Attitudes towards returning wolves (Canis lupus) in Germany: Exposure, information sources and trust matter.

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ABSTRACT

Understanding how exposure and information affect public attitudes towards returning large carnivores in Europe is critical for human-carnivore coexistence, especially for developing efficient and de-escalating communication strategies. The ongoing recolonization of wolves (*Canis lupus*) in Germany provides a unique opportunity to test the role of different information sources and trust on people's attitudes towards wolves. We conducted a phone survey (n=1250) and compared country-wide attitudes towards wolves with attitudes in a specific region where wolves initially recolonized and have been present since 2000. In particular, we investigate the relationship between information sources, trust and people's attitudes while accounting for factors like knowledge, exposure and socio-cultural determinants of respondents. We found significant differences in attitudes and knowledge about wolves as well as in the use and frequency of information sources between the two population samples. Higher knowledge, information from books and films, science-based information, and higher trust in information sources related positively with positive attitudes towards wolves. Comparatively, information from press or TV news was associated with more negative attitudes. Providing science-based information to the public and building trust in information is likely to be one measure, among others, to dampen extreme attitudes and improve people's appreciation of costs and benefits of human-carnivore coexistence. Management of conflictual situations emerging from large carnivore recolonization in Europe and beyond should consider incorporating assessments of people's use of and trust in information in addition to existing tools to pave new ways for constructive human-carnivore coexistence.

KEYWORDS:

Attitudes, Human-wildlife coexistence, Large carnivores, Media, Science communication, Social survey.

INTRODUCTION

Large carnivores are currently recolonizing parts of their former ranges in Europe, benefiting from stronger protection (Trouwborst 2010) and effective policy (Linnell et al. 2001; Chapron et al. 2014; Mech 2017). The lack of remote areas where large carnivores could thrive without human interactions in European human-dominated landscapes results in carnivores and people sharing the same landscapes (Chapron et al. 2014; Mech 2017). Coexistence between carnivores and humans can be challenging because of perceived or real threats carnivores pose to human property or safety (Johansson & Frank 2016; Eklund et al. 2017). Thus, investigating people's attitudes towards large carnivores is necessary for human-carnivore coexistence. Attitudes are composed of cognitive (i.e. personal beliefs, opinions, values) and affective components (i.e. emotional states or traits) that can be influenced by a variety of different factors (Glikman et al. 2012; Bruskotter & Wilson, 2013). The extent to which people are exposed to and informed about carnivores can affect both cognitive and affective components of people's attitudes and the potential for human-carnivore coexistence. Attitudes can ultimately translate into specific behaviour such as supportive, tolerant or intolerant behaviours (Bruskotter et al. 2013). For instance, people exposed to increasing carnivore populations (Majić et al. 2011) or living in closer proximity to carnivores (Karlsson & Sjöström 2007) tend to have lower acceptance for these species. Novel exposures to carnivores during their recolonization can result in higher damages to unprotected livestock, in higher competition with hunters for game species and trigger high levels of uncertainty and fear, often receiving higher media attention and polarizing the discussion (Bisi et al. 2007; Fernández-Gil et al. 2016). However, these novel exposures and the underlying variations in people's experience and information sources have rarely been studied in combination. With expanding carnivore populations in Europe, it is crucial to investigate factors simultaneously influencing attitudes towards carnivores (Huber et al. 2009; Majić & Bath 2010; Carter & Linnell 2016).

The currently recolonizing wolf (*Canis lupus*) population in Germany offers a unique opportunity to expand understanding of the role of information sources and trust on attitudes towards recolonizing carnivores in human-dominated landscapes. Recolonization started in 2000 (Reinhardt et al. 2013) with a first reproduction event by a pair of wolves originating from Poland (Hindrikson et al. 2017). Only 17 years later, the presence of 60 packs has been confirmed in 7 Federal States throughout Germany (www.dbb-wolf.de). This rapid recolonization, also seen in other European countries like Sweden, France or Switzerland

(Chapron et al. 2014) creates a very dynamic human-carnivore system, where people living in different regions experience varying levels of direct and indirect exposure to carnivore populations and varying levels and sources of information. This situation provides a unique setting to assess factors affecting societal acceptance within one country and newly colonized areas (Behr et al. 2017). We focus here on the individual level as a means to assess societal acceptance towards carnivores. Involving the broader public is a necessary first step to develop a democratic and legitimate pathway towards coexistence with recolonizing carnivores (López-Bao et al. 2017a, Redpath et al. 2017, Young et al. 2016b).

During recolonization, exposure to wolves, defined here as the extent to which one is exposed to and has experience with wolves (Kansky & Knight 2014), can be characterized as direct or indirect. As a direct consequence of their return, people may be more likely to observe, encounter the animal or experience depredations (Eriksson et al. 2014). An indirect consequence of their return is the change in the socio-cultural context: experiences lived by one's relatives or increased media coverage (Houston et al. 2010; Fernández-Gil et al. 2016) potentially affect people's perceived threat from carnivores. While direct exposures (i.e. distance to carnivores) and knowledge are known to affect attitudes towards carnivores (Glikman et al. 2012; Piédallu et al. 2016), to our knowledge, no study has assessed the importance of different types of exposures, of information sources and the trust people have in these information on attitudes towards recolonizing carnivores in a single framework.

Access to and trust in information is rarely addressed in attitude studies, although information influences public opinion, beliefs and attitudes in multiple ways and in relation to a wide range of topics (Happer et al. 2013; Young et al. 2016a). For example, a communication experiment showed that acceptance of black bears in the United States increased with exposure to positive framing of bear presence (Slagle et al. 2013). Information can be conveyed by different media such as press or TV news, traditional or online media, magazines or by different actors such as one's relatives, NGOs or zoos. People receive information differently and their trust in an information source depends on the context (Flanagin & Metzger 2000; Hesse et al. 2005). For instance, a phone survey in Milwaukee showed that science media were more trusted than information from press or TV news (Brewer & Ley 2013). Social media can spread accurate or misleading information very quickly in times of crisis (Castillo et al. 2011; Westerman et al. 2014) and information content can have important effects in the context of coexistence with carnivores (Fernández-Gil et al. 2016; Johansson et al. 2016). Communication and trust are fundamental for

decision-making in conservation (Addison et al. 2013) and the time is ripe for expanding knowledge on how people's access to information and people's trust in different sources is related to their attitudes towards carnivores.

We conducted a phone survey to investigate attitudes towards recolonizing wolves in Germany, and in a specific rural region with the longest coexistence with wolves in. This specific region has experienced wolf presence and media coverage the longest and had 7 wolf packs and one territorial pair at the time of the study (monitoring year 2015/2016, DBBW 2017). This region also hosts an independent wolf information centre dedicated to the diffusion of wolf-related information to the public (http://www.wolf-sachsen.de/de/). In this context, we expected to find notable differences in exposure to wolves and in use and access to information between people from across Germany and those from the wolf region. Our main objective was to understand how the combination of exposure, knowledge, information sources and trust could influence attitudes towards recolonizing carnivores, while controlling for socio-demographic factors (Kansky & Knight 2014; Dressel et al. 2015).

