (NGSS: National Research Council 2013) place experiential learning at the heart of effective education standards to improve student engagement and promote a deeper understanding of core concepts (Bransford et al. 2000). Despite strong theoretical support for authentic, inquiry-based learning, our experience interacting with educators suggests that implementation remains difficult due to classroom constraints, pressure to meet standardized testing norms, and a lack of experience in the process of scientific inquiry, a trend that is widely reported in the literature (Au 2007; McDonald and Songer 2008; Bell 2010). Meanwhile, as ecologists we are required to advance scientific understanding while simultaneously building non-academic collaborative partnerships and satisfying outreach requirements (Bodmer 1985; Brewer 2002).

In a Special Issue in *Frontiers*, Enquist et al. (2017) presented an integrated approach to socioecological problem solving that emphasized co-production of actionable science by ecologists, decision makers, and stakeholders: translational ecology (TE). Six principles were identified as defining the foundations of TE: communication, collaboration, engagement, commitment, process, and decision framing (WebFigure 1; Enquist et al. 2017). While thinking about science education reform and the importance of developing mutually beneficial partnerships between scientists and educators, we relied on the principles of TE to provide a natural framework for organizing our thoughts about science



WebPanel 1. Agenda-driven science? The case of spotted owls and fire

Balancing forest ecosystem restoration and spotted owl conservation

Spotted owls (*Strix occidentalis*) have been at the center of forest management debates in the western US for nearly half a century. The conflict initially revolved around logging of commercially valuable older forests used by spotted owls (Simberloff 1987; Gutiérrez *et al.* 1995; Gutiérrez 2015). More recently, the debate has shifted to the potential for impacts to spotted owls from fuels reduction and forest restoration techniques that, in addition to the increased use of prescribed and managed fire, include logging of small- and medium-sized trees in forests with high canopy closure used by owls as primary habitat (Lehmkuhl *et al.* 2007, 2015; Collins *et al.* 2010; Tempel *et al.* 2014, 2015, 2016). Restoration appears necessary because fire suppression since the 19th century in the dry forests of western North America has resulted in unnaturally high densities of shade-tolerant trees, with a concomitant increase in surface and ladder fuels (ie “departed” forests) (Collins *et al.* 2017; Hagemann *et al.* 2017) – both of which increase the risk of large, severe fires (Calkin *et al.* 2005; North *et al.* 2015; Steel *et al.* 2015).

Spotted owls use these “departed” forests (as well as old-growth forests influenced by natural fire regimes) for nesting, roosting, and foraging, and there is concern by managers that high tree densities in owl habitat exacerbate the risk of large, high-severity fires. Logging and related management activities (eg mastication, chipping) are used to reduce densities of smaller trees and surface fuels, curb severe fire, and restore forest ecosystems, but modify forest structure in a way that may negatively impact spotted owls (Ager *et al.* 2007; Stephens *et al.* 2014; Tempel *et al.* 2014, 2015, 2016). Therefore, a key issue in the ecosystem restoration versus spotted owl conservation debate is the extent to which spot-

ted owls are affected by wildfire. If large, severe fires negatively affect spotted owl populations, some argue that short-term negative effects of fuels reduction treatments on spotted owls may provide long-term benefits by reducing wildfire impacts (Tempel *et al.* 2015). How owls respond to wildfire also has implications for post-fire management such as salvage logging and tree planting; if spotted owls avoid severely burned forests, an argument could be made that these activities can be implemented with limited adverse impacts to spotted owls. Thus, determining the extent to which severe fire affects spotted owls is key for restoring and managing both “green” and burned forests in a region experiencing rapidly warming and drying climatic conditions (Differbaugh *et al.* 2015; Mann and Gleick 2015; Williams *et al.* 2015; Crockett and Westerling 2018).

