CHAPTER

21

Animals as Ethnozooindicators of Weather and Climate

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INTRODUCTION

Many elements of numerous ethnic worldviews are rooted in a holistic foundation that connects land, air, and water; earth and sky; plants and animals; and people and spirit (Deloria and Wildcat, 2001; Wildcat, 2009). This perspective recognizes earth as a social–biophysical system in which all things are linked (Levin, 1999); so it is not surprising that many human cultures exert important feedback to the global ecosystem (ACIA, 2005; IPCC, 2007). Human communities that rely directly upon natural resources for subsistence usually possess a detailed knowledge of their local biota and its implicit environmental cycles (Nishida et al., 2006b,c). Knowledge resulting from interactions with a local environment is acquired through experience and observation. Such knowledge has been referred to by several different names in the literature, but for this chapter we have adopted the term local ecological knowledge (LEK).

Since time immemorial, human beings have been adapting to environmental conditions in their struggle for survival (Ayal1 et al., 2015; Ziervogel and Opere, 2010). Through observations of biotic indicators that forecast future weather conditions, many cultures throughout the world have developed refined local knowledge of when, where, and how animals, plants, algae, and fungi could be best used for their multiple needs (Alves et al., 2016; Alves et al., 2015; Barboza et al., 2016). Behavioral, physiological, and reproductive characteristics of many animal species are used by people as natural signs for predicting weather. The extent of LEK regarding animals as climate indicators reflects millennia of experiences, and has become culturally conserved and passed on from generation to generation (Blukis Onat, 2002; Huntington et al., 2005). This knowledge has been vital for human beings because, in combination with other stressors, climate change may affect societal relationships regarding water and food, such as access, availability, harvest, storage, processing, and the traditional use of these resources (Colombi, 2009; Jones et al., 2008).

Predicting climate and weather using animals has been part of numerous human cultures since time immemorial, and these relationships have persisted through generations

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until today. The number of examples of animal behavior useful to human communities for predicting the weather is vast (Krupnik and Jolly, 2002; Voggesser et al., 2013). Indeed, numerous practical activities (including farming and hunting–gathering) are, to some extent, determined and circumscribed by meteorological events. For example, plant, animal, and human body conditions are used in Zimbabwe for forecasting the weather (Joshua et al., 2012; Shoko, 2012). In Nigeria and Kenya, native tribes make direct observations and interpretations of animal behaviors to gain insight into future weather conditions (Shukurat et al., 2012; Speranza et al., 2010; Ziervogel and Opere, 2010). Comparable practices are evident among ritual specialist elders in Burkina Faso and Swaziland, who also conjecture future climate forecasts based on physical indications from plants and animals (Roncoli et al., 2001). In South Africa, inhabitants rely on birds, toads, and white ants to forecast the summer season and the onset of rains (Merchant et al., 1987; Olbrich and King, 2003), while in northeastern Tanzania they look at behavioral patterns of birds and mammals (Prendergast et al., 1999). According to Selma and Fuentes (2015), in the municipality of Retirolândia, Bahia, Brazil, insects, birds, amphibians, and arachnids are considered indicators that can be used to predict changes in the weather through their behavior.

These human/animal relationships for predicting weather shape the core elements of fauna conservation and embody an emerging field of discourse about human LEK worldwide (Alves et al., 2016; Ayal et al., 2015). Information on this subject is often diluted in works of various academic fields including anthropology, geography, history, and ethnobiology, while research that deals specifically with this subject is rather scarce. In this chapter we have sought to assemble all the existing information on, and provide a brief overview of, the main forms of interactions between people and animals in the context of forecasting the weather and climate. We propose the term "climate ethnozooindicators" to designate animals used by humans as indicators of future weather and climate.

Natural Weather Forecasting: A Brief History

Observations of their immediate natural environment provided early humans the first signs for forecasting weather. Personal observations of the phenology of certain plants and/or the behaviors of certain animals have been among the most commonly used predictors of climatic events since prehistoric times.

Ancient written documents reveal that humankind has long had an awareness and understanding of ecological interactions between biotic and abiotic factors. For example, in his *Natural History Encyclopedia*, Gaius Plinius Secundus (AD 23–August 25, AD 79), a natural philosopher, provided detailed material relating astronomical phenomena to weather, and he did not discount the effects of celestial bodies and climate on terrestrial life. He recorded that the influence of the moon causes the shells of oysters, cockles, and all shellfish to grow bulkier, and then again smaller. Moreover, he held that the phases of the moon have an effect on the tissues of the shrew mouse and the smallest animal, the ant, since they are sensitive to the influence of the planet's weather and of the new moon (Pliny Natural History, BOOK II. VI. 32–36). Ethnobiological studies reinforce these earlier findings (Alves et al., 2005; Nishida et al., 2006a,b,c). Nishida et al. (2006c), for example, recorded that mollusk gatherers of northeastern Brazil recognize that mollusk meat production increases during spring tide and decreases during neap tide, which they confirmed experimentally by finding the condition index to increase during spring tide and to decrease during neap tide. Other examples of weather indicators and their use were recorded by Claudius Aelianus, a sophist of the first third of the 3rd century, in

his extraordinary stories and anecdotes about animals in his work "On the Characteristics of Animals" (Taub, 2003). Some of these narratives report the abilities of different animals, including birds, to predict weather. Aelianus quotes some of his sources, highlighting Aristotle and giving him credit regarding the observation that "cranes flying in to land from the sea indicate to the intelligent man that a violent storm is threatening" and also "the Libyans and goats also give clear signs of impending rain" (Taub, 2003).

Moreover, the usage of myths and legends to elucidate this set of phenomena and the reliance on signs and omens to predict the weather are an important part of the fabric of many cultures including several that are ancient and which link astronomical events to animal behavior. For example, during medieval times in Europe many societies believed that thunderstorms were evil spirits, and so people often laid down on beds made of feathers and kept away from wet dogs and horses (Dennis and Wolff, 2013). In old German mythologies, it was commonly believed that winter was caused by an ancient spirit called Mother Frost, who would shake geese feathers from her bed that fell to earth as snow (Taub, 2003). Many of the Zulu warriors of ancient southeast Africa thought of rainbow as a serpent that drank from lakes on the ground and, according to the legend, the serpent would inhabit whatever lake it was drinking from and would devour anyone who happened to be bathing therein (Dennis and Wolff, 2013).