METHODS

- *Survey design*

The survey targeted two population samples: one representative sample of the overall German population (n=1,000, "Germany" hereafter) and one representative sample of the specific region with the longest coexistence with wolves (n=250, Görlitz region in Saxony; "wolf region" hereafter). The questionnaire included 51 questions divided into 5 sections, designed to be comparable with previous attitude studies (Kansky & Knight 2014; Dressel et al. 2015) and to address the knowledge gaps we identified. These sections represent respondents' i) knowledge on wolves (Section A), ii) information sources on wolves (Section B), iii) exposure and experience with wolves (Section C), iv) attitudes towards wolves (Section D) and v) socio-demographic characteristics (Section E) (Methods S1). The phone survey addressed adults in both population samples.

- *Factors potentially explaining attitudes towards wolves*

We treated answers to questions of Sections A-B-C-E as potential predictors of attitudes (Table 1). We calculated the distance to the nearest wolf territory in ArcGIS (v. 10.3.1) as the distance between the respondents' place of residence (given by respondent's postal code) and the nearest wolf territory (monitoring year 2015/2016, DBBW 2017). We transformed the three questions related to personal exposure with wolves into binary categorical variables

(have seen wolves in captivity or not – C1 –, outside Germany –C2 –, within Germany – C3) to have sufficient sample size in each category for the multiple regression analysis (Table 1). We defined three types of exposure, namely exposure as i) living in the wolf region, ii) the distance to the nearest wolf territory, and iii) personal and relatives' experiences with wolves.

To understand respondents' use of information in the two different contexts of this study (whole Germany vs. wolf region), we performed Chi-squared tests of independence for level of information (question B1), source of information (question B2) and frequency of information (question B5), with the underlying assumption that a rejection of the null hypothesis would mean that the use and frequency of information is different in the two contexts.

We assessed collinearity among categorical predictors using the Cramer's V index of correlation (function "assocstats", package "vcd"), which is based on Chi-square tests for categorical data with more than 2 levels. Collinearity was not an issue among categorical variables (correlation values < 0.50, Table S1). We assessed collinearity among numeric variables using Pearson's coefficient (function "cor", package "stats") and collinearity was not an issue either (coefficients < 0.50, Table S2).

- *Principal Component Analysis and response variable*

To evaluate the internal consistency of the 17 answers relating to respondents' attitudes towards wolves (Section D except D4, related to distance), we calculated Cronbach's alpha (package "psych") (Behr et al. 2017, Zeller & Carmines 1980). The reliability was excellent (0.93), and we performed a Principal Component Analysis (PCA) to summarize the information on attitudes into principal components explaining most of the variance in the data and which are used as response variables in multiple linear regressions models (Piédallu et al. 2016; Behr et al. 2017).

- *Multiple linear regression models*

First, we specified a single model pooling all data to check for differences in respondents' attitudes between the wolf region and Germany. The model included all predictor variables in Table 1. We adopted a stepwise procedure for model selection (backward selection based on Akaike Information Criterion) because we postulated that each answer in the questionnaire could explain attitudes towards wolves. We detected significant differences in respondents' attitudes between the wolf region and Germany (Table 2); we therefore used two models to understand the determinants of attitudes in each population sample. We used the same model

selection procedure described above for the two separate models. All analyses were performed using R and dedicated packages (v.3.3.2, R core Team 2016).

RESULTS

- *Respondents' characteristics in the two population samples*

We excluded 404 incomplete questionnaires and kept 846 questionnaires for analysis (176 in the wolf region and 670 in Germany, respectively) (see details in Methods S2). Respondents from the wolf region lived 10 times closer to regions of permanent wolf presence than the average across Germany (14 km away vs 138 km away respectively; t-test, $p < 0.001$). Knowledge of wolves was significantly higher in the wolf region than in Germany (average knowledge score of 4.3 vs 3.4 respectively; t-test, $p < 0.001$). Respondents' socio-demographic characteristics are described in Table 3.

- *Information on wolves in the two population samples*

The main information source on wolves was the press or TV news (54.5% and 66.9% in wolf region and Germany, respectively). Yet, respondents used different information sources in Germany and in the wolf region (Chi-squared test, $\chi^2 = 95.57$, $p < 0.01$), where in the latter respondents mentioned the wolf information centre as an important source of information (20.5%) (Fig. 1a). We also found significant differences in the self-reported level of information ($\chi^2 = 86.34$, $p < 0.01$) and the frequency of information ($\chi^2 = 63.15$, $p < 0.01$), both being higher in the wolf region than in Germany (Fig. 1b, c). We did not detect any notable difference in respondents' trust in the different information sources (Fig. 1a).

- *Attitudes towards wolves in Germany*

The variation in attitudes towards wolves could be described along two PCA components. The first component (Fig. 2) was interpreted as "tolerance towards wolves" and described a continuum of attitudes from negative feelings such as fear (questions D11 & D12) to positive attitudes such as the respondents' opinion about wolves in general and in Germany in particular (question D1 & D2); higher scores indicate more tolerance. The second component was related to respondents' "desired population trend" as it was primarily associated with this question (question D6) and the question on means of control in the survey (question D14) (Fig. S1); higher scores indicate a wish for more wolves in Germany. Tolerance towards wolves explained 52.9% of the variation across all answers on attitudes, while desired population trend explained 6.2% of the variation only. We thus kept only the tolerance variable for further analysis.

In the regression model combining data from the wolf region and Germany, exposure as "distance to the next wolf territory" did not affect attitudes (excluded from model), whereas exposure as "negative experiences" (e.g. a relative losing an animal after a wolf attack) negatively affected attitudes (model coefficient $\beta = -1.59$, Table 2). More importantly, exposure as "living in the wolf region" had an effect on attitudes: respondents from the wolf region had more neutral attitudes towards wolves than in Germany, where attitudes were mainly positive (Fig. 2, Table 2, $\beta = -1.14$). Knowledge scores ($\beta = 0.23$), information provided in books and films or diffused on social networks, and trust in information sources ($\beta = 0.25$) had positive effects on attitudes towards wolves (Table 2).

- *Drivers of attitudes towards wolves in the two population samples*

Direct individual exposure to wolves had a limited effect on attitudes and was not the most important factor, as it did not have any effect in either of the two distinct models of attitudes (excluded from both models), except wolves seen outside Germany in the German model ($\beta = 0.52$). Exposure as distance to the next wolf territory was not significant in the wolf region model, although its effect on attitudes was the strongest ($\beta = -3.18$, $p=0.17$, Table 4) and excluded from the Germany model. Negative experiences with wolf attacks (question C5) had a relatively strong negative effect on attitudes in both models ($\beta = -1.34$ and $\beta = -1.48$ in wolf region and Germany respectively, Fig. 3). Interestingly, the factor "source of information" was always on of the five most important factors affecting attitudes towards wolves in the models selected by the AIC.