The science of spotted owls and fire

Spotted owls inhabiting seasonally dry forests are expected to be adapted to disturbance regimes characterized by frequent fires that, historically, were typically of low and moderate severity (Gutiérrez *et al.* 1995, 2017). This hypothesis is supported by virtually all research thus far published on the response of owls to low- and moderate-severity fires (Bond 2016; Ganey *et al.* 2017). However, conflicting accounts exist regarding the effects of high-severity fire on spotted owls (Ganey *et al.* 2017). Several studies from one research group (Lee, Bond, and Hanson; hereafter “LBH”) indicate that (1) territory occupancy rates (the fraction of historical territories containing spotted owls at time t) either are not affected, or are affected to a negligible degree, by high-severity fire (Lee *et al.* 2012, 2013; Lee and Bond 2015a,b; Hanson *et al.* 2018); and (2) spotted owls marked with radio-transmitters do not avoid severely burned patches of forest when foraging (Bond *et al.* 2009, 2016). By contrast, recent studies by four independent research groups (see Table 1 in Ganey *et al.* 2017) reveal negative effects of large, severe fires on spotted owl populations (Jones *et al.* 2016; Rockweit *et al.*

2017) and avoidance of severely burned forests by spotted owls marked with radio-transmitters or GPS tags (Comfort *et al.* 2016; Jones *et al.* 2016; Eyes *et al.* 2017).

Conflicting results may, in part, be attributable to differences in landscape patterns of severe fire among studies. For example, Jones *et al.* (2016) examined changes in territory occupancy by spotted owls following the ~40,000-ha King Fire, which was one of the largest and most homogeneously severe forest fire events in recent California history (Stevens *et al.* 2017). Spatial patterns of severe fire in the larger (~104,000-ha) Rim Fire studied by Lee and Bond (2015a) were relatively heterogeneous by comparison, which may have resulted in less or no impact on territory occupancy (Jones *et al.* 2016; Ganey *et al.* 2017). Similarly, individual territories in Lee *et al.* (2012, 2013) and Lee and Bond (2015b) may not have experienced the same degree of high severity fire as territories in the Jones *et al.* (2016) study, although it is difficult to make direct comparisons owing to limited information provided by Lee and co-authors. Nevertheless, it is not unreasonable to expect that varying spatial patterns of severe fire might affect spotted owls differently, and it would not be surprising if some of the differences in results among the aforementioned studies emerged because the studies focused on fires with different characteristics.

Competing findings may also have resulted from differences among studies in methods employed. Studies suggesting negative effects of severe fire on spotted owl populations were based on designs using color-marked individuals, whereas studies that did not report negative effects were based on unmarked individuals. Thus, studies reporting little or no effect on spotted owls often assigned territory occupancy status by means of nocturnal detections of owls (Lee *et al.* 2012, 2013; Lee and Bond 2015a,b; Hanson *et al.* 2018). However, wide-ranging nocturnal movements by individual owls can lead to the apparent use of multiple territories (ie the same bird detected in

several territories that are actually unoccupied), resulting in assignment (false positive) bias that can dramatically inflate occupancy rates (Miller *et al.* 2011; Sutherland *et al.* 2013) and mask the effect of fire in unmarked owl populations (Berigan *et al.* 2018). In contrast, Jones *et al.* (2016), using data from a long-term demographic study of a marked population of owls, excluded such false positive detections in unoccupied territories and were able to estimate high extinction rates for territories that experienced large (>50%) amounts of severe fire. Also using color-marked owls, Rockweit *et al.* (2017) demonstrated that survival rates of individual owls were lower in landscapes that experienced relatively large amounts of high-severity fire. Thus, occupancy-based studies detected neutral or weak effects of severe fire on unmarked spotted owls (Lee *et al.* 2012, 2013; Lee and Bond 2015a,b) may not have captured the full demographic impacts of severe fire on their study populations.

Understanding why significant differences in results have occurred among spotted owl–fire studies has major implications for balancing ecosystem restoration and species conservation objectives in dry forest ecosystems. If severe fire negatively affects spotted owls and some studies failed to detect the effects of severe fire because they were conducted on unmarked populations, a logical management implication would be that reducing severe fire could benefit spotted owls. If, however, differences in studies are the result of differences in ecological context, where, for example, severe fire primarily impacts spotted owls when these fires occur in large, homogeneous patches, the calculus becomes considerably complex. Specifically, the benefits of reducing severe fire to owls will depend in part on when, and how frequently, severe fire exceeds some currently unknown threshold size and level of homogeneity. We therefore believe much remains to be learned about wildfire effects on spotted owls and additional study is warranted.