The earliest Indians of Canada believed that wind was formed by the flapping wings of an eagle, and that the harder its wings flapped, the stronger and more abundant the wind was. If there was too much wind the tribe's eldest climbed to the top of a mountain to tie the wings of the wind eagle; however, when the weather became too hot the elder had to climb again to cut the eagle's bond (Dennis and Wolff, 2013). The ancestors of modern Cherokee Indians of North America believed that spiders spun their web in the shape of the circularly rayed sun because the grandmother spider god stole a piece of the sun from a greedy band of people and hoarded its light on the other side of the world, thus producing the numerous changes in the weather throughout the year (Taub, 2003). Another lore from early North America comes from the Cree Indians, who believed that in the beginning of the world animals could talk and had the power of day and night. Daytime animals used all their power to keep the sun in the sky, while nighttime animals forced darkness to fall; each group arguing and bringing different seasons to the earth (Taub, 2003).

In Rome, ancient folk tales describe a faith in Sirius, the dog star, which caused very hot temperatures in July and August because it was the brightest summer star; from this belief came the expression "dogs day of summer" (Taub, 2003). In Baltic and Slavic mythology, the "fiery rooster," which is a sort of Slavic phoenix, was considered the thunder god for Pērkons, Perun. Also, black roosters were sacrificed to both the Slavic Perun and the Baltic Pērkons people, especially during droughts (Downden, 2000). Placing a rooster on top of a weather vane was supposed to protect a house from thunder (Taub, 2003). Interestingly, there is a belief in Serbia that the devil runs away from Christian cross, but he is even more fearful of roosters during the thunder. So it is possible that a rooster was placed on houses' roofs to also ward off evil spirits (Dennis and Wolff, 2013). About 100 years later, Pope Leo IV placed a rooster weather vane on the old St. Peter's Basilica, and Pope Nicholas the first did in fact order that all churches display the rooster on their dome or steeple (Downden, 2000). Currently, there are roosters on top of many churches in Europe.

The Use of Local Ecological Knowledge in Forecasting

All living things interact with the global ecosystem—the combination of land, atmosphere, and oceans—which includes our environment

(National Research Council, 2010). Thus, as part of the global ecosystem, humans are susceptible to its natural variation including that of climate, which is one of the most important variables of an ecosystem. Therefore, it is not surprising that for millennia humans have tried to forecast the weather, and in doing so they have looked for indicators or signs, both among biotic and abiotic resources. Flora, fauna, astrological constellations, lunar cycles, and winds are among the various indicators that have been used by humans to forecast seasonal climate (Alves and Nishida, 2002; Araujo et al., 2005; Bezerra et al., 2012, 2013; Gilles et al., 2013; Speranza et al., 2010). The observation and interpretation of these indicators certainly represents the oldest form of predicting the climate and weather, and which is still used to this day by local communities that continue to depend on "own knowledge of ecological systems for perceiving the environment and dealing with natural adversities." Currently, modern meteorological forecasting is performed by collecting instrumental data and analyzing parameters such as sea surface temperatures, wind direction and speed, temperature, humidity, and atmospheric pressure. Therefore, as pointed out by Ziervogel and Opere (2010), there are two main types of seasonal climate forecasts: meteorological climate forecasts and LEK-based climate forecasts.

Such forms of forecasting coexist in many regions of the world, demonstrating that they are not mutually exclusive and may even complement one another. This perspective is defended by some authors (Enock, 2013; Shumba, 1999), who support the integration of these two forms of forecasting, emphasizing that LEK can be significantly valuable and boost forecasting accuracy and reliability if it is systematically researched, documented, and subsequently integrated with conventional forecasting systems. As Tekwa and Belel (2009) highlight, the idea of integrating the know-how of contemporary science with insight from LEK for more rigorous weather forecasting is welcomed, since weather information is imperative to pastoral and agricultural decisions concerning planting crops, fertilizing, stocking, and rain-fed farm management (Ayal et al., 2015; Doherty et al., 2009; Field, 2005; Oba, 1997; Tekwa and Belel, 2009).

According to Stigter (2010) and Zuma-Netshiukhwi et al. (2013), local experiences with weather and climate include meticulous observations at different scales in time and space, and are useful as a complement to instrumental climatic data. Therefore, as a consequence of the decreasing popularity of traditional forecasting, some endemic species that were once used for weather forecasting are lost (Kipkorir et al., 2010; Roncoli et al., 2002). Furthermore, the development of modern education and monotheistic religions has also contributed to the decline in the view of TEK as being reasonable (Ayal et al., 2015; Joshua et al., 2012). In many places around the world, the unreliable and precarious subsistence of traditional weather and climate forecasting skills is further destabilized by poverty, famine, and continuous drought, as well as limited understanding of transmission mechanisms and insufficient research (Ayal et al., 2015; Chang'a et al., 2010; Chengula and Nyambo, 2016; Makwara, 2013; Nakashima et al., 2012; Shoko, 2012; Speranza et al., 2010). Thus far, contemporary science has not come up with a categorical position for, or contrary to, the information provided by traditional LEK for weather forecasting, even though some consider that modern science may gain valuable insights from LEK (Ayal et al., 2015; Mundy and Compton, 1991).

Local methods for forecasting weather and climatic events have been studied mainly within the context of ethnometeorology and ethnoclimatology (Cabrera et al., 2001; Lammel et al., 2008; Orlove et al., 2002; Sánchez-Cortés and Chavero, 2011). Understanding forecasting with LEK is interesting in its own right and is a way to preserve cultural traditions, but it can also help present-day providers of scientific weather information better communicate their findings

to particular sectors of the public and thus lead to complementary exchanges of ideas (Peppler, 2008). Orlove et al. (2002), for example, uncovered a scientific basis (absence or presence of El Niño-produced sub-visual cirrus clouds) of the successful forecasts of coming rains by potato farmers in the Andes of Peru and Bolivia. Knowledge of nature may also have contemporary relevance in coping with, and adapting to, environmental extremes such as drought or climate change (e.g., Suzuki and Knudtson, 1992).

Animals are one of the most popular climate indicators. To guide their climate predictions, people observe behavioral, physiological, and reproductive aspects of these organisms. As a consequence, numerous animal species are used as climatic indicators throughout the world, which is the subject of discussion in the next section.

Ethnozooindicators: Animals as Climate Indicators

For centuries human communities have relied on natural indicators, such as plants and animals, for weather forecasting and climate prediction (Chisadza et al., 2015). Farmers and agro-pastoralists are familiar with the relationships between weather, crop suitability, crop selection, planting schedule, and raising livestock in a particular season (Mercer et al., 2007; Sillitoe, 2007). When and what to do is determined by integrated weather/climatic indicators and interpreting them within the context of the environment.

In this scenario, animals play a very important role as climatic indicators, and many species are used in this manner by people in the most varied regions of the world. These traditional weather-related faunal indicators differ across the cultural experience of different communities and are used to guide local choices regarding farming or hunting-gathering activities (Chisadza et al., 2013; Garay-Barayazarra and Puri, 2011; Hart, 2007; Zuma-Netshiukhwi et al., 2013).

Our review has revealed that at least 201 animal species of 48 orders and 10 classes are used in traditional climatic and weather forecasting worldwide. The taxonomic group with the largest number of species is birds, followed by insects and mammals (Table 21.1).