In the wolf region model, attitudes were significantly related to information sources: respondents obtaining information from books and films ($\beta = 1.86$) or from the wolf information centre ($\beta = 1.23$) showed more positive attitudes towards wolves in comparison to press or TV news (Fig. 3, Table 4). Respondents with higher trust in information sources had more positive attitudes towards wolves ($\beta = 0.97$, Fig. 3).

In the Germany model, people with higher knowledge about wolves ($\beta = 0.25$), feeling well informed ($\beta = 0.19$) and getting information from books and films ($\beta = 0.66$, Fig. 3, Table 4) were more tolerant towards wolves.

DISCUSSION

Respondents to the phone survey showed overall positive attitudes towards wolves recolonizing Germany (Fig. 2). However, we found significant differences in attitudes,

knowledge, use and frequency of information between respondents from the wolf region and those from across Germany. In particular, respondents' sources of information and trust in these information sources were important factors affecting attitudes towards wolves.

- *Longer indirect exposure leads to neutral attitudes*

Our survey highlights the predominance of positive attitudes towards recolonizing wolves in central Europe. This result is consistent with previous findings in Germany (Kaczensky 2006) and elsewhere in Europe, like Italy (Glikman et al. 2012) and Croatia (Majić & Bath 2010). We found that the attitudes towards wolves become more neutral in rural landscapes with an increased duration of coexistence, a common trend in Europe (Dressel et al. 2015). The finding that neutral, rather than negative attitudes dominate in the wolf-affected rural population 17 years after wolf recolonization is particularly interesting for human-carnivore coexistence. While overly negative or positive attitudes might reflect debate polarization and human-human conflicts (Redpath et al. 2013; Jacobsen & Linnell 2016), neutral attitudes might hint at a better understanding of carnivore ecology (Majić & Bath 2010) or a successful process of building trust and conflict mitigation adapted over time (Young et al. 2016a).

Overall, our results show that a minority of people in Germany have direct experiences with wolves (10.9% of respondents claimed to have seen wolves in the wild in Germany). Direct exposures (i.e. wolf observations or distance to wolves) did not have a strong influence in our models. Attitudes towards carnivores are thus more likely to reflect indirect rather than direct exposure to carnivores (Karlsson & Sjöström 2007). In our study, respondents knowing someone who suffered from wolf depredation (i.e. indirect exposure) tended to be less tolerant towards wolves (Fig. 3). Hence, indirect exposures and social contexts play an important role in explaining risk perception and attitudes (Dickman 2010). Our results thus concur with previous findings claiming that human-carnivore relationships are dynamic and context-specific (Karlsson & Sjöström 2007; Piédallu et al. 2016), owing among other factors to rural-urban differences, local history, trust and culture (Lescureux & Linnell 2013; Piédallu et al. 2016).

- *Information sources shape attitudes towards carnivores*

The socio-cultural contexts around human-carnivore coexistence can be diverse and defined by a wide range of political, cultural or economic factors (Lescureux & Linnell 2013), and one specific factor at stake is the access to and frequency of information. It is critical to understand the role of information because information on carnivores are often negatively

framed (Jürgens & Hackett 2017), which has been demonstrated to have greater influence on people's attitudes than positive information in psychological, social and political studies (Soroka 2006). Knowing which information sources are associated with attitudes is a necessary preliminary step to understand the complexity of information reception and processing (Metzger & Flanagin 2013). Our study is the first to quantify the role of information sources in combination to other drivers of attitudes in the context of ongoing carnivore recolonization in Europe. Few studies have assessed the importance of information in shaping attitudes towards carnivores (Houston et al. 2010, Johansson et al. 2017), although media coverage is thought to be an important component of human-carnivore coexistence (Fernández-Gil et al. 2016). Recent publications in Europe and Northern America have demonstrated that media coverage of wolf can drastically vary depending on management (Killion et al. 2018) or local vs. national scales (Chandelier et al. 2018). Carnivores recolonizing new areas are subject to higher attention from the media (Houston et al. 2010), which can have strong impacts on public perception of carnivores.

We investigated the effects of different sources of information on attitudes, namely press or TV news, books and films, social networks, discussions with relatives, NGOs, zoos and wolf information centre. The analysis of the specific information conveyed by these different sources was outside the scope of this study, but our results clearly hint at an influence of information sources on attitudes, and further work is required to investigate the impacts of specific sources and their content on people's emotions and beliefs. Beliefs are expected to play an important role in determining people's attitudes and behaviour (Doll & Ajzen,1992) and understanding how positive or negative beliefs are formed could be critical in the context of human-wildlife interactions (Apps et al. 2015) and human-carnivore coexistence in particular. One hypothesis is that one's beliefs is influenced by knowledge (Guy et al. 2014) and that beliefs could therefore be directly or indirectly influenced by the type of information provided by different media sources, over a certain period of time. In this regard, our results show that people obtaining information from books and films were more tolerant towards wolves than people getting their knowledge on wolves primarily from press or TV news (Fig. 3). It may be that these respondents are less subject to peaks of publications in the news following wolf return; alternatively, people with positive attitudes towards wolves may be more prone to reading books and watching films reporting on carnivores, but our survey cannot tease these effects apart.

Our results show that in the wolf region, respondents had higher knowledge, felt better and more frequently informed, and used the wolf information centre as an important information provider. Besides, respondents obtaining information from the wolf information centre were more tolerant towards wolves (Fig. 3). The credibility and reliability of information is particularly important in crisis periods (Westerman et al. 2014) and we contend that such reliable information provider is fundamental in the context of carnivore recolonization that are subject to higher media coverage (Fernández-Gil et al. 2016). More generally, these findings have a broad resonance in contexts of human-carnivore coexistence worldwide, and the establishment of information centres distributing independent (i.e. not belonging to interest groups), science-based and reliable information on carnivore biology, status and management in a regular and timely manner should be viewed as an effective tool, among others like e.g. conflict prevention, damage compensation or participatory decision-making to facilitate human-carnivore coexistence in Europe and beyond.

- *Public trust in information sources improves tolerance towards carnivores*

Trust in information sources was an important component of attitudes towards wolves (Table 2, Table 4). Evidence-based information is necessary for accurate decision-making in conservation (Pullin et al. 2004; Sutherland et al. 2004; Cook et al. 2010) and is fundamental for maintaining people's trust towards the information provided to them. Building trust among stakeholders has proven a key element in resolving conservation conflicts (Young et al. 2016a), successfully implementing damage compensation programs (López-Bao et al. 2017b) and reducing fear towards carnivores (Johansson et al. 2017). Our study confirms that people who felt well informed and trusted their sources of information tended to be more tolerant towards wolves.