Evidence for agenda-driven science in the spotted owl–wildfire debate?

Despite growing consensus among research groups that severe fire can, in some circumstances, adversely affect spotted owls (Ganey *et al.* 2017), those studies demonstrating such negative effects have been contested by a single research group (LBH) whose studies suggest severe fire has little or no effect on owls. Members of this research group also advocate that:

“...the federal timber sales program must be ended in order for ecological management of our national forests and other federal forestlands to occur.”

–John Muir Project of Earth Island Institute (2014)

“We propose expansion of the National Park Service model of forest management to encompass all California’s US Forest Service lands.”

–Wild Nature Institute (2019)

Certainly, advocacy in support of these positions could, in some cases, be justified because fuels treatments and salvage logging have the potential to be detrimental to owl habitat and forest ecosystems, respectively (Lindenmayer and Noss 2006; Ganey *et al.* 2017). However, as detailed below, it is our opinion that LBH appear to have engaged in six activities outside of professional norms in support of their advocacy that promote a narrative that high-severity wildfire does not threaten spotted owls. These apparent activities include: (i) mixing science and litigation without disclosing potential conflicts of interest; (ii) using social media (rather than peer-reviewed journals) to conduct critical scientific reviews of studies that do not support the findings of their own work; (iii) pressuring scientists and graduate students with different research findings to retract their papers or not publish their thesis findings; (iv) conducting erroneous analyses using data they did not collect and with which they were unfamiliar; (v) selectively using data that support their agendas; and (vi) making management recommendations beyond

what is reasonably supported by scientific findings. Individually, we consider each of these activities to fall outside of scientific norms. Collectively, however, they may be symptomatic of agenda-driven science involving attempts to understate uncertainty and promote a narrative not fully supported by the scientific literature that aims to influence forest management. As described in the main text of the associated letter, recognizing when scientific activities “cross the line” and enter the realm of agenda-driven science is a “gray area” and is thus subjective. Consequently, we leave it to the reader to decide whether, taken together, these activities constitute agenda-driven science. Following our description of each of the questionable activities exhibited by LBH, we discuss how these six activities can be identified and rebutted in conservation science.

Mixing science and litigation without declaring potential conflicts of interest

Hanson (of LBH) is both a lawyer and a scientist who cites the peer-reviewed publications of LBH in litigation activities opposed to fuels reduction treatments and salvage logging on national forests (eg Earth Island Institute vs US Forest Service 2006). His legal arguments depend on (i) severe wildfire mostly being benign to spotted owls, regardless of scale and extent; and (ii) forest restoration activities posing the primary threat to this species, as he and his colleagues have suggested is the case in many publications (eg Bond 2016; Hanson *et al.* 2018; Lee 2018). Moreover, Bond and Lee are frequently involved in Hanson’s cases as expert witnesses who produce declarations arguing that severe wildfire does not substantially impact spotted owls. And, in some cases, court cases have been decided in favor of the plaintiffs and prevented planned forest management, with judgments citing LBH’s studies finding that severe fire is mostly benign to spotted owl habitat (Earth Island Institute vs US Forest Service 2006). Nevertheless, these litigation activities – and potential conflicts of interest – are not disclosed in their scientific papers

(eg Lee and Bond 2015b; Hanson *et al.* 2018).

While scientists will inevitably be party to litigation for legitimate reasons, science conducted “to prove a point” in support of litigation is antithetical to the scientific process. We agree with others that agenda-driven science is particularly likely to emerge when science is produced to support litigation (Haack 2008). Indeed, the objectives of attorneys (to advocate on behalf of clients) and scientists (to seek truth) are fundamentally different and individuals engaged in both science and litigation are confronted with a substantial conflict of interest (Murphy and Noon 1991; Noon and Murphy 1994). However, if an individual or a group is centrally involved in both the production of science and litigation (as is the case with LBH), it is difficult to know whether the two processes (science and litigation) are independent, or whether the science is produced in order to provide support to an argument (ie an agenda) in the courtroom. For this reason, we suggest that scientific journals make these potential conflicts of interest more transparent by requiring that authors disclose any litigation activities they have been involved in related to the study they seek to publish, which would facilitate greater scrutiny for signs of agenda-driven science.