INVERTEBRATES

Our results identified at least 42 invertebrates that are used as climate ethnoindicators (Table 21.1). As a group, arthropods possess a great diversity of behavioral activities that are observed by humans for predicting weather and climatic events. According to Kihupi et al. (2003) and Dunn (2000), insects, such as houseflies, fleas, cockroaches, and tarantulas, among numerous others, are signals for the coming of summer in Japan. In some southern municipalities in Japan, peasants stated that cockroaches disappear into the ground before and during the winter (Kihupi et al., 2003). In some provinces of Burkina Faso, Africa, women also gain insight by observing insect behavior at water sources and in rubbish piles. For instance, the emergence of larval black insects, usually Orthoptera, from concave dirt nests predicts a good farming season and a resultant full granary (Roncoli et al., 2002). Variation in insect population dynamics has been proven to occur throughout the seasons of the year (Changa et al., 2010; Lowman, 1982; Zuma-Netshiukhwi et al., 2013). For example, in southwestern Free State, Africa, the appearance of ants and the mushrooming of anthills during the planting season indicate that daily temperatures are warm enough for ants to come out of hibernation and roam around in and on the soil. This also indicates that it is warm enough to plant crops that are sensitive to low temperatures (Zuma-Netshiukhwi et al., 2013).

Pareek and Trivedi (2011) studied how the local beliefs and traditional knowledge of the pastoral communities of Rajasthan (India) were used to predict weather change and natural

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
MOLLUSCA			
Gastropoda			
Helix aspersa (O. F. Müller, 1774)—shelled snails/ garden snail	Tanzania	Occurrence during times of year when they are not expected is a sign that there will be much rain during the short rainy season	Prospect of a good season for crop
INSECTS			
Hymenoptera			
Ants	Southwestern Africa	Occurrence of red ants and rapidly increasing size of anthills, which are moist, are used to predict good rains	Preparation for (late) sowing season
	Bahia (Brazil)	Construction and position of anthill; larval transportation; and row movement behavior are a sign of good winter	Abundance of water to raise animals
	Santa Cruz do Sul—RS, Brazil	Whenever their work increases that's a sign of bad weather ahead	Preparation for good winter
	Native American Tribes	Preparing the ground and anthill building	Preparation of coming rains or hard winters
	Rajasthan, India	Occurrence of ants indicate imminent rainfall onset	Prospect for a very good season
	Tanzania	Their presence on *Albizia* trees with water dripping from them is an indication of a good season	Preparation for much water
	Zimbabwe	Ants searching food and sealing off the holes of anthill	Preparation to rainy season about to start
	India	Ants carrying their eggs and larvae to safe places predicts the occurrence of rain	Good season for plantation
	Philippines	Exit of ants from their caves usually carrying stored food	Preparation to onset of rainy season
	Brazil	When winged adults leave the anthills, it is a sign of imminent rainfall	Good rainy season
	Mexico	Moving in line across the width of a sidewalk or road predicts rain onset	Attention to the weather
Wasps	Philippines	Hide their honeycomb under the leaves	Good rainy season or drought
Polistes spp.—Marimbondo	Ceará, Brazil	When they get into houses, it is a sign of impending rain	Good winter season
Pogonomyrmex spp.	Southwestern highland of Tanzania	Indicators of forthcoming rainfall	Preparation for abundant water

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Dorylus spp.	Uganda	Occurrence and uphill movement of African army ants is an indicator for the onset of the dry season	Preparations of field fertilization and livestock management
Dorylus wilverthi (Emery, 1899)	Southwestern highland of Tanzania	When ants and flying ants are seen during rainy season that's a prediction of abundant rainfall during the year	Herds will have permanent food for a year
Camponotus herculeanus (Linnaeus, 1758)—black ant	India	Row movement behavior of thousands of black ants in a stream, indicates rain	Attention to the short rainy season
Eciton burchellii(Westwood, 1842)—army ants	Tanzania	Appearance in great numbers almost everywhere including houses beavering agitatedly is a prediction of onset of rains and mostly heavy during short rainy season	Preparation for rains in 1 or 2 weeks
Apis mellifera (Linnaeus, 1758)—honey bee	Uganda	Occurrence and movement is an indicators for the onset of the dry season	Storage of resources
	Tanzania	Appearing in larger groups predicts that rains are forthcoming	Preparations for much rain during season
	Ceará, Brazil	When they get into houses it is a sign of impending rain	Good water season
Orthoptera			
Not identified	Burkina Faso	Larvae coming from concave nests symbolize a good harvest season	Preparation for a full granary
Crickets	Philippines	Appearance predicts droughts	Indicative of water shortage
	Nigeria	when crickets dig holes and make loud chirping courtship calls	Indicative that rains are well established
Melanoplus differentialis (Thomas, C., 1865)—green grasshopper	Tanzania	Occurrence of green grasshoppers in great numbers in the fields predicts the onset of rainfall especially during the short rainy season	Preparations for crop plantation
Hesperotettix speciosus (Scudder, 1872)—grasshopper	Southwestern highland of Tanzania	Occurrence of many grasshoppers in a particular area indicates drought and shortage	Food and water storage
Zonocerus variegatus (Linnaeus, 1758)—variegated grasshopper	Nigeria	its occurrence is a typical sign of weather changing	Attention to much rain or drought
Ruspolia baileyi (Otte, D., 1997)—bush cricket	Uganda	Occurrence and movement is an indicator for the onset of the dry season	Storage of resources
Brachytrupes membranaceus (Drury, 1770)—tobacco cricket	Zimbabwe	Abundance predicts rainfall and good rainy season	Preparation to water and food storage

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature —cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Blattodea			
Blattaria spp.	Mount Kilimanjaro in Moshi rural district of Tanzania	Moving into houses avoiding wet conditions and lurking for shelter and food is a prediction of forthcoming rainy season	Crop preparations
Coleoptera			
Holotrichia spp.	Philippines	Becoming earthbound	Indicative of an upcoming rain
Ephemeroptera			
Mayflies	Burkina Faso	Occurrence of large numbers of flies during maize planting is a prediction of good season	Attention to production of staple grains
Diptera			
Musca domestica (Linnaeus, 1758)—fly	India	Swarms of house flies predict imminent rain	Attention to the short rainy season
	Ceará, Brazil	When they get into houses it is a sign of impending rain	Good water season
Odonata			
Dragonflies	India	When flying low, may indicate rain in the same day	Decisions on threshing floor, fodder; keeping the livestock under protection
Isoptera			
Termites	Rajasthan, India	Occurrence of termites indicate imminent rainfall onset	Prospect for a very good season
	Zimbabwe	Collecting and storing grass	Indicative that the summer season is just around
	India	Flying in the evening hours is a sign that there will be rain	Much water
	Philippines	Abundance of winged termites fluttering around light sources especially at night	Indicative of an upcoming rain
	Nigeria	Termites' nuptial flights	Indicative that rains are fully established
Ancistrotermes sp.—termites	Southwestern highland of Tanzania	Many termites is an indication of near rainfall onset	Crop preparations