Altogether, our findings highlight the importance of indirect exposure to carnivores for people's attitudes, in the form of information sources that people decide to trust or not. Our approach linking information, people's trust in information sources and their attitudes could be extremely useful in contexts involving other carnivore species like bear (*Ursus arctos*), lynx (*Lynx lynx*), and wolverine (*Gulo gulo*) in Europe or puma (*Puma concolor*), leopard (*Panthera pardus*), lion (*Panthera leo*) or dingo (*Canis dingo*) elsewhere. In particular, we recommend that managers in charge of carnivore management and education actively engage with media and other information providers to increase the quality and

reliability of information on large carnivore issues. For example, trans-disciplinary engagement in the form of workshops has proven successful in addressing human-leopard conflicts around the Sanjay Gandhi National Park in Mumbai (India) for example (Hathaway et al. 2017). Clear objectives could be 1) to appoint local carnivore experts, designated by legitimate authorities to engage with the media and verify the accuracy of information pertaining to large carnivore-related facts; 2) to implement fast and adaptive information release to counter the quick spread of disinformation from e.g. social media; 3) to encourage information providers to include more diverse opinions to avoid so-called "one-sided" information and balance the prevalence of costs and benefits of carnivores. Thus, management programs with the objective to develop human-carnivore coexistence should focus on building trust among different stakeholders, including society as a whole. In this respect, one important step is to ensure the delivery of trusted science-based information on costs and benefits of large carnivore conservation.

REFERENCES

Addison, P.F.E., Rumpff, L., Sana Bau, S., Carey, J.M., Chee, Y.E., Jarrad, F.C., Mcbride, M.F. & Burgman, M.A. (2013). Practical solutions for making models indispensable in conservation decision-making. Divers. Distrib., 19, 490–502.

Apps, K., Dimmock, K. & Lloyd, D. (2015). Scuba divers and the Greynurse Shark: Beliefs, knowledge, and behavior. Hum. Dimens. of Wildl., 20, 425–439.

Behr, D.M., Ozgul, A. & Cozzi, G. (2017). Combining human acceptance and habitat suitability in a unified socio-ecological suitability model: a case study of the wolf in Switzerland. J. Appl. Ecol.

Bisi, J., Kurki, S., Svensberg, M. & Liukkonen, T. (2007). Human dimensions of wolf (Canis lupus) conflicts in Finland. Eur. J. Wildl. Res., 53, 304–314.

Brewer, P.R. & Ley, B.L. (2013). Whose science do you believe? Explaining trust in sources of scientific information about the environment. Sci. Commun., 35, 115–137.

Bruskotter, J.T. & Wilson, R.S. (2013). Determining where the wild things will be: Using psychological theory to find tolerance for large carnivores. Conserv. Lett., 7, 158–165.

Carter, N.H. & Linnell, J.D.C. (2016). Co-adaptation is key to coexisting with large carnivores. Trends Ecol. Evol., 31, 575–578.

Castillo, C., Mendoza, M. & Poblete, B. (2011). Information credibility on twitter. In: Proc. 20th Int. Conf. on World Wide Web. ACM, New York, 675–684.

Chandelier, M., Steuckardt, A., Mathevet, R., Diwersy, S. & Gimenez, O. (2018). Content analysis of newspaper coverage of wolf recolonization in France using structural topic modeling. Biol. Conserv., 220, 254–261.

Chapron, G., Kaczensky, P., Linnell, J.D.C., Arx, M. von, Huber, D., Andrén, H., López-Bao, J.V., Adamec, M., Álvares, F., Anders, O., Balčiauskas, L., Balys, V., Bedő, P., Bego, F., Blanco, J.C., Breitenmoser, U., Brøseth, H., Bufka, L., Bunikyte, R., Ciucci, P., Dutsov, A., Engleder, T., Fuxjäger, C., Groff, C., Holmala, K., Hoxha, B., Iliopoulos, Y., Ionescu, O., Jeremić, J., Jerina, K., Kluth, G., Knauer, F., Kojola, I., Kos, I., Krofel, M., Kubala, J., Kunovac, S., Kusak, J., Kutal, M., Liberg, O., Majić, A., Männil, P., Manz, R., Marboutin, E., Marucco, F., Melovski, D., Mersini, K., Mertzanis, Y., Mysłajek, R.W., Nowak, S., Odden, J., Ozolins, J., Palomero, G., Paunović, M., Persson, J., Potočnik, H., Quenette, P.-Y., Rauer, G., Reinhardt, I., Rigg, R., Ryser, A., Salvatori, V.,

383 Skrbinšek, T., Stojanov, A., Swenson, J.E., Szemethy, L., Trajçe, A., Tsingarska-
384 Sedefcheva, E., Váňa, M., Veeroja, R., Wabakken, P., Wölfl, M., Wölfl, S.,
385 Zimmermann, F., Zlatanova, D. & Boitani, L. (2014). Recovery of large carnivores in
386 Europe's modern human-dominated landscapes. Science, 346, 1517–1519.

387 Cook, C.N., Hockings, M. & Carter, R.B. (2010). Conservation in the dark? The information
388 used to support management decisions. Front. Ecol. Environ., 8, 181–186.

389 DBBW, Dokumentations- und Beratungsstelle des Bundes zum Thema Wolf (2017). Wölfe
390 in Deutschland. Statusbericht 2015/16. 28 pp. https://www.dbb-wolf.de/mehr/literatur-
391 download/statusberichte

392 Dickman, A.J. (2010). Complexities of conflict: The importance of considering social factors
393 for effectively resolving human-wildlife conflict. Anim. Conserv., 13, 458–466.

394 Doll, J., Ajzen, I., 1992. Accessibility and stability of predictors in the theory of planned
395 behavior. J. Pers. Soc. Psychol. 63, 754–765.

396 Dressel, S., Sandström, C. & Ericsson, G. (2015). A meta-analysis of studies on attitudes
397 toward bears and wolves across Europe 1976-2012. Conserv. Biol., 29, 565–574.

398 Eklund, A., López-Bao, J.V., Tourani, M., Chapron, G. & Frank, J. (2017). Limited evidence
399 on the effectiveness of interventions to reduce livestock predation by large carnivores.
400 Sci. Rep., 7, 2097.

401 Eriksson, M., Sandström, C. & Ericsson, G. (2014). Direct experience and attitude change
402 towards bears and wolves. Wildlife Biol., 21, 131–137.

403 Fernández-Gil, A., Naves, J., Ordiz, A., Quevedo, M., Revilla, E. & Delibes, M. (2016).
404 Conflict misleads large carnivore management and conservation: Brown bears and
405 wolves in Spain. PLoS One, 11, e0151541.

406 Flanagin, A.J. & Metzger, M.J. (2000). Perceptions of internet information credibility.
407 Journal. Mass Commun. Q., 77, 515–540.

408 Glikman, J.A., Vaske, J.J., Bath, A.J., Ciucci, P. & Boitani, L. (2012). Residents' support for
409 wolf and bear conservation: the moderating influence of knowledge. Eur. J. Wildl. Res.,
410 58, 295–302.