Inappropriate scientific rebuttal through social and quasi-scientific media

LBH have engaged in an information campaign via social media and quasi-scientific media outside of the peer-review process to discredit a study published in *Frontiers in Ecology and the Environment* (hereafter, “*Frontiers*”) that documented effects of a large, severe fire on spotted owls (Jones *et al.* 2016) (note: several authors of the present letter [Jones, Peery, and Gutiérrez; JPG] were co-authors on Jones *et al.* 2016). Specifically, members of LBH posted a scientific review titled “Jones *et al.* ‘Megafire’ paper is bad science” as a blog on their website (Wild Nature Institute 2016), with one member posting a similar criticism on social media demanding that Jones

and coworkers retract their study (eg Lee 2016). Soon thereafter, the editor of *Frontiers* informed JPG that a Write Back letter, critical of Jones *et al.* (2016), had been submitted to *Frontiers* and that, if the response was accepted, we would be given an opportunity to respond. As this letter has not appeared and we did not receive a request to respond, we can only assume it was rejected for lack of scientific merit. However, shortly after we were informed of the critical response submitted to *Frontiers*, Bond and Lee posted criticisms similar to those made on the Wild Nature Institute blog to the website PubPeer (Bond and Lee 2016). In addition, members of LBH collaborated with a science writer to produce a misleading article in the quasi-scientific online publication *BOOM California*, which mistakenly claimed that the effects of severe fire on owls in Jones *et al.* (2016) were spurious (Khosla 2017). For example, the author inaccurately claimed, among other things, that Jones *et al.* (2016) misclassified the occupancy status of several spotted owl territories without contacting Jones and coworkers to verify this statement or to obtain their perspective. The author also misrepresented the fact that Bond and Lee’s rebuttal (Bond and Lee 2016) was presumably rejected from *Frontiers* by only stating Lee had “alerted” the editors of *Frontiers* to the errors in Jones *et al.* (2016).

The proliferation of social media and other online forums has greatly increased opportunities for scientists to engage in professional networking and share science with their peers. While we applaud and welcome these opportunities, we do not believe the adjudication of scientific debates on social and related media is appropriate. Posting scientific reviews of peer-reviewed papers on social media or blogs, for example, does not allow for customary rebuttals or the oversight of peer review. Nor is it appropriate for a scientist to call for retraction of a peer-reviewed paper on social media without having his/her own arguments for such a retraction peer reviewed. Scientists confronted with agenda-driven science via critical reviews on social

media and antagonistic online information campaigns face a quandary. Should they respond and defend their work using similar forums? While we recognize that opinions will vary, we believe that scientific debates are unlikely to be resolved in unmoderated forums. Rather, we suggest the best approach is for scientists who find fault with a published paper to respond in peer-reviewed journal forums where they can present a body of well-supported scientific criticism and to which the criticized authors can also provide their formal responses – all within the context of peer review. The promotion of agenda-driven science via the popular press, however, poses a different dilemma, as the target audience is the general public. Given the importance of public opinion in developing effective conservation policy, responding to agenda-driven science via the popular press may be important. Thus, we suggest that scientists take criticisms leveled in the popular press on a case-by-case basis; when there is a considerable risk that the public is being misinformed, setting the record straight is both justified and essential.

Harassment of scientists publishing competing studies

Members of LBH and their funders apply pressure to scientists – including graduate students – that have found negative effects of severe wildfire on spotted owls to retract or not publish their scientific papers (eg GM Jones, pers comm; SA Eyes, pers comm). In their correspondence pressuring scientists to do so, members of LBH employ a “strategy of guilt”, arguing that results from these studies are being used by natural resource agencies to promote management actions deleterious to conservation of spotted owls, the implication being that the scientist (or graduate student) is contributing to further jeopardy to the owl.