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Hemiptera			
Spittle bugs	Mount Kilimanjaro in Moshi rural district of Tanzania	Presence on trees is indicative of impending rains	Preparing for the planting season
Huechys sanguinea (De Geer, 1773)—cicada	Philippines	Beginning their incessant high-pitched droning call	Indicative of an upcoming rain
Hymenoptera			
Reticulitermes spp.	Tanzania	Appearing after strong sunshine predicts the star of rainy season	Indication of good year for arable rain-fed farming
Lepidoptera			
Butterflies	Uganda	Occurrence and movement is an indicator for the onset of the dry season	Storage of resources
	Rajasthan, India	Occurrence of many butterflies indicates early rainfall onset	Prospect for a very good season
Armyworms	Southwestern Africa	Occurrence is an indication of drought to come	Preparation for very dry season
Red caterpillars	Uganda	Occurrence and movement are indicators for the onset of the dry season	Storage of resources
Papilio spp.	Tanzania	Migration of butterflies is a premonition of rains	Preparations for much rain during season
Amsacta albistriga (Walker, 1864)—red hairy caterpillar	India	Quick movement is considered as an indicator of rain	Attention to coming of short rainy season
Acentrocneme hesperiaris (Walker, 1856)—maguey butterfly	Mexico	Great abundance predicts good rainy season	Good season for maize crop
Spodoptera exigua (Hübner, 1808)—locusts	Tanzania	Presence of many is a prediction of long rains	Prospect for a very good season
Charaxes pollux (Cramer, 1775)—black bordered charaxes	Southwestern Highland of Tanzania	Abundance of black butterflies in a particular area indicates great rainfall season	Attention to field fertilization and herds managing
Spodoptera exempta (Walker, 1856)—armyworms	Southwestern highland of Tanzania	Armyworms all over trees during October testifies abundant rainfall in the upcoming season	Water storage
	Nigeria	Appearance after planting, a period of dry spell is imminent	Water storage

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Thysanoptera			
Various species	Tanzania	Insects near wetland areas indicate good rainy season	Preparation for abundant water
DIPLOPODA			
Millipedes	Uganda	Appearance and movement	Indicative for the onset of the rainy season
	Zimbabwe	Presence of millipedes indicate the start of the rain season	Preparation for much water
MALACOSTRACA			
Crabs	Cultures which live near sea	Crabs block the mouth of the hill and scratch (or not) the sand flat	Indicative of windy weather with high probability of rainfall
	Mount Kilimanjaro in Moshi rural district of Tanzania	Crabs migration behavior from rivers and streams looking for upper grounds predicts occurrence of floods and heavy storm	Preparation for water storage
	Philippines	Female native crabs migrating from rivers to brackish water predict onset of rainfall	Preparation to onset of rainy season
	India	If crab makes a bigger hole in its channel	Good moment for weeding and harvesting, plowing, and arranging seeds for sowing
ARACHNIDA			
Spiders	Native American Tribes	Spider webs in the air and in trees	Imminent hard and cold winter
	Zimbabwe	Spiders appearing around houses	Rains about to start
Araneae			
Acanthoscurria geniculata (C. L. Koch, 1841)—Brazilian whiteknee tarântula	Bahia (Brazil)	Occurrence in houses indicates great rainfall	Attention to field fertilization and herds managing
Scorpiones			
Scorpion	Tanzania	Occurrence of black scorpions during September and October is a prediction of much rain	Good year to feed animals

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
ACTINOPTERYGII			
Characiformes			
Hoplias malabaricus (Bloch, 1794)—Haimara; Traira	Ceará, Brazil	If they are ovate during the last months of the year, it is a prediction of good rainy season and that they will spawn in the new waters	Good rainy season
Prochilodus lineatus (Valenciennes, 1837)	Ceará, Brazil	If they are ovate during the last months of the year, it is a prediction of good rainy season and that they will spawn in the new waters	Good rainy season
AMPHIBIA			
Anura			
Frogs	Southwestern highland of Tanzania	When frogs vocalize that is a prediction of good rainfall in the coming rainy season	Abundance of water to raise animals
	Santa Cruz do Sul—RS, Brazil	When frogs and toads croak a lot, it is a sign of rain ahead	Good winter
	Uganda	When frogs in swampy areas start croaking at night, it is indicative of the onset of the rainy season	Preparations of field fertilization and livestock management
	Rajasthan, India	When frogs start to make a lot of noise	Prospect for a very good season
	Zimbabwe	When frogs start to make a "hiss," it's a typical sign of precipitation	Good season to raise animals
	India	Well or tank full of frogs making noise at night times clearly indicates heavy rain	Advice for plantation
	Kingdom of Swaziland, Africa	Continuous "cry" calls in a certain pattern is considered a sign of imminent rainfall	Preparing for the planting season
	Tanzania	Appearance of frogs making much of noise predicts coming rains and when delay occurs, the silence evidenciates rainy season is yet to start	Attentions to rainy season
	Philippines	Croaking calls of endemic frogs in swampy areas and hide their egg mass	Preparation to onset of rainy season
Xenopus laevis (Daudin, 1802)—African clawed frog	Tanzania	Making a lot of loud vocalization is a prediction of rainfall onset and good season	Preparations of field fertilization and livestock management
Lithobates pipiens (Schreber, 1782)—northern leopard frog	Bahia (Brazil)	When frogs "sing" it is a prediction of coming rain	Attention to field fertilization and herds managing

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Hoplobatrachus tigerinus (Daudin, 1802)—Indian bullfrog	India	Croaking underneath stones, leaping over small frogs predicts rain onset	Attention to start of short rainy season
REPTILIA			
Squamata			
Snakes	Southwestern Africa	Some snakes species moving down the mountain is a prediction of great rains	Indicative to engage into different agricultural activities such as land preparation, planting, weeding, spraying, etc.
	Zimbabwe	Occurrence of mating predicts that winter is approaching	Preparation for hard winter
Chameleon sp.	Pakistan	Singing out loud is a sign of a good rainy season	Preparation to much rain
	Nigeria	Appearance on crops after rainfall commencement is a prediction of a period of dry spell	Preparation to water shortage
	Rio Grande do Norte, Brazil	When it buries underground, It is a sign of "early winter"	Preparations of field fertilization and livestock management
Salvator merianae (Duméril and Bibron, 1839)—black-and-white Tegu; Tejú	Rio Grande do Norte, Brazil	When they do not come out from within the burrow, signs of "early winter"	Preparations of field fertilization and livestock management
Heloderma suspectum (Cope, 1869)—gila monster	Native American Tribes	Roaming around	Indicative of a long and very cold winter
Testudines			
Tortoises	Southwestern Africa	Usual appearance of tortoises around is a sign of good rains	Indicative to engage into different agricultural activities such as land preparation, planting weeding, spraying, etc.
AVES			
Birds	Santa Cruz do Sul—RS, Brazil	Birds when they fly low and agitated perceive climate change	Indicative of rain ahead
	Rajasthan, India	When some birds "cry," it is a prediction of the rainy season onset	Prospect for a very good season
	Burkina Faso	Nests of the small quail-like bird hanging high or low of tree is a prediction of heavy or low rains during year	Preparation for much rain or storage

