Article
Jonny Löe and Eivin Röskaft

Large Carnivores and Human Safety: A Review

Attacks by large carnivores on humans can occasionally help to generate significant resistance to carnivore conservation efforts. We have reviewed research addressing concerns for human safety in large carnivore conservation, and have evaluated statements about the frequencies and causes of attacks based on our findings concerning *i)* existing data on the number of attacks by large carnivores in various parts of the world; *ii)* information systems documenting details of attacks; and *iii)* research that provides credible advice on what to do when encountering a large carnivore, to minimize the likelihood of being attacked. We conclude that little information exists for any of these criteria and what is available is often inadequate to determine the frequency of attacks, their causes and how to avoid them. We suggest that information systems, including database(s) on attacks and encounters, should be established for large carnivore conservation efforts, to supply information and to answer future requests for this information.

INTRODUCTION

Large carnivores are threatened throughout the world by habitat destruction, degradation and fragmentation, legal and illegal hunting, and depletion of wild prey populations (1–3). Even though many carnivore species are protected by international agreements (e.g. 4, 5) and national legislation such as the Endangered Species Act, the decline in carnivore populations continues (6). In some areas, the re-introduction of large carnivores to areas in which they have become extinct seems to have been successful (2). An important criterion for the success of large carnivore protection and re-introduction is to maintain a low level of conflict with humans (7). This can be difficult in multi-use landscapes inhabited by both people and large carnivores. Important tasks that conservation administrations face in large carnivore conservation are *i)* the establishment of satisfactory multi-use landscape management plans; *ii)* limiting livestock depredation; *iii)* analyzing predator-prey relationships to reveal to what extent carnivores and humans compete for game; *iv)* stopping illegal hunting; *v)* establishing information programs which aim to reduce fear and resistance to large carnivore conservation efforts; and *vi)* handling human safety concerns (8, 9).

Attacks by large carnivores that result in human injury or death may undermine conservation efforts by resulting in negative attitudes towards such efforts (10, 11) and more illegal hunting (12). A large carnivore that has attacked a human being in a predatory manner may attack again (13, 14). Local people have sometimes responded to such predatory attacks by 'hunting-campaigns', resulting in the killing of numerous innocent carnivore individuals (15, 16). Evidence suggests that some attacks can be avoided by separating humans and large carnivores, or by removing problem animals (13, 14). It has also been shown that human behavior during encounters with aggressively behaving carnivores can influence their outcome (13) and even prevent attacks (e.g. 13, 17). Minimizing the number of attacks and related influence on human attitudes to conservation efforts require clear monitoring of attack situations so that key factors or attack patterns can be recognized by conservation authorities. The aim of this paper is to review research addressing human safety concerns in large carnivore conservation and evaluate whether there is sufficient information to draw conclusions about the frequencies and causes of attacks. It also considers the benefit of acquiring high-quality information about attacks and discusses potential ways of monitoring attack situations.

DATA COLLECTION

In this review, a study of current scientific literature is combined with interviews of wildlife managers in areas having populations of large carnivores, researchers working on large carnivore behavior and ecology, park personnel working in areas where attacks by large carnivores occur, and researchers who have contributed other scientific information regarding attacks by large carnivores on people. At least 250 individuals were asked to inform us about information systems developed by institutions, which address human safety in large carnivore conservation. It is impossible to know exactly how many since the questionnaire was spread further by those who received it initially. Those responding to the questionnaire supplied information about *i)* attacks by carnivores on humans during the 20th century; *ii)* information systems handling human safety issues in large carnivore conservation; and *iii)* existing carnivore attack databases. Because injuries may not be recorded, in particular minor injuries occurring in remote areas (18), only data on human deaths caused by large carnivores were taken into account. We tried to restrict the data to attacks by wild, free-ranging carnivores, but this was often impossible to assess. All data collected on deaths were accepted, but the difficulties in assessing such deaths are discussed. Thirty-nine respondents knew of databases carrying information on carnivore attacks on humans, and eight of these have been used in this study, including the 'Abbreviated Shark Attack Questionnaire' prepared by the International Shark Attack File (19). More databases obviously exist, but several were designed to record other kinds of information and give no insight into the circumstances of attacks. Such databases were excluded from this review. Finally, some existing databases were unavailable. To evaluate statements about the frequencies and causes of attack, we base our conclusions on our findings concerning *i)* existing sources on the number of attacks by various species of large carnivores in different areas; *ii)* information systems documenting details of attacks; and *iii)* research that can give credible advice on what to do when encountering a large carnivore to minimize the likelihood of being attacked. The first criterion is important for making credible statements about the frequency of attacks and is necessary to estimate the probability of attacks in a specific area. The second is crucial when considering attacks in the past and is needed to carry out studies described in criterion.