While critique is an essential part of the scientific process and every scientist has the right to question other scientists about their methods or conclusions in a constructive manner, using guilt about how scientific results will be applied to

conservation is not an appropriate way to resolve conflicts. As scientists, we are obliged to seek the truth and we should not avoid pursuing research simply because someone might misuse it. Moreover, the strategy of guilt is particularly inappropriate when more senior scientists pressure junior scientists, particularly graduate students, into conforming to their own perspective. Graduate students are at a vulnerable career stage, and they are learning to navigate the complex intersections among science, management, and policy. Mentors, institutions, and the broader scientific community should support and defend graduate students and junior scientists whose work is targeted by advocacy groups.

Inappropriate use of other scientists' data

Many, if not most, of the spotted owl-wildfire publications LBH have produced used data they did not collect themselves. Moreover, LBH regularly use the Freedom of Information Act (FOIA) as a mechanism to obtain or try to obtain other researchers' data without seeking collaboration or offering co-authorship (A Franklin, pers comm; D Lesmeister, pers comm; J Keane, pers comm). While open-access data and data sharing are becoming increasingly important in scientific research, we believe that a lack of understanding of the data collected by other scientists has likely led LBH to make analytical errors and draw erroneous inferences about effects of wildfire on spotted owls. For example, the data Lee and Bond (2015b) used to infer high rates of territory occupancy one year after the 2013 Rim Fire had not yet been vetted and contained several hundred errors at the time the data were obtained from US Forest Service biologists (without the consent of the principal investigator; J Keane, pers comm). Further, LBH made no attempt to contact the principal investigator or the biologists who collected the data to detect, understand, or correct data errors (J Keane, pers comm). Hanson *et al.* (2018) also lacked complete information on spotted owl territory occupan-

cy histories when they re-analyzed data collected and published by Jones *et al.* (2016). For example, Hanson *et al.* treated one territory ("PLA0065"; a unique code corresponding with USFS-delineated spotted owl management units) as unoccupied both before (2014) and after the King Fire (2015). However, this territory was field-verified shortly before the fire to be occupied by a banded pair of owls that fledged three young in 2014 and went extinct after experiencing high severity fire across 95% of its area (the burned remains of the banded male were found near the nest site in the spring following the fire). Further, Hanson *et al.* treated a different territory (PLA0039) as occupied before and after the fire, while in fact this territory became unoccupied after the fire. We surmise this error occurred because LBH misattributed an apparent detection of owls in PLA0039 in 2015 to an adjacent (but spatially overlapping) territory (PLA0080) that was the primary nest/roost area being used by spotted owls in that year. Therefore, PLA0039 should have been classified as unoccupied post-fire (Berigan *et al.* 2018). Together, these errors contributed to Hanson *et al.* (2018) concluding that the 2014 King Fire did not negatively impact spotted owls.

The trend toward open-access data in science has both increased transparency and catalyzed scientific advances. However, messy data are inherent in ecological research and faulty inferences can easily result when data are re-analyzed with little understanding of the data collection process. Thus, we consider the repeated use of other's data without their involvement and without a thorough understanding of those data to be inappropriate in conservation research. Indeed, the "ambiguities" of raw ecological data underscore the importance of pursuing collaborative science as part of resolving conservation conflicts. Politically charged science can also be resolved through independent review mechanisms, such as meta-analysis workshops that include outside scientists (Anderson *et al.* 1999).

Selective use of data

Hanson *et al.* (2018) re-analyzed some data from Jones *et al.* (2016), wherein Jones *et al.* reported that extensive severe wildfire can reduce spotted owl territory occupancy. However, Hanson *et al.* excluded the four most severely burned territories from their analysis (91–99% of the area within these territories burned at a high severity: PLA0050, PLA0067, PLA0013, and PLA0065). They thereby eliminated the territories most likely to demonstrate severe fire effects. Moreover, all four territories were occupied in the breeding season prior to the King Fire but were unoccupied following the fire (ie they went extinct). Hanson *et al.*'s justification for excluding these data was that including sites that burned >80% at high severity would disrupt their factorial design intended to distinguish between the categorical effects of severe fire (20–49% vs 50–80% of territory area affected) and salvage logging (<5% vs ≥5% of territory area), because few of these sites experienced <5% salvage logging. However, if the objective of a study is to examine an effect, whether it be fire and/or salvage logging, why exclude data that had potential to test the effect? Rather than treating severe fire and salvage logging as categorical effects, Hanson *et al.* could simply have treated them as continuous predictors of occupancy. This approach would have circumvented the problem they invoked as justification, and strengthened their ability to detect effects (Cottingham *et al.* 2005).