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
	Zimbabwe	When birds such as *hwidzi kwidzi* (black or blue birds) sing melodious songs, it continuously heralds the commencement of the rainy season; when migratory birds begin to surface in a particular environment, it predicts imminent rain	Much water during the season
	Tanzania	Occurrence of walking to the valley or wetlands indicates short rainy seasons	Preparation for rains
	Mount Kilimanjaro in Moshi rural district of Tanzania	Birds calling in the morning and evening near water lakes indicates onset of rains	Much water ahead
Passeriformes			
Crow/raven	Pakistan and India	They help predict rainfall through their behavior, movement, calls, and flight, between 12 a.m. and 6 p.m.	Preparation for good winter
	Zimbabwe	When the weather conditions are overcast and a crow calls, that is a prediction of clear day in the following morning	Expecting good weather condition to harvest
Swallows	Southwestern Africa	Flock of swallows preceeding dark clouds	Good sign of rainfall
	Tanzania	Flocks of swallows roaming from south to north in a particular area are an indication of onset of short rainy season	Preparation to start of rain in the next 2 or 3 days
	Zimbabwe	Flying at low altitude is a sign of imminent rain	Good for water storage
Ploceus spp.	Kingdom of Swaziland, Africa	The height of the nests on trees is a prediction of floods	Attention to imminent floods
Turdus spp.—Sabiá	Brazil	The bird song predicts drought or winter approaching	Preparation for much water or shortage
Corvus macrorhynchos philippinus (Bonaparte, 1853)—large-billed crow	Philippines	Making mournful calls or seem to be crying in tree branches	Preparation to onset of rainy season
Passer melanurus (Müller, 1776)—Sparrows	Southwestern Africa	First appearance of sparrows	Rainy season is very close
Artamus leucoryn (Linnaeus, 1771)—white-bellied wood swallow	Philippines	Birds flying low to capture insects predict upcoming rain	Preparation to onset of rainy season
Psalidoprocne pristoptera (Rüppell, 1836)—blue saw-wing	Kingdom of Swaziland, Africa	Abundance of flocks in the sky during the months of September and October is a sign of close rainfall	Preparing for the planting season

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Oriolus auratus (Vieillot, 1817)—golden oriole	Tanzania	Singing out loud is a sign of good rainfall season	Preparation for rains
Furnarius rufus (Gmelin, 1788)—*Rufous Hornero*	Santa Cruz do Sul—RS, Brazil	When it sings, regardless of weather conditions, it is a sign of good weather	Indication of good year for arable rain-fed farming
Zonotrichia capensis (Müller, 1776)—rufous-collared sparrow; Salta-caminho	Santa Cruz do Sul—RS, Brazil	Usually sings during daytime. When it happens to sing at night it is a sign of rain	Good year for water storage
Motacilla aguimp (Dumont, 1821)—African pied wagtail	Uganda	Occurrence and movement is indicative of the onset of the dry season	Storage of resources
Ploceus philippinus (Linnaeus, 1766)—Baya weaver	India	Depending how the bird builds its nest on a well, it is believed that it predicts the start of a good or bad monsoon season	Attention to the start of monsoon
Laniarius aethiopicus (Gmelin, 1788)—tropical boubou	Mount Kilimanjaro in Moshi rural district of Tanzania	When it appears hovering over water bodies, it is a prediction of imminent rainfall	Preparation for field fertilization
Nectarinia famosa (Linnaeus, 1766)—malachite sunbird	Southwestern highland of Tanzania	The bird's song after a prolonged drought predicts an imminent onset of a good rainy season	Indicative of abundance of food and that crops will grow
Aethopyga saturata (Hodgson, 1836)—black-throated sunbird	India	Unusual chirping	Onset of rainy season
Alophoixus flaveolus (Gould, 1836)—white-throated bulbul	India	Unusual chirping and bathing with sand	Upcoming rain
Chloropsis hardwickii (Jardine and Selby, 1830)—orange-bellied leafbird	India	Unusual chirping and flying low to chase insects	Onset of rainy season
Copsychus malabaricus (Scopoli, 1788)—white-rumped shama	India	Unusual chirping	Onset of rainy season
Culicicapa ceylonensis (Swainson, 1820)—grey-headed canary-flycatcher	India	Unusual chirping and flying in the low catchment area	Onset of rainy season
Cyornis concretus (Müller, 1835)—white-tailed flycatcher	India	Unusual chirping and flying in the low catchment area	Adverse weather condition (typhoon or flood)

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Gracula religiosa Linnaeus, 1758—hill myna	India	Unusual chirping and aggressive behavior	Adverse weather condition (typhoon or flood)
Lonchura striata (Linnaus, 1766)—white-rumped munia	India	Unusual chirping with shrill sound	Adverse weather condition (typhoon or flood)
Melanochlora sultanea (Hodgson, 1837)—sultan tit	India	Unusual chirping	Upcoming rain
Myiomela leucura (Hodgson, 1845)—white-tailed robin	India	Unusual chirping with very low tune	Upcoming rain
Myophonus caeruleus (Scopoli, 1786)—blue whistling-thrush	India	Unusual chirping with very low tune	Upcoming rain
Orthotomus atrogularis (Temminck, 1836)—dark-necked tailorbird	India	Unusual chirping and very fast movement	Upcoming rain
Orthotomus sutorius (Pennant, 1769)—common tailorbird	India	Unusual chirping and very fast movement	Upcoming rain
Pycnonotus jocosus (Linnaeus, 1758)—red-whiskered bulbul	India	Unusual chirping	Upcoming rain
Toxostoma curvirostre (Swainson, 1827)—curve-billed thrasher; Cuitlacoche	Mexico	Singing in the morning is considered an indication of frost	Attention to the weather
Onychognathus morio (Linnaeus, 1766)—red winged starling	Southwestern highland of Tanzania	The bird's song after a prolonged drought predicts an imminent onset of a good rainy season	Indicative of abundance of food and arable rain-fed farming
Troglodytes aedon (Vieillot, 1809)—house wren	Mexico	Singing on the trees in the morning is a prediction of air streams	Attention to the weather
Hirundo smithii (Leach, 1818)—wire-tailed swallow	Tanzania	Appearance of flocks predicts the onset of rains and leads to the prediction of forthcoming heavy rainfall	Preparations of good rainy season
Hirundo rustica (Linnaeus, 1758)—barn swallow; swallow	Mexico	If it flies at low altitudes near crop season, it means that it will rain soon	Quantity of rainfall will be favorable for crops
Furnarius leucopus (Swainson, 1837) - Pale-legged Hornero, João de Barro	Brazil	Building its nest with the entrance facing west predicts much rain for the season	Good year for water storage and crops