Table 1. Reported numbers of people killed by large carnivores in the 20th century.

Species	Countries where attacks by large carnivores on humans during the 20th century are reported	Numbers of humans killed	References
Bears, Ursidae			
Black bear (*Ursus americanus*)	Canada, USA	37	13, 53, 62
Brown bear (*Ursus arctos*)	Canada, China, Japan, Yugoslavia, Kazakhstan, Kyrgyztan, Mongolia, Norway, Rumania, Russia, Sweden, USA	313	38
Polar bear (*Ursus maritimus*)	Canada, Norway (Svalbard), USA	12	53, 63, 64, I. Gjertz pers. comm., A.E. Derocher pers. comm.
Sloth bear (*Melursus ursinus*)	India	48	37
Dogs, Canidae			
Coyote (*Canis latrans*)	Canada, USA	1	49
Wolf (*Canis lupus*)	Afghanistan, Canada, China, Estonia, France, India, Iran, Italy[a], Latvia, Lithuania, Poland, Russia, Slovakia, Spain, USA	607[b]	23, 25, 65
Hyanids, Hyanidae			
Spotted hyena (*Crocuta crocuta*)	Uganda	4	21
Striped hyena (*Hyena hyena*)	India	2	59
Cats, Felidae			
Tiger (*Panthera tigris*)	Bangladesh, China, India, Indonesia, Malaysia, Myanmar, Nepal, Russia, Singapore, Thailand, Vietnam	12 599	1,11, 23, 24, 31, 66, 67, 68, 69, C. McDougal pers. comm., V. Flint pers. comm.
Leopard (*Panthera pardus*)	India, Nepal, South Africa, Uganda	840	10, 14, 21, 45, 46, 70
Lion (*Panthera leo*)	India, South Africa, Tanzania, Uganda, Zambia	552	21, 23, 71, 72
Puma (*Felis concolor*)	Chile, Canada, USA	18	43, 73, L. Fitzhugh pers. comm.

a) Linnell et al. (25) could not substantiate these deaths; rather they seemed to derive from a tale claimed by the local people of several villages to have occurred in their own village.
b) The majority of deaths are caused by rabies transmitted by wolves.
A few authors (15, 18, 22, 65) report more fatalities than mentioned here. Because of uncertainty of overlap with numbers given here, they are not used.

HUMAN SAFETY CONCERNS IN LARGE CARNIVORE CONSERVATION

Large carnivores are likely to have always posed a threat to human beings (20, 21) and will probably continue to do so as long as humans and carnivores exist in the same area (22). Some information on carnivore attacks has been shown to be speculative, exaggerated and anecdotal (e.g. 23). The British Government of India kept records on victims of wildlife attacks during the early 20th century (24). According to these records, thousands of people were killed by tigers *Panthera tigris* every decade, 7662 in 1902–1910 alone (24). Unfortunately, the statistics were discontinued after 1927. According to the High Commissioner for India, this was because the numbers were considered unreliable. Guggisberg (24) questioned how many of those recorded as wildlife victims were really homicide victims, human sacrifices or simply died of natural causes. Similar problems with the quality of data are likely in other records, such as those kept by the *Ugandan Game Department* from 1923 to 1994 (21). Wild, large carnivores have also recently been claimed to be responsible for human deaths which postmortem examination showed had other causes (25). Still, the numbers of humans killed by large carnivores given in Table 1 may be a gross underestimation of the real number of lethal attacks because information from many periods is not available.