411 Guy, S., Kashima, Y., Walker, I., O'Neill, S. (2014). Investigating the effects of knowledge
412 and ideology on climate change beliefs. Eur. J. Soc. Psychol., 44, 421–429.

Hathaway, R.S., Bryant, S.E.M., Draheim, M.M., Vinod, P., Limaye, S. & Athreya, V. (2017). From fear to understanding: Changes in media representations of leopard incidences after media awareness workshops in Mumbai, India. Journal of Urban Ecology, 3, jux009.

Happer, C., Philo, G. & Philo, G. (2013). The role of the media in the construction of public belief and social change. J. Soc. Polit. Psychol., 1, 321–336.

Hesse, B.W., Nelson, D.E., Kreps, G.L., Croyle, R.T., Arora, N.K., Rimer, B.K. & Viswanath, K. (2005). Trust and sources of health information. Arch. Intern. Med., 165, 2618–2624.

Hindrikson, M., Remm, J., Pilot, M., Godinho, R., Stronen, A.V., Baltrūnaitė, L., Czarnomska, S.D., Leonard, J.A., Randi, E., Nowak, C., Åkesson, M., López-Bao, J.V., Álvares, F., Llaneza, L., Echegaray, J., Vilà, C., Ozolins, J., Rungis, D., Aspi, J., Paule, L., Skrbinšek, T. & Saarma, U. (2017). Wolf population genetics in Europe: a systematic review, meta-analysis and suggestions for conservation and management. Biol. Rev., 92, 1601–1629.

Houston, M., Bruskotter, J. & Fan, D. (2010). Attitudes toward wolves in the United States and Canada: A content analysis of the print news media, 1999-2008. Hum. Dimens. Wildl., 15, 389–403.

Huber, D., Kusak, J., Majić-Skrbinšek, A., Majnarić, D. & Sindičić, M. (2009). A multidimensional approach to managing the European brown bear in Croatia. Ursus, 19, 22–32.

Jacobsen, K.S. & Linnell, J.D.C. (2016). Perceptions of environmental justice and the conflict surrounding large carnivore management in Norway — Implications for conflict management. Biol. Conserv., 203, 197–206.

Johansson, M., Ferreira, I.A., Støen, O.-G., Frank, J. & Flykt, A. (2016). Targeting human fear of large carnivores — Many ideas but few known effects. Biol. Conserv., 201, 261–269.

Johansson, M. & Frank, J. (2016). The impact of access to an ultrasonic scaring device on human fear of wolves. Wildlife Biol., 22, 29–36.

442 Johansson, M., Frank, J., Støen, O.-G. & Flykt, A. (2017). An evaluation of information
443 meetings as a tool for addressing fear of large carnivores. Soc. Nat. Resour., 30, 281–
444 298.

445 Jürgens, U.M. & Hackett, P.M.W. (2017). The big bad wolf: The formation of a stereotype.
446 Ecopsychology, 9, 33–43.

447 Kaczensky, P., Jerina, K., Jonozovič, M., Krofel, M., Skrbinšek, T., Rauer, G., Kos, I. &
448 Gutleb, B. (2011). Illegal killings may hamper brown bear recovery in the Eastern Alps.
449 Ursus, 22, 37–46.

450 Kansky, R. & Knight, A.T. (2014). Key factors driving attitudes towards large mammals in
451 conflict with humans. Biol. Conserv., 179, 93–105.

452 Karlsson, J. & Sjöström, M. (2007). Human attitudes towards wolves, a matter of distance.
453 Biol. Conserv., 137, 610–616.

454 Killion, A., Melvin, T., Lindquist, E. & Carter, N.H. (2018). Tracking half-century of media
455 reporting on gray wolves. Cons. Biol.

456 Lescureux, N. & Linnell, D.J.C. (2013). The effect of rapid social changes during post-
457 communist transition on perceptions of the human - wolf relationships in Macedonia and
458 Kyrgyzstan. Pastor. Res. Policy Pract., 3.

459 Linnell, J., Swenson, J.E. & Andersen, R. (2001). Predators and people: conservation of large
460 carnivores is possible at high human densities if management policy is favourable. Anim.
461 Conserv., 4, 345–349.

462 López-Bao, J.V., Chapron, G. & Treves, A. (2017a). The Achilles heel of participatory
463 conservation. Biol. Conserv., 212, 139–143.

464 López-Bao, J. V, Frank, J., Svensson, L., Åkesson, M. & Langefors, Å. (2017b). Building
465 public trust in compensation programs through accuracy assessments of damage
466 verification protocols. Biol. Conserv., 213, 36–41.

467 Majić, A. & Bath, A.J. (2010). Changes in attitudes toward wolves in Croatia. Biol. Conserv.,
468 143, 255–260.

469 Majić, A., Marino Taussig de Bodonia, A., Huber, duro & Bunnefeld, N. (2011). Dynamics
470 of public attitudes toward bears and the role of bear hunting in Croatia. Biol. Conserv.,
471 144, 3018–3027.

Mech, L.D. (2017). Where can wolves live and how can we live with them? Biol. Conserv., 210, 310–317.

Metzger, M.J. & Flanagin, A.J. (2013). Credibility and trust of information in online environments: The use of cognitive heuristics. J. Pragmat., 59, 210–220.

Piédallu, B., Quenette, P.Y., Mounet, C., Lescureux, N., Borelli-Massines, M., Dubarry, E., Camarra, J.J. & Gimenez, O. (2016). Spatial variation in public attitudes towards brown bears in the French Pyrénées. Biol. Conserv., 197, 90–97.

Pullin, A.S., Knight, T.M., Stone, D.A. & Charman, K. (2004). Do conservation managers use scientific evidence to support their decision-making? Biol. Conserv., 119, 245–252.

Redpath, S.M., Young, J., Evely, A., Adams, W.M., Sutherland, W.J., Whitehouse, A., Amar, A., Lambert, R.A., Linnell, J.D.C., Watt, A. & Gutiérrez R.J. (2013). Understanding and managing conservation conflicts. Trends Ecol. Evol., 28, 100–109.

Redpath, S.M., Linnell, J.D.C., Festa-Bianchet, M., Boitani, L., Bunnefeld, N., Dickman, A., Gutiérrez, R.J., Irvine, R.J., Johansson, M., Majíc, A., McMahon, B.J., Pooley, S., Sandström, C., Sjölander-Lindqvist, A., Skogen, K., Swenson, J.E., Trouwborst, A., Young, J. & Milner-Gulland, E.J. (2017). Don't forget to look down – collaborative approaches to predator conservation. Biol. Rev., 92, 2157–2163.

Reinhardt, I., Kluth, G., Nowak, S. & Mysłajek, R.W. (2013). A review of wolf management in Poland and Germany with recommendations for future transboundary collaboration. BfN-Skripten, 356, 1–115.

Slagle, K., Zajac, R., Bruskotter, J., Wilson, R. & Prange, S. (2013). Building tolerance for bears: A communications experiment. J. Wildl. Manage., 77, 863–869.

Soroka, S.N. (2006). Good news and bad news: Asymmetric responses to economic information. J. Polit., 68, 372–385.

Sutherland, W.J., Pullin, A.S., Dolman, P.M. & Knight, T.M. (2004). The need for evidence-based conservation. TRENDS Ecol. Evol., 19, 305–308.

Trouwborst, A. (2010). Managing the carnivore comeback: International and EU species protection law and the return of lynx, wolf and bear to Western Europe. J. Environ. Law, 22, 347–372.

501 Westerman, D., Spence, P.R. & Van Der Heide, B. (2014). Social media as information
502 source: Recency of updates and credibility of information. J. Comput. Commun., 19,
503 171–183.

504 Young, J.C., Searle, K., Butler, A., Simmons, P., Watt, A.D. & Jordan, A. (2016a). The role
505 of trust in the resolution of conservation conflicts. Biol. Conserv., 195, 196–202.

506 Young, J.C., Thompson D.B.A., Moore, P., MacGugan, A., Watt, A. & Redpath, S.M.
507 (2016b). A conflict management tool for conservation agencies. J. Appl. Ecol., 53, 705–
508 711.

509 Zeller, R. & Carmines, E. (1980). Measurement in social sciences: the link between theory
510 and data. Cambridge University Press, Chelsea, United Kingdom.

511

512 **Table 1.** Description of the variables used as potential predictors of respondents' attitudes
513 towards wolves in Germany, which correspond to answers on knowledge (Section A),
514 sources of information (Section B), exposure and experience with wolves (Section C) and
515 socio-demographic factors (Section E) in the questionnaire (see Supporting Information,
516 Methods S1).

Predictor variables	**Description**
Knowledge score	**Numeric;** Aggregation of correct answers to 6 questions on "wolves in Germany": - Wolves are back since 10-20 years - There are 200-500 individuals wolves (Monitoring year 2015/2016) - 50 km or less accuracy in the distance between place of residence and nearest wolf pack - wolves recolonization is a natural process - wolves feed mainly on big game species - less than 20 persons killed since 1950
B1 – Feels well informed on wolves	**Numeric;** Likert scale from 1 to 5
B2 – Origin of knowledge	**Categorical;** Press or TV news (reference level); books & films; social networks; family & friends; NGO; zoo; regional wolf information office
B3 – Most frequent source of info	**Categorical;** Press or TV news (reference level); books & films; social networks; family & friends; NGO; zoo; regional wolf information office
B4 – Trust in the information sources	**Numeric;** Likert scale from 1 to 5
B5 – Frequency of information	**Numeric;** Count from 1=never to 6=once a day
C1 – Seen a wolf in captivity	**Binary;** 1=no; 2= yes
C2 – Seen a wolf outside Germany	**Binary;** 1=no; 2= yes
C3 – Seen a wolf within Germany	**Binary;** 1=no; 2= yes

C4 – Lost an animal	**Binary;** 1=no; 2= yes
C5 – Relative lost an animal	**Binary;** 1=no; 2= yes
Pop_sample – which population sample respondents belong to	**Binary;** 1= Germany; 2=wolf region
Dist_Wolf – distance to the nearest wolf territory	**Numeric;** Variable scaled (centred and standardized)
E1 – Age categories	**Numeric;** Count from 1=18-29 years old to 5=more than 60 years old
E2 – Gender	**Binary;** 1=male; 2=female
E3 – Highest level of education	**Numerical;** Count from 1=still in high school to 11=University
E4 – Time spent in nature	**Numerical;** Count from 1=never to 5=hours a day
E5 – Wolves have the right to live in Germany	**Numeric;** Likert scale from 1 to 5
E6 – Humans shape the environment to fit their needs	**Numeric;** Likert scale from 1 to 5
E7 – Important to protect nature	**Numeric;** Likert scale from 1 to 5
E8 – Hunter	**Binary;** 1=no; 2=yes
E9 – Livestock owner	**Binary;** 1=no; 2=yes
E10 – Dog owner	**Binary;** 1=no; 2=yes
BLAND_Name – Name of the Federal State	**Categorical;** 16 German Federal states
Pop_size – Local population size	**Numeric;** 1=less than 2.000 inhabitants; 2=2000-5000; 3=5000-20,000; 4=20,000-50,000; 5=50,000-100,000; 6=100,000-500,000;7=more than 500,000 inhabitants.

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Table 2. Results of a multiple linear regression of attitudes towards wolves in Germany against predictors associated with exposure and experience with wolves, knowledge about wolves, information sources and socio-demographic characteristics, after a stepwise model selection (model combines both German and wolf region population samples). Coeff = model estimate; se=standard error. Pop_sample is a factor with German population sample as a reference and wolf region population sample for comparison.

	Combined population samples (R^2-adj. = 0.31)		
Variable	coeff (se)	t-value	p-value
Pop_sample	-1.14 (0.25)	-4.47	< 0.001***
C5-lost animal	-1.59 (0.35)	-4.56	< 0.001***
Knowledge score	0.23 (0.07)	3.14	< 0.01**
B1-feel informed	0.15 (0.09)	1.80	0.07
B2-information source			
- Books & films	0.92 (0.25)	3.62	<0.001***
- Social networks	1.06 (0.40)	2.66	< 0.01**
B4-trust in information	0.25 (0.10)	2.55	0.01*
E1-Age	-0.38 (0.07)	-5.32	< 0.001***
E2-Gender	-0.98 (0.18)	-5.55	< 0.001***
E5-animal rights	1.42 (0.21)	6.79	< 0.001***
E6-exploit environment	-0.64 (0.08)	-7.86	< 0.001***
E7-importance of protecting	0.62 (0.18)	3.48	< 0.001***
E8-hunter	-1.72 (0.66)	-2.59	< 0.01**
E9-livestock owner	-0.46 (0.31)	-1.48	0.14
Pop_size	0.11 (0.06)	1.91	0.06

Table 3. Socio-demographic characteristics of respondents from the wolf region (n=176) and Germany (n=670) population samples. Age, Highest education level and Local population size are averages for each population sample; Gender, Hunter and Livestock owner are expressed as proportions of the population sample.

Socio-demographic characteristics	Germany	Wolf region
Age	51.4	55.6
Gender ratio - %Male / %Female	49.1 / 50.9	44.9 / 55.1
Highest education level	6.9	7.1
	Corresponds to “Abitur”, diploma after 13 years of education	Corresponds to “Abitur”, diploma after 13 years of education
Local population size	5.5	4.2
	Corresponds to 50.000 to 100.000 people	Corresponds to 20.000 to 50.000 people
Hunter (% of population)	2.2	0.0
Livestock owner (% of population)	7.5	15.3

Table 4. Results of two multiple linear regression models (for German population and wolf region population) of attitudes towards wolves in Germany against predictors associated with exposure and experience with wolves, knowledge about wolves, information sources, and socio-demographic characteristics, after stepwise model selections. Coeff = model estimate; se=standard error; X=variable not retained by the model selection procedure.

	Germany (R^2-adj. = 0.29)			Wolf region (R^2-adj. = 0.35)		
	coeff (se)	t-value	p-value	coeff (se)	t-value	p-value
Distance to wolves	X	X	X	-3.18 (2.28)	-1.39	0.17
C2-seen wolves out	0.52 (0.33)	1.59	0.11	X	X	X
C5-lost animal	-1.48 (0.50)	-2.97	< 0.01**	-1.34 (0.52)	-2.58	0.01*
Knowledge score	0.25 (0.08)	3.05	< 0.01**	X	X	X
B1-feel informed	0.19 (0.09)	2.19	0.03*	X	X	X
B2-information source						
- Books & films	0.66 (0.28)	2.34	0.02*	1.86 (0.60)	3.10	< 0.01**
- Wolf information centre	-	-	-	1.23 (0.53)	2.35	0.02*
B4-trust in information	X	X	X	0.97 (0.22)	4.39	< 0.001***
E1-Age	-0.43 (0.08)	-5.58	< 0.001***	X	X	X
E2-Gender	-0.79 (0.19)	-4.07	< 0.001***	-1.33 (0.42)	-3.20	< 0.01**
E3-Education	X	X	X	-0.23 (0.08)	-2.68	< 0.01**
E4-time in nature	-0.24 (0.13)	-1.80	0.07	X	X	X
E5-protect nature	1.43 (0.23)	6.31	< 0.001***	1.20 (0.51)	2.36	0.02*
E6-exploit environment	-0.62 (0.09)	-6.99	< 0.001***	-0.81 (0.20)	-4.07	< 0.001***
E7-importance of protecting nature	0.63 (0.19)	3.24	< 0.01**	X	X	X
E8-hunter	-1.74 (0.66)	-2.63	< 0.01**	X	X	X
E9-livestock owner	-0.65 (0.38)	-1.72	0.09	X	X	X
E10-dog owner	0.42 (0.23)	1.80	0.07	X	X	X
Pop_size	0.16 (0.08)	2.03	0.04*	X	X	X

FIGURES

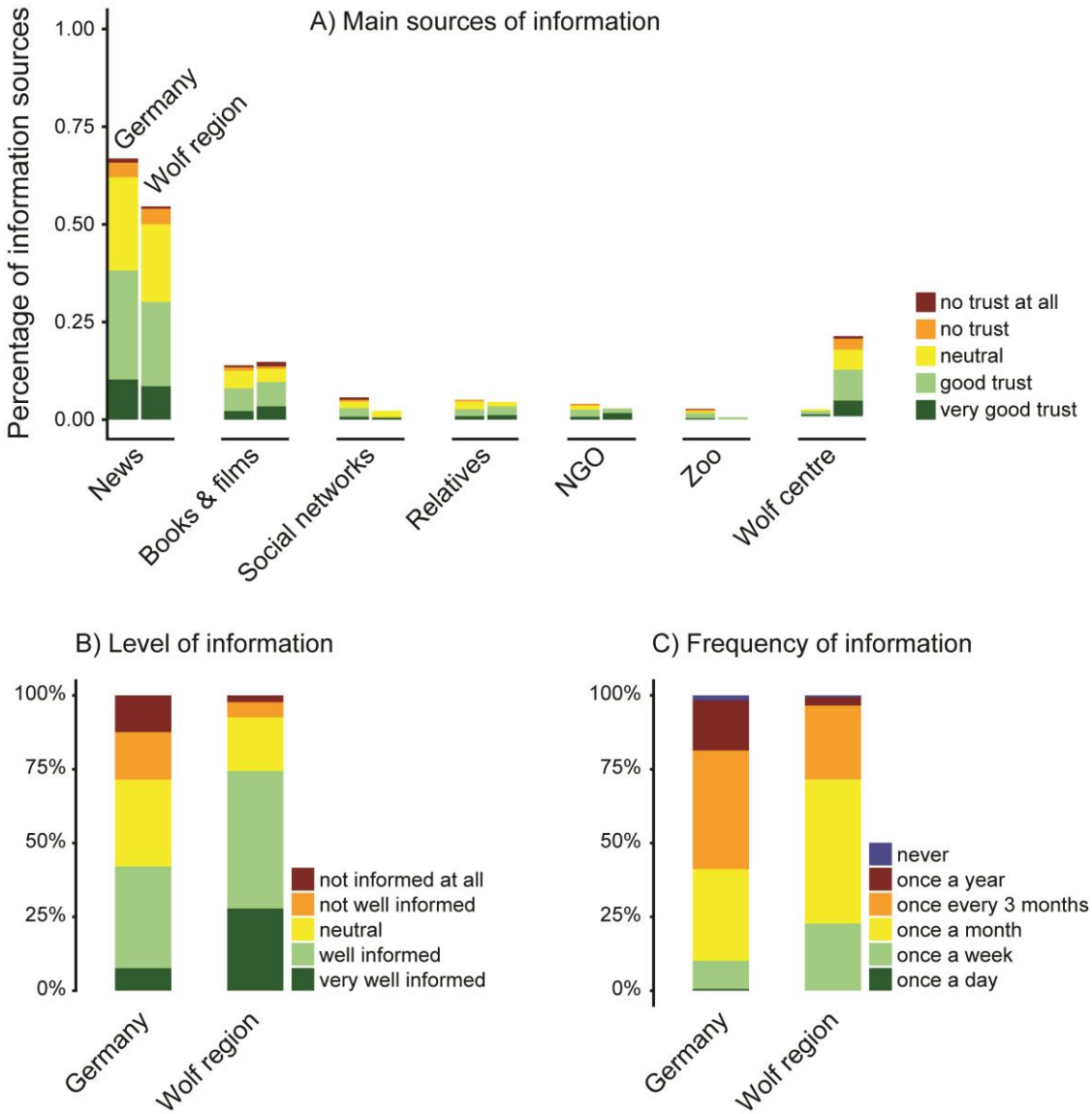

Figure 1. Differences between Germany and the wolf region population samples in a) their main sources of information on wolves and their trust in these sources, b) their self-reported level of information on wolves, and c) the frequency at which they receive information on wolves. We found significant differences in respondents' use and frequency of information between Germany and the wolf region (see Results).

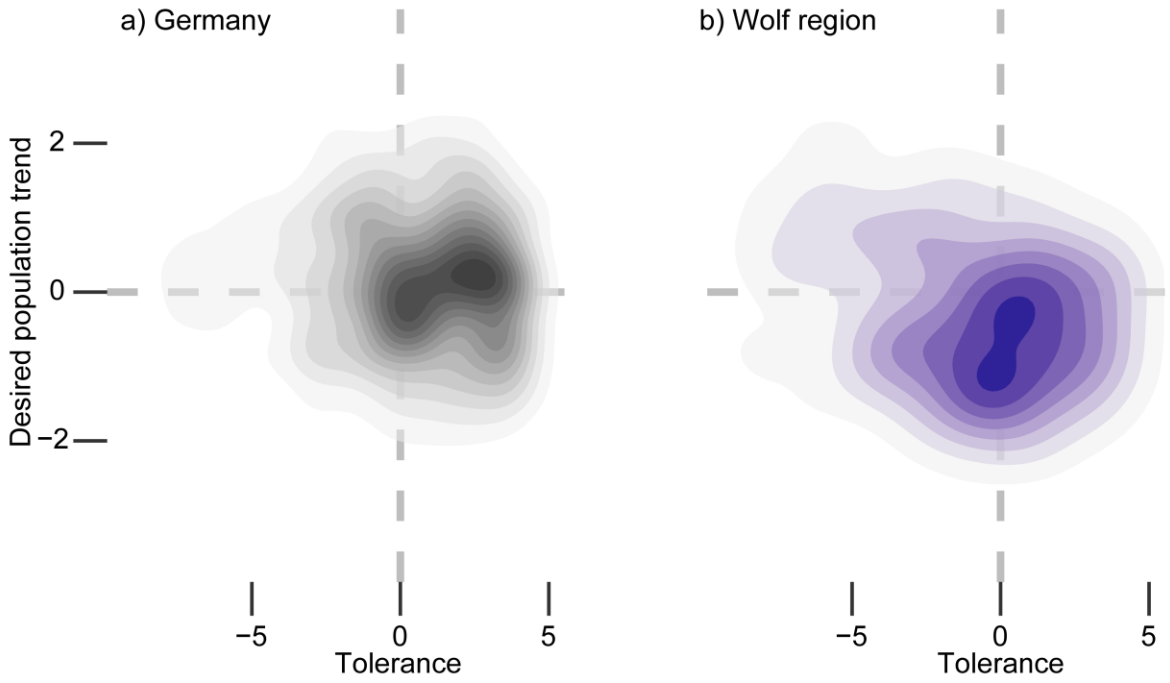

Figure 2. Differences in attitudes towards wolves between a) Germany and b) the wolf region population samples, as shown by Principal Component Analysis results. We display a 2-dimensional kernel density estimation with darker contour indicating higher density of respondents in each plot. X-axis represents a gradient of tolerance towards wolves in Germany with higher values reflecting higher tolerance (52.9% of the variation in answers related to attitudes). Y-axis represents respondents' opinions concerning their desired wolf population trend with positive values indicating a wish for more wolves in Germany (6.2% of the variation). Distributions along X-axis were unimodal (dip test, p = 0.88 in German sample, p = 0.97 in wolf region sample).

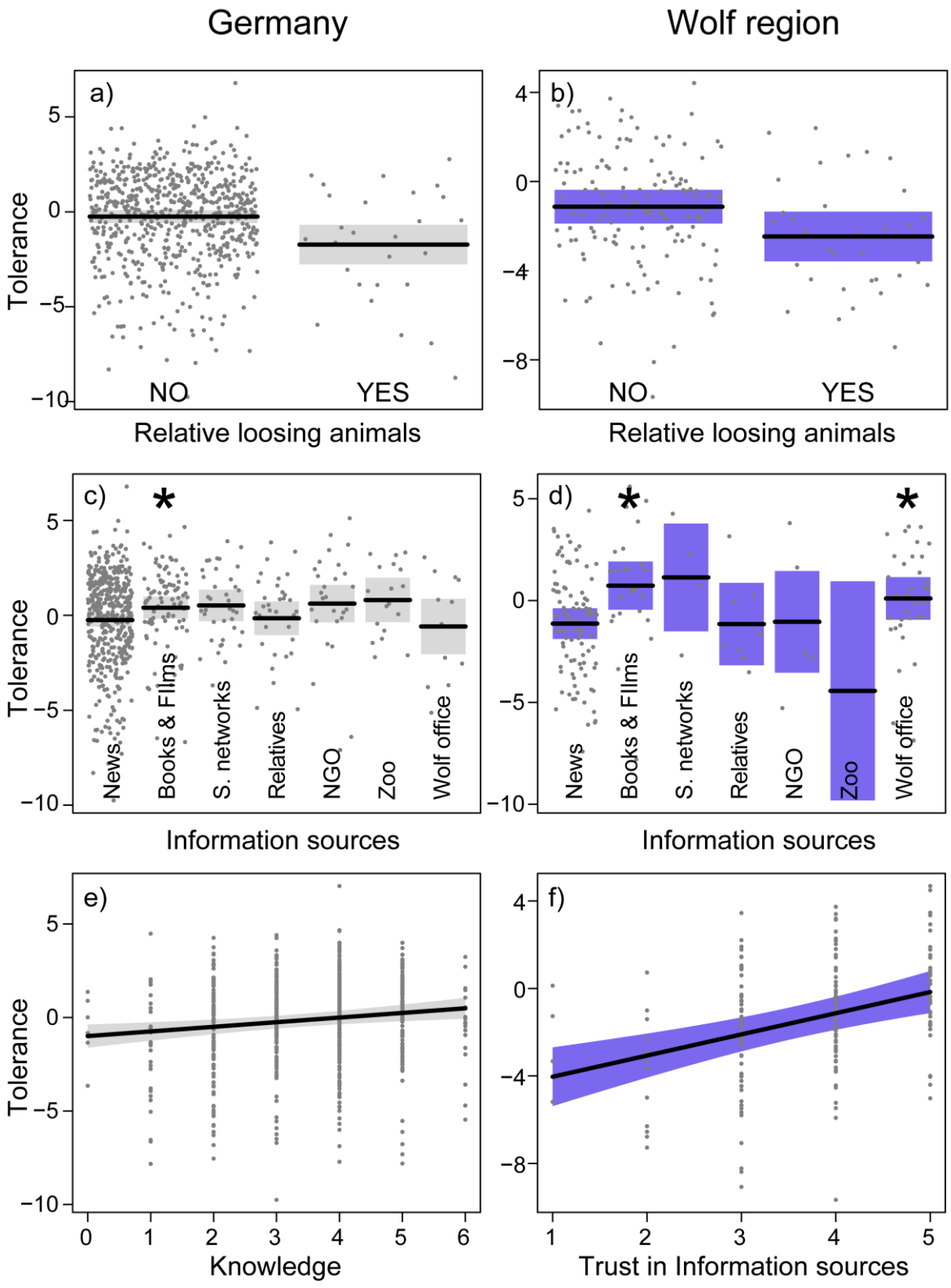

Figure 3. Significant effects of variables related to exposure (a-b), information sources (c-d), knowledge (e) and trust in information sources (f) on tolerance towards recolonizing wolves in Germany (left panels) and the wolf region (right panels). Graphs show partial residuals and mean effects with confidence intervals from multiple linear regressions.