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Cyanocompsa brissonii (Lichtenstein, 1823)—ultramarine grosbeak; Azulão	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signs of rain	Attention to crops
Paroaria dominicana (Linnaeus, 1758)—red-cowled cardinal; Galo de Campina	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signs of rain	Attention to crops
Turdus rufiventris (Vieillot, 1818)—rufous-bellied thrush; Sabiá	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signs of rain	Attention to crops
Fluvicola nengeta (Linnaeus, 1766)—masked water-tyrant; Lavandeira	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signsof rain	Attention to crops
Icterus jamacaii (Gmelin, 1788)—Campo Troupial; Concriz	Brazil	Behavior of breeding and egg laying is indicative of imminent rainfall	Good winter season
Icterus cayanensis (Linnaeus, 1766)—Epaulet oriole; Xexeu-de-bananeira	Brazil	When it makes a safe hole in dams and barriers, it indicates rainfall	Good water season
Volatinia jacarina (Linnaeus, 1766)—blue-black grassquit; Nego-Tziu	Brazil	Behavior of flight, height, and jump is a prediction of rainfall	Good winter season
Cyanocorax cyanopogon (Wied, 1821)—White-naped Jay, Cancão	Brazil	The bird's song indicates drought or winter is approaching	Preparation for much water or shortage
Luscinia megarhynchos (Brehm, 1831)—common nightingale; Rouxinol	Rio Grande do Norte—Brazil	Make nest on the roof of houses in November. Signs of "early winter"	Good season to fertilize crops
Mimus saturninus (Lichtenstein, 1823) - Chalk-browed mockingbird; Papa-sebo	Rio Grande do Norte—Brazil	Mating in the end of year predicts good winter season	Attention to field fertilization and herds managing
Cuculiformes			
Cuckoos	Uganda	Occurrence and vocalization is indicative of the onset of the rainy season	Preparations of field fertilization and livestock management
Cuculus solitarius (Stephens, 1815)—red-chested cuckoo	Kingdom of Swaziland, Africa	The "cry" call of the bird signals the start of the wet season in August–November	Preparations for the planting season
Cuculus clamosus (Latham, 1801)—black cuckoo	India	Melodious sounds are often taken as indicative of rain	Attention to start of short rainy season

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Clamator jacobinus (Boddaert, 1783)—Jacobin cuckoo	Asia, Africa, Zimbabwe, Tanzania, and India	As the rainy season approaches, this bird starts to sings. By hearing it is singing people understand that the rainfall has come	Indicative of floods and monsoons
Cacomantis merulinus (Scopoli, 1786)—Plaintive cuckoo	Philippines	Making mournful calls or seem to be crying in tree branches	Preparation to onset of rainy season
Chalcites lucidus (Gmelin, 1788)—Pïpïwharauroa, shining bronze-cuckoo	New Zealand	Appearance at a specific area predicts the beginning of warm weather	Good time to fertilize crops
Urodynamis taitensis (Sparrman, 1787)—Koekoeä, long-tailed cuckoo	New Zealand	Appearance at a specific area predicts the onset of better weather	Good time to fertilize crops
Centropus superciliosus (Hemprich and Ehrenberg, 1833)—white-browed coucal	Southwestern highland of Tanzania	The bird's song after a prolonged drought predicts an imminent onset of a good rainy season	Indicative of abundance of food and that crops will grow
Centropus superciliosus burchellii (Swainson, 1838)—white-browed coucal	Kingdom of Swaziland, Africa	When the bird chirps from October to April, it is a sign of an approaching thunderstorm	Preparing for the planting season
Centropus bengalensis philippinensis (Mees, 1971)—Lesser coucal	Philippines	Unusual chirping of birds	Preparation to onset of rainy season
Guira guira (Gmelin, 1788)—Guira cuckoo; Anum-branco	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicativesigns of rain	Attention to crops
Crotophaga ani (Linnaeus, 1758)—Smooth-billed Ani, Anum Preto	Brazil	Singing in the afternoon is a sign of rain, if in the morning, it is a prediction of drought	Preparation for much water or shortage
Columbiformes			
Pigeon/Dove	Many countries	If pigeons sings from morning to evening, it is a prediction that rain will fall after 8–15 days	Preparation of field fertilization and arable rain-fed farming
Columbina spp.—Rolinhas	Brazil	Beginning of nest building predicts rain or droughts	Preparation for much water or shortage
Turtur afer (Linnaeus, 1766)—blue-spotted wood dove	Kingdom of Swaziland, Africa	The appearance predicts impending long drought and famine	Preparations for food and water storage

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Ducula badia (Raffles, 1822)—mountain imperial pigeon	India	Unusual movement to take shelter in shadow of leaves	Adverse weather condition (typhoon or flood)
Spilopelia chinensis (Scopoli, 1786)—spotted dove	India	Unusual chirping, move in pairs, and take shelter in shadow of leaves	Upcoming rain
Treron curvirostra (Gmelin, 1789)—Thick-billed green pigeon	India	Unusual chirping and unusual movement to take shelter in shadow of leaves	Upcoming rain
Leptotila rufaxilla (Richard & Bernard, 1792)—grey-fronted dove; Juruti	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative of rain	Attention to crops
Patagioenas picazuro (Temminck, 1813)—Picazuro pigeon; Asa branca	Brazil	Behavior of breeding and egg laying is indicative of imminent rainfall	Good winter season
Columbina minuta (Linnaeus, 1766)—plain-breasted ground-dove, Rolinha Cambute	Brazil	Behavior of breeding and egg laying is indicative of imminent rainfall	Good winter season
Zenaida auriculata (Des Murs, 1847)—eared dove; Ribaçã	Brazil	Occurrence in the region predicts rainfall	Preparation for good winter
Anseriformes			
Wild ducks	Uganda	Occurrence and vocalization is indicative of the onset of rainy season	Preparations of field fertilization and livestock management
Wild geese	Native American Tribes	Flying back south at high or low altitude	Indicative of a hard winter (high altitude); mild winter or fall (low altitude)
Anas platyrhynchos domesticus (Linnaeus, 1758)—domestic duck	Tanzania	Stretching their wings and playing in dust is a sign of the onset of rains	Preparation for field fertilization
	Kingdom of Swaziland, Africa	Restlessness and noisy behavior indicates an imminent heavy storm	Preparation for much water
Marmaronetta angustirostris (Ménétriés, 1832)—marbled teal	Asia, Africa, Zimbabwe, Tanzania, and India	Agitated behavior during morning and afternoon	Indicative of monsoons ahead
Dendrocygna viduata (Linnaeus, 1766)—white-faced whistling-duck; Marreca	Brazil	Occurrence in the region predicts rainfall	Preparation for good winter

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Pelecaniformes			
Bubulcus ibis (Linnaeus, 1758)—cattle egret	Uganda	Occurrence and movement of this migratory bird is indicative of the onset of dry season	Storage of resources
	Tanzania	Occurrence during October and November is a prediction of imminent rainfall onset; appearance brings bad weather because it is linked to livestock diseases	Good rainfall season for resources storage; Preparation to rain shortage
Botaurus poiciloptilus (Wagler, 1827)—Matuku-hürepo, Australasian bittern	New Zealand	The continuous crying of the bird as it moves around at night predicts that a season of flood will follow	Attention to much water during season
Accipitriformes			
Eagles	Native American Tribes	Hovering around	Prediction of better weather conditions
Aquila verreauxii (Lesson, 1830)—black eagle	Uganda	Occurrence and vocalization is indicative of the onset of the dry season	Storage of resources
Terathopius ecaudatus (Daudin, 1800)—Bateleur	Uganda	Occurrence and vocalization is indicative of the onset of the dry season	Storage of resources
Psittaciformes			
Agapornis fischeri (Reichenow, 1887)—Fischer's lovebird	Tanzania	The "crying" call is a prediction of short rainy season	Preparation for rains
Loriculus vernalis (Sparrman, 1787)—vernal hanging parrot	India	Unusual chirping and flying in fleet	Upcoming rain
Nestor meridionalis (Gmelin, 1788)—Käkä, New Zealand Kaka	New Zealand	Twisting and squawking above the forest	Attention to a storm that is forthcoming
Amazona aestiva (Linnaeus, 1758)—Turquoise-fronted Amazon; Papagaio	Brazil	Building of nest predicts rains onset	Good winter season
Psittacula krameri manillensis (Bechstein, 1800)—rose-ringed parakeet	India	Migration of parakeet in N–S direction indicates a possible occurrence of rain	Attention to start of short rainy season
Gruiformes			
Cuckoos	Uganda	Occurrence and vocalization is indicative of the onset of rainy season	Preparations of field fertilization and livestock management
Balearica regulorum (Bennett, 1834)—grey crowned crane	Santa Cruz do Sul—RS, Brazil	Usually vocalizes at dusk, if it does at another time it is because it perceives climate change	Prediction of wind and winter

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Aramides saracura (Spix, 1825)—slaty-breasted wood-rail	Philippines	Unusual chirping of birds	Preparation to onset of rainy season
Hypotaenidia torquata (Linnaeus, 1766)—barred rail	Philippines	Unusual chirping of birds	Preparation to onset of rainy season
Porphyrio porphyrio melanotus (Temminck, 1820)—Pükeko, Australasian swamphen	New Zealand	Looking for higher ground	Attention to imminent storm and flooding
Lewinia striata (Linnaeus, 1766)—Slaty-breasted rail	Philippines	Unusual chirping of birds	Preparation to onset of rainy season
Anthropoides virgo (Linnaeus, 1758)—Demoiselle crane	Pakistan	Agitated behavior such as movement and calls predict rainy season	During rainfall if this bird is seen hovering over in a triangle shape it is a sign of more rain
Aramides cajaneus (Müller, 1776)—grey-necked wood-rail, Três Cocos	Brazil	Singing at dusk is a sign of imminent rain	Good winter season
Aramus guarauna (Linnaeus, 1766)—Limpkin, Carão	Brazil	The bird's song predicts drought or winter approaching	Preparation for much water or shortage
Bucerotiformes			
Buceros bicornis (Linnaeus, 1758)—great hornbill	Tanzania	Flocks hovering in the sky are an indicator of short rainy season	Preparation for rains
Ciconiiformes			
Ciconia nigra (Linnaeus, 1758)—black stork	India	Parabolic flight behavior is a prediction of rain	Attention to rain season
Coraciiformes			
Halcyon smyrnensis gularis (Kuhl, 1820)—white-throated kingfisher	Philippines	Unusual chirping of birds	Preparation to onset of rainy season
Merops hirundineus (Lichtenstein, 1793)—swallow-tailed bee-eater	Tanzania	Occurrence of swallow flock all over sky during November is a sign of imminent heavy rain in one particular area	Good season to fertilize crops
Merops philippinus (Linnaeus, 1766)—blue-tailed bee-eater	Philippines	Migration to mountains	Preparation to onset of rainy season

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Caprimulgiformes			
Aerodramus brevirostris (Horsfield, 1840)—Himalayan swiftlet	Philippines	Birds flying low to capture insects predicts an upcoming rain	Preparation to onset of rainy season
Nyctibius griseus (Gmelin, 1789)—common potoo; Mãe-da-lua	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signs of rain	Attention to crops
Charadriiformes			
Vanellus miles (Boddaert, 1783)—masked lapwing	Australia	Prediction based on where it lays its eggs on the field indicates good or poor rains	Good rainy season or drought
Limosa lapponica (Linnaeus, 1758)—Küaka, bar-tailed godwit	New Zealand	The bird's arrival on a specific area predicts the start of a warm season	Good weather
Vanellus chilensis (Molina, 1782)—southern lapwing; Tetéu	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicativesigns of rain	Attention to crops
Galliformes			
Guinea fowls	Zimbabwe	Laying eggs predicts onset of summer season	Good food storage
	Nigeria	Laying eggs at onset of rains and lay daily when rains are fully established	Good rainy season
	Rio Grande do Norte—Brazil	Laying eggs in November	Attention to field fertilization and herds managing
Gallus gallus domesticus (Linnaeus, 1758)—rooster	Bahia (Brazil)	When rooster "sings" very much it is a prediction of coming rain	Indicative of good rainy season
	Santa Cruz do Sul—RS, Brazil	When hens clean their feathers, it is a sign of rain	Abundance of water to raise animals
	Zimbabwe	Feeding during rain is a sign that there will be more rainfall	Preparation for more precipitation
	Tanzania	Stretching their wings repeatedly is a prediction of short rains	Preparations of field fertilization and livestock management
	India	When poultry sit in a place for a long time inserting feathers in the soil, it is a prediction of forthcoming rain	Water storage
	Mexico	When the rooster calls after hours (afternoon or evening), it is an indicator that it will stop raining for a while during the rainy season	Attention to the weather

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Pavo cristatus (Linnaeus, 1758)—peacock	Many countries	Dancing behavior	Rainy season is very close
	Kingdom of Swaziland, Africa	Restlessness and noisy behavior indicates an imminent heavy storm	Preparation for much water
	India	Making sound early in the morning and late in the evening predicts cool breeze or imminent rainfall	Attention to short rainy season
Arborophila atrogularis (Blyth, 1850)—white-cheeked partridge	India	Unusual chirping and flying up in the sky	Adverse weather condition (typhoon or flood)
Athene cunicularia (Molina, 1782)—burrowing owl	Ceará, Brazil	The high and persistent call of the owl in the early days of the year predicts rainy weather	Good season to crop
Piciformes			
Megalaima asiatica (Latham, 1790)—blue-throated barbet	India	Unusual chirping	Upcoming rain
Megalaima australis (Horsfield, 1821)—blue-eared barbet	India	Unusual chirping and flying low	Upcoming rain
Picus canus (Gmelin, 1788)—grey-headed woodpecker	India	Unusual activity with rotation around the tree	Upcoming rain
Nystalus maculatus (Gmelin, 1788)—Caatinga puffbird, Fura Barreira	Brazil	Building its nest in higher places is a prediction of forthcoming rainfall	Good rain season
Falconiformes			
Falco novaeseelandiae (Gmelin, 1788)—Kärearea, New Zealand falcon	New Zealand	Screaming on a fine day; on a rainy day	It will rain the next day; will be fine the next day
Herpetotheres cachinnans (Linnaeus, 1758)—laughing falcon, Acauã	Brazil	Singing at dusk it is a sign of near rain	Good winter season
Struthioniformes			
Nothura maculosa (Temminck, 1815)—spotted Nothura; Codorniz	Brazil	Vocalizations like singing, crying, whistling, shouting, chirping are indicative signsof rain	Attention to crops
Cariamiformes			
Cariama cristata (Linnaeus, 1766)—red-legged seriema, Siriema	Brazil	Singing at midday it is a sign of near rain	Good winter season

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Strigiformes			
Owl	Pakistan	Depending on the direction of its flight it is a sign of winter or summer	Attention to field fertilization and herds managing
	Tanzania	Prediction of planting season	Preparation for field fertilization
Tyto alba pratincola (Bonaparte, 1838)—Western barn owl	India	Squeaking indicates rain onset	Attention to start of short rainy season
MAMMALIA			
Carnivora			
Foxes	India	howling in the morning and evening indicating impending rain	Short rainy season
Canis lupus familiaris—Dogs	Mount Kilimanjaro in Moshi Rural District of Tanzania	Barking and mating during night predicts near precipitation	Preparation for rainy day
	Philippines	Unusual behavior of dogs can also predict an upcoming storm	Predictions of rain ahead
	India	If dog jumps irregularly on the road at midday, it is a sign of imminent rain	Expecting good weather condition to harvest
	Mexico	Cheerful and impetuous behavior predicts good weather (heavy rain or hail frost) and a calm or sad behavior predicts cessation of rains and possible occurrence of frost or drought	Attention to weather
Felis catus domestica—Cats	England	If a cat washes behind its ears, it will rain	
	Indonesia	Pouring water on a cat will bring rain	
	Rio Grande do Norte—Brazil	Mating in December is a prediction of good winter	Attention to field fertilization and herds managing
Canis latrans (Say, 1823)—coyote	Native American Tribes	When coyotes howl most mournfully	Prediction of cold winds
	Mexico	When it howls melodically, it predicts next rains; or if obnoxious or clipped, it will not rain soon or even it will be dry during maize growth	Attention to the weather
Panthera pardus (Linnaeus, 1758)—leopard	Tanzania	Appearance in the village is a sign of a good rainfall season	Preparation for rains
Crocuta crocuta (Erxleben, 1777)—spotted hyena	Tanzania	Depending on the calls, it can predicts the rainfall season	Preparation to receive rains for crops fertilization

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Artiodactyla			
Camel	Zimbabwe	Appearance of injuries on camel's legs is a prediction of rainfall ahead	Water storage
Bos taurus (Linnaeus, 1758)—cattle	Southwestern Africa	Well-fed calves jumping around during their foraging time near mountains and unwilling to graze the following morning indicates good rains are on the way	Preparation of field fertilization and good rains
	Native American Tribes	When herd head for high ridges even during a storm in winter	Indicative that storm will be over by the following morning
	Pakistan	When the cow lies down, it is a sign of abundant rainfall	Indicative of forthcoming rains
	India	When the cow licks each other, it is a prediction of drought	Preparation for food and water storage
	Uganda	Cattle are restless and start jumping	Indicative of the onset of the rainy season
	Tanzania	Ear flapping is a prediction of onset and prospects of a good season	Preparation for rainy day
*Ovis arie*s (Linnaeus, 1758)/*Capra hircus* (Linnaeus, 1758)—sheep, goat	Southwestern Africa	Much libido in goats and sheep with increased mating is a sign for good rains	Indicative to engage into different agricultural activities such as land preparation, planting weeding, spraying, etc.
	Tanzania	Ear flapping is a prediction of onset and prospects of a good season	Preparation for rains
	Zimbabwe	Constant mating predicts onset of rain season	Good year for water storage
	Mexico	Cheerful and impetuous behavior predicts good weather (heavy rain or hail frost) and a calm or sad behavior predicts cessation of rains and possible occurrence of frost or drought	Attention to weather for crop management
Sus scrofa domesticus (Erxleben, 1777)	Southwestern Africa	Grunting is an indicative of low humidity and increase in temperature	Preparation for agricultural activities
	Native American Tribes	When a pig is butchered, usually in the fall, they look for its spleen	If found to be thick, then it's a prediction of a hard winter, and lots of snow
	Kingdom of Swaziland, Africa	Restlessness and noisy behavior indicates an imminent heavy storm	Preparation for much water

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Perissodactyla			
Equus asinus (Linnaeus, 1758)—donkey	Santa Cruz do Sul—RS, Brazil	Rolling on the ground	Predictions of rain ahead
Equus (*Equus*) *caballus* (Linnaeus, 1758)—horse	Native American Tribes	When horses play with each other and stamp around	Indicative of a coming winter storm
	Santa Cruz do Sul—RS, Brazil	Approach each other	Predictions of rain ahead
	Mexico	When horse trembles in the evening, it is a sign that a frost is imminent on the fields	Attention to the weather
Cetartiodactyla			
Antilope cervicapra (Linnaeus, 1758)—antelopes, blackbuck	Tanzania	Appearance in the village is a sign of a good rainfall season	Preparation for rains
Lagomorpha			
Rabbit	Native American Tribes	Getting fat or not during the autumn	Fat in fall is a prediction of mild winter, if not it means cold winter
	Native American Tribes