Socioeconomic factors may influence variations found in the number of attacks (22). For example, most attacks in urban societies occur when people are engaged in outdoor activities, such as hiking in bear habitats (13), whereas most attacks in rural societies occur during everyday domestic activities (18, 26). The presence of a high rural population is often related to the economic structure of a country (27). High human density in areas inhabited by large carnivores makes encounters between carnivores and people more likely than when they are separated. Some Asian and African countries often have a high proportion of rural inhabitants (28) and Löe (22) found that more than 90% of the recorded attacks on humans by large carnivores between 1950 and 2000 occurred in Asia and Africa.

Efforts to understand the circumstances of attacks began relatively recently. Attacks on humans by tigers have been a subject of scientific interest for a few decades. Corbett's (14) observations of factors associated with tiger and leopard (*P. pardus*) attacks have high credibility. Hendrich (29) suggested that variations in reported tiger aggressiveness towards humans were related to environmental differences. He suggested that the high rate of attacks by the Bengal tiger (*P. t. tigris*) on humans in Sunderban compared to most other areas was due to lack of available fresh water, a hypothesis yet to be tested. Jackson (26) hypothesized that tigers in Sunderban attacked humans who entered their established territories in search of wood, honey or fish, thus causing them to defend their territories. This hypothesis does not explain why tigers are less aggressive in other areas where humans enter for the same reasons. For example in Ranghambhore, India, Thapar and Rathore (30) reported no such conflict, despite a high human population. The number of tiger attacks on humans may be higher outside suitable areas for tigers, where numerous humans are present but which contain little wild prey for tigers (26, 31). This can be created when tigers, which are known to be highly territorial (32), are compelled to move to a neighboring area when they can no longer protect their territory. Young tigers trying to find a territory for the first time may react likewise (14). Tigers

forced into inappropriate environments may find no other food items than livestock and humans, thus allowing the so-called man-eaters to develop (14). Guidelines for declaring tigers and leopards as man-eaters were drawn up by *Project Tiger* at the Cat Specialist Group Workshop held in Kanha, Nepal, in April 1984 (33). The actual guidelines are generally not strictly followed, but the practice of recognizing and eliminating man-eaters now follows essentially the same approach everywhere (P.K. Sen pers. comm.). At the International Symposium on Global Survival Strategies for Tigers held in Minneapolis in April 1986, H. Mishra, a member secretary of the King Mahendra Trust in Nepal, stressed the importance of finding solutions to tiger depredation in Nepal to ensure that both politicians and local people would commit themselves to tiger preservation (34). Tiger attacks on humans are addressed as an impact factor for tiger conservation in the *Status Survey and Conservation Action Plan for Cats* (1). However, few serious efforts are being made to alleviate problems arising from tiger attacks on humans. A notable exception is the *Community-based Conservation Programme* started by the *Sumatran Tiger Project* in the second half of the 1990s (35). Its aim was to thoroughly document the nature of the tiger-human conflict in Way Kambas National Park, Sumatra, to enable conservation authorities to resolve it using a comprehensive database rather than anecdotes and opinions (35). The program, which is a collaborative conservation effort between the Republic of Indonesia's Directorate General of Forest Protection and Nature Conservation, the Tiger Foundation (Canada) and the Sumatran Tiger Trust (UK), addresses various aspects of conserving tigers in the area and produces annual reports on progress made in reducing conflicts with tigers (36). No center for compiling all the information on tiger attacks on humans exists.

Attacks on humans by other species of large carnivore have also attracted scientific interest in recent decades. A huge amount of literature exists on bear *Ursidae* attacks (reviews in 25, 37–39). Herrero (13) analyzed brown bear (*Ursus arctos*) and American black bear (*U. americanus*) attacks in North America. He found that they make two generalized types of attack. Defensive attacks may occur when the bear is stressed and feels threatened, often as a result of suddenly encountering a person. Offensive attacks occur when a bear wants something such as food or space, or in extreme cases a person as prey. Herrero (13) examined benign human behavior when encountering a bear that is behaving aggressively. He concluded that attacks depend on extenuating circumstances and that information on attacks must be analyzed with care. He suggested that a human confronting a bear could contribute significantly to reducing the chance of an attack, or lessen its violence. He also recognized that more bear attacks were reported in some areas than in others. Where bears had learned to seek food in rubbish dumps close to human dwellings, or human food at campsites, they may become unafraid of humans and even attracted to them, relating human smell or activity with food. That bear attacks have an impact on bear conservation is reflected in the status survey and conservation action plan for bears (3). Still, a center for gathering information on bear attacks on humans does not exist. Bear attacks on humans have been addressed in other ways. Besides studies of attacks, local programs addressing human safety concerns have been initiated in the USA and Canada. One example is the *British Columbia's Bear Smart Community Program* (40) which was designed by the Ministry of Water, Land and Air Protection in partnership with the British Columbia Conservation Foundation and the Union of British Columbia Municipalities to address the causes of bear/human conflicts, human safety concerns being an integral part of the program.

More than half a century ago, Young and Goldman (41) reviewed tales of wolf (*Canis lupus*) attacks in North America, but no broad, in-depth study of wolf attacks has occurred until recently. The Ministry of the Environment, Norway, financed a review of wolf attacks with the aim of reducing the fear of people and to make recommendations to management authorities to reduce the risk of attacks (25). The authors found that *i)* the vast majority of cases were attributed to rabies; *ii)* there was an increased risk of attacks when wolves had lost their fear of humans; *iii)* provocation was often associated with non-rabid wolf attacks; and *iv)* highly modified environments with respect to low prey abundance and a high human population were associated with many wolf attacks, both in the past in Europe and more recently in India. Linnell et al. also gave advice on what to do if a wolf appears and acts unafraid or aggressive (25). However, there has been no thorough study of beneficial behavior in the event of a sudden encounter with an aggressively behaving wolf.

Literature dealing with puma (*Felis concolor*) attacks on humans has been summarized by Conrad (17), Beier (42), and Etling (43). In addition, informative and popular books on the topic have been published (e.g. 44). Beier (42) found that only incomplete historical records of puma attacks were available to assist in suggesting ways to minimize the risk of attack. He was nevertheless able to make some suggestions. For example, he found that aggressive response seemed to be effective in deterring attacks, but could find no evidence that it was helpful to avoid eye contact when confronted with an aggressive puma. K. Aune (pers. comm.), at the Montana Department of Fish, Wildlife and Parks, tells us that there are still no uniform procedures on how to file information on puma attacks.

Several authors have studied the magnitude of leopard attacks on people (e.g. 10, 21, 22, 45, 46). Mohan (10) related his study in Chamoli Garhwal, Uttar Pradesh, India to the task of spreading conservation sentiments to the local people. He argued that it was necessary to reduce the conflict considerably in his study area if local people should commit themselves to preserve leopards. There is a need for further research to find solutions to human-leopard conflicts in Uttar Pradesh, India (10, 45). While Forest Department staff in India monitor numbers of humans killed by leopards and other large wildlife, such activities were found to be scarce in African countries. No uniform rules of monitoring information related to leopard attacks on humans exist.

Lion (*Panthera leo*) attacks on humans are found to be numerous compared with attacks by most other carnivores (22). While the scale of the problem concerning the African lion is unclear due to unavailable records, attacks on humans by the Asiatic lion (*P. l. persica*) in the Gir Forest in Gujarat, India, are monitored by the Gujarat Forest Department. Numbers of attacks have varied from year to year, but peaked during a severe drought in 1987–1991 (12). The cause of this peak is unclear, however, Paulson (12) stressed the importance of immediate response on lion-human conflicts in Gir if lion conservation is to succeed (12). No study exploring the effects of benign human behavior when confronting a lion exists.

Researchers have often failed to base their conclusions on complete data sets when analyzing the number and causes of attacks (25, 38). Although there are exceptions (e.g. 13), data relating to attacks often go unrecorded or exist only in the form of magazine articles or media reports. Callaham (18) concluded that animal bites on humans are not subject to verification. On the other hand, as exemplified by our review of existing databases on attacks (Table 2), conservation administrations,

NGOs, and others have kept and still keep extensive information on large carnivore attacks on humans in some areas.

Table 2. Comparison of information provided by eight files containing information on encounters with, and attacks on, humans by large carnivores*.

Information recorded	1	2	3	4	5	6	7	8
Species encountered	X	X	X	X	X	X	X	X
Numbers		X	X		X			X
Number of cubs		X	X					X
Type of interaction	X	X	X	X	X	X	X	X
Outcome of interaction	X	X	X	X	X	X	X	X
Location	X	X	X	X	X	X		X
Time and date	X	X	X	X (date)	X	X	X(date)	X
Numbers of humans involved	X	X	X	X		X		X
Sex and age of humans involved	X (victim)	X			X (victim)			X (victim's age)
Description of what happened	X	X	X	X	X	X	X	X
Human activity before interaction	X	X	X	X				X
Human behavior during interaction		X	X					
Animal's behavior	X	X	X					X
Witnesses interviewed	X	X	X	X	X	X	X	X
Attack site studied	X	X	X	X	X	X	X	X
Published statistics	X	X	X	X	X	X	X	X

1) International Shark Attack File, Abbreviated Shark Attack Questionnaire. The questionnaire can be downloaded from the web pages of the International Shark Attack File, Florida Museum of Natural History, University of Florida, Gainesville, FL 32611 USA: http://www.flmnh.ufl.edu/fish/Sharks/ISAF/ISAF.htm.
2) Bear-human aggressive encounter database. Provided by Professor Steve Herrero, Faculty of Environmental Design, University of Calgary, Canada.
3) The Swedish Pest Center Report on encounters with large carnivores. This scheme can be downloaded from the web pages of the Swedish Pest Center, Grimsö Research Station, SE-730 91 Riddarhyttan, Sweden: http://www.viltskadecenter.com/
4) Attacks by tigers and estuarine crocodiles Crocodilus porosus in the Sunderban Biosphere Reserve. Provided by Pranabes Sanyal, Assistant Chief Conservator of Forests, West Bengal.
5) Information filed on attacks at the Forest Departments of Latehar, Hazaribagh and Koderma, Jharkhand State, India. Provided by Dr. Kishan Singh Rajpurohit at the Wildlife Institute of India.
6) California Wildlife Incident Report Form. Provided by Doug Updike at the California Department of Fish and Game. An incident command system is obligatory when human safety is threatened and in the event of injury or death.
7) State of Nevada, Department of Conservation and Natural Resources, Division of Wildlife – Report of Human Interaction with Mountain Lion. Provided by Russell Woolstenhulme, Nevada Division of Wildlife.
8) The Wyoming Trophy Game Incident Report and the Wyoming Wildlife/Human Interaction Form. The Wyoming Game and Fish Department administers the Trophy Game Incident Report and the Wyoming Wildlife/Human Interaction Form. Reg Rothwell, director of biological services for the Wyoming Game and Fish Department, provided us with this information.

*The preciseness of information filed varied greatly between cells in most rows. This made it hard to prepare even this simple Table. Please notify the authors if you have knowledge pertinent to the content of this Table. This can be done by sending an e-mail to: Jonny Löe: jonnyloe@online.no

BENEFITS OF ACQUIRING AND MAINTAINING RELIABLE DATA ON ENCOUNTERS AND ATTACKS

Reliable data on carnivore attacks enable scientists and managers to disperse information about the frequencies and circumstances of attacks, and sound conservation strategies can be devised to mitigate problems. Stakeholders like government agencies, park administrations, conservationists, researchers and the media sometimes cite information on numbers of attacks, temporal and spatial patterns, and circumstances and causes. However, while such information may at times reflect scientific data, inconsistencies still frequently occur. An example is the following: *"Since 1970, across the United States, there has been an average of 14 mountain lion attacks per year on people …"* (Environmental News Service, 5 Aug. 2002). The source of the article includes attacks where neither human death nor injury was the outcome (P. Beier, pers. comm.). However, this is not mentioned in the article. Beier's (42) data covered every state in Canada and the USA from 1890 to 1990 and he could only substantiate that 48 people had been injured and 10 killed in such encounters in this period. The issue of how to give the public substantiated information regarding human safety concerns in large carnivore conservation has become increasingly recognized and is exemplified by the *British Columbia Bear Smart Community Programme* (40) and the wildlife protocols of the Nevada Department for the Conservation of Natural Resources, Division of Wildlife (MLP1-Mountain Lion Conflict 1995). Both strategies have implemented procedures to identify conflicts and determine ways of responding to them, including recording information related to each conflict. To be able to learn something from carnivore attacks on humans, the information system implemented should ensure true, consistent and useful information about attacks. Yet, there exist major differences in systems dealing with information on attacks, especially regarding what information should be recorded (Table 2).

The number of attacks can be regarded as an environmental variable at local, regional and global scales (22). Several reasons for high attack rates have been recognized, including *i)* high encounter rates (16, 47); *ii)* failure to remove problem animals (14); *iii)* rabies (25, 48); and *iv)* reduced fear and increased aggressiveness due to feeding (13, 49). While these as well as other causes (22) seem important when explaining variations in attacks throughout the world, much knowledge remains only in the minds of conservationists, forest department staff and other people dealing with attacks. More complete data on attacks and the circumstances surrounding them are badly needed to help researchers evaluate the factors behind such attacks and to distribute information to the general public.

Data on how people have reacted during encounters can lead to guidelines on how to behave in an unexpected encounter with a carnivore. Such data could be used to prepare information on how to avoid an attack or reduce injury during an attack (13, 17, 42). Banff National Park in Canada provides advice on the Internet regarding pumas, bears, and other wildlife (50), and Parks Canada has prepared a guide on safety when travelling in bear habitats (51). Herrero (13) pointed out that detailed information and analyses of available data are urgently required to be able to give advice on how to behave to avoid attacks in an encounter with a bear, similar to that which ISAF started in 1958 (52) to avoid attacks by sharks. To be able to give such advice, data on the circumstances leading up to, and the behavior during, actual attacks need to be compared with data on aggressive encounters that did not result in an attack (13).

Information relating to attacks may provide biological insight. Many carnivores which threaten or attack humans are killed (e.g. 53, 54) and become a source for biometrics and age and health data. DNA samples from hair and tissue can yield insight into the genetic ecology of species (55) and, above all, the traits of individuals that become 'problem animals'. Scientists can gather data on the circumstances leading to encounters by posing standardized questions to people who have been in close contact with aggressive carnivores (56).

FILING INFORMATION ON ENCOUNTERS AND ATTACKS

It is necessary to agree on the specific information needed about attack situations. It is also important to establish clearly stated objectives in gathering data. The differences in the databases on attacks which we have learnt of (Table 2) result from disagreement regarding what information is necessary, and specific variables are often treated differently. For example, five databases contain information on human behavior during an encounter (Table 2). *Nevada's Report Form on Interactions with Mountain Lions* and the *Californian Wildlife Incident Report Form* record narrative, descriptive information. In the *Swedish Pest Center Report on Encounters with Large Carnivores*, 12 kinds of exhibited actions can be reported in addition to an open field where other behavior can be described. Herrero (13) categorizes information in his *Bear-human Aggressive Encounter Database* quite differently from that done by the Swedish Pest Center. Categorizing information makes comparison easy, but descriptions may still provide valuable insight. Information on encounters that do not lead to injury is important for comparison (13). Once agreement is reached on what information should be gathered, a system for effectively recording and analyzing it should be implemented. This task could be performed by existing wildlife agencies, but as these vary greatly in their organizational structure, the task is global in character and attacks are rare, perhaps a completely new system administered by a multinational NGO should be devised with the support of agencies reacting to carnivore attacks on humans. The system should provide relevant information to all interested parties.

DISCUSSION

Sources detailing the number of carnivore attacks on humans have proved to be few, often fragmentary and difficult to find. Most respondents said they had no knowledge of databases dealing with attacks. We found no two files of information on carnivore encounters or attacks on people that were similar (Table 2). This suggests that no formal information system analysis has been performed on how such data should be handled in general (57). The poor availability of information to fulfil our criteria *i* and *ii* has made studies of the kind mentioned in criterion *iii* difficult.

A number of problems arise when information relating to carnivore attacks on humans is being gathered. For instance, there may be a lack of resources to prepare filing systems. Personnel are needed to record information, interview victims and witnesses, and study attack sites in each case. Agency administrations must provide funds and personnel for such work. Obtaining appropriately trained personnel to follow up attacks may also be a problem (10), as will be the ability to obtain correct information from witnesses, who are not always objective or unbiased observers of the event (e.g. 25). Individual reactions to an encounter with a large carnivore depend upon experience with the animal in question (J.E. Swenson pers. comm.) and may also be related to other factors (9), thus biasing information. This is one reason why uniform ways of questioning witnesses and investigating attack sites are important. Some jurisdictional authorities in India pay compensation to the family of a person killed by an Indian elephant (*Elaphus maximus*), a leopard or a tiger (10, 58, 59). The demand for evidence and the slow bureaucratic handling of compensation claims sometimes result in local people neglecting to report attacks (K.S. Rajpurohit pers. comm.). In the Sunderban region, some attacks are unlikely to be reported because they occur in areas where people are not allowed to enter (P. Jackson pers. comm.). However, compensation gives an incentive to report information, and may even result in false claims (16, 24). Linnell and colleagues (25) give several examples of sources of error in information provided through historical records of attacks, including recording errors, exaggerations and translation problems. These and other problems in obtaining 'true' information about attacks are well known to those dealing with these issues and undermine the efforts of researchers to increase knowledge about attacks. An important step in implementing an information system for encounters will be to prepare guidelines that ensure control with these problems. A. Morgan (pers. comm.) informed us that the same biases apply when gathering information about shark attacks, but that experience in working with information on attacks and a file allowing uncertain information to be filed as 'no entries can be made', minimize the problem.

It seems clear that the number of attacks can be reduced, but much information on human safety issues is still speculative. In areas where carnivore populations are increasing, their range will expand, and attacks on livestock, pets, and human beings are likely to increase, leading to more requests for better statistical information. Underwater organisms cause only 5% of lethal diving accidents, and sharks are responsible for just a few of these (60), killing three people in 2002 (61). Despite this low level of conflict, ISAF has gathered worldwide information on shark attacks since the mid-1500s, and its establishment in 1958 has resulted in new and better information on how to avoid shark attacks. Our review shows that, worldwide, large carnivores have killed at least 150 people a year on average throughout the 20th century. In expectation of a similar efficiency in extracting knowledge of large carnivore attacks on humans as for shark attacks, an effort for compiling attack data is justified.

CONCLUSIONS

The true number of carnivore attacks is unknown and only speculative estimates can be made. Statistical information regarding avoidance of attacks is even scarcer. Two general solutions exist for reducing the number of carnivore attacks on humans. The first is to eliminate encounters between humans and large carnivores. The second is to behave in such a way that an encounter does not develop into an attack. Management strategies should place emphasis on avoiding encounters, because this is by far the most effective solution. This includes protecting areas where large carnivores can live undisturbed by human activities, effective removal of problem animals, and providing the public with information on how to behave in the presence of large carnivores. However, the conservation and protection of large carnivores like tigers, leopards and wolves frequently has to take place in multi-use areas populated by people. In these areas, the total number of encounters is likely to increase. Consequently, the importance of providing knowledge on how to behave to minimize the risk of attack in the event of a sudden encounter is increasing. We conclude that present knowledge often is unsatisfactory to draw conclusions about the occurrence and cause of attacks. We suggest that formal information systems that include database(s) covering attacks and encounters should be implemented in large carnivore conservation, to be able to respond to future requests for information. Establishing a central organization to gather and disperse all information on large carnivore attacks might be an effective way of achieving this.

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Jonny Löe, MSc in bioresources in planning and management from the Norwegian University of Science and Technology (NTNU), Trondheim, Norway. He has over the last few years studied information about carnivore attacks on humans. He is currently a teacher at Gjettum Lower Secondary School, Baerum, Norway. His address: Sogneprest Münther Kaas vei 55, N-1346 Gjettum, Norway.
jonnyloe@online.no

Eivin Röskaft is professor of evolutionary biology at the Norwegian University of Science and Technology (NTNU). He has studied birds on most continents, but over the last few years become more interested in conservation biology related to behavioral ecology, using both mammals and humans as models. Röskaft has been Director of the Centre for Environment and Development at NTNU as well as Director of the Norwegian Institute of Nature Research (NINA). Presently he is Head of the Department of Biology, NTNU. His address: Department of Biology, Norwegian University of Science and Technology, N-7491 Trondheim, Norway.
roskaft@nt.ntnu.no