Recognizing whether data have been intentionally used in a selective manner is challenging, and may simply be the product of unintentional poor scholarship on the part of a scientist. Without direct evidence of intent, such actions, then, must be considered within the context of a scientist's broader pattern of behavior. For example, does he/she have a conflict of interest that might compel him/her to make such decisions to exclude relevant, indeed critical, data? In light of the difficulties in detecting such biases, we suggest that editors and reviewers be alert to selective use of data when reviewing studies that criticize oth-

er papers, especially when “re-analyses” of data occur to support such criticism.

Drawing conclusions beyond scientific findings

Lee (2018) conducted a meta-analysis testing for effects of wildfire on spotted owls across 21 published studies and did not detect a significant overall effect of fire on foraging, demography, or territory occupancy. He concluded that:

“Contrary to current perceptions and recovery efforts for the Spotted Owl, mixed-severity fire does not appear to be a serious threat to owl populations; rather, wildfire has arguably more benefits than costs for Spotted Owls.”

Lee’s conclusion oversteps his results for three reasons. First, the estimated overall (negative) effect of wildfire on spotted owl territory occupancy was nearly statistically significant at the 0.05 level ($P = 0.07$). Second, meta-analyses that focus on summary effects when among-study variability is high are likely to lead to conclusions that are wrong, perhaps seriously so (Bailar 1997; Borenstein *et al.* 2009). Thus, even if the negative effect of fire on occupancy had been statistically significant, it would have been difficult or impossible to interpret directly because of high variation in estimated fire effects among studies. Indeed, variability in the estimated effect size of fire on occupancy was extremely high by meta-analytical standards as measured by its I^2 value (Higgins *et al.* 2003) of 97.7% ($P < 0.001$), where generalizations should be avoided when I^2 values exceed 50–75% (Higgins and Thompson 2002; Higgins *et al.* 2003). I^2 values were nearly as extreme for the other variables examined (demography = 84.0%, $P < 0.001$; foraging = 84.4%, $P < 0.001$). Moreover, variability in estimated fire effects among studies was greater at burned than unburned territories. This high level of variability betrays generalization, making Lee’s conclusion that fire does not threaten owl populations unsubstantiated. Instead, the high variability among studies should have led to the conclusion that

effects of wildfire are likely context specific, perhaps related to spatial patterns of burned areas. Third, the conclusion that wildfire does not pose a threat to spotted owls does not take into account that wildfires in many forest ecosystems are predicted to become larger and more severe as the climate changes (Westerling and Bryant 2008; Stephens *et al.* 2013; Liu *et al.* 2013; Millar and Stephenson 2015; Abatzoglou and Williams 2016).

Determining whether conclusions and management recommendations that extend beyond the results of a study were made intentionally is challenging, because interpretation of results can be subjective; even when conclusions are unsupported, intent will often be unknown. However, sweeping conclusions that previous studies are in error, and conclusions that emphasize certainty instead of uncertainty and complexity, are potential signs of agenda-driven science.

Whether deliberate or inadvertent, LBH appear to have engaged in a series of activities, both within and outside of the peer-review process, that have resulted in the under-appreciation of the effects of severe wildfire on spotted owls. This case study underscores the importance of recognizing and understanding how to respond to activities that may be symptomatic of agenda-driven science. In the case of spotted owls, ignoring negative effects of severe wildfire could compromise the ability to conserve this species and restore forest ecosystems that are experiencing increasingly large and severe fires as the climate becomes warmer and drier. Meeting these dual objectives will be complex, but the process is made more complicated and challenging if scientists engage in activities that lead to incorrect scientific narratives rather than collaboratively trying to solve the problem.

Acknowledgements

The USDA Forest Service, California Department of Fish and Wildlife, and US Fish and Wildlife Service funded the original King Fire study (Jones *et al.* 2016) discussed herein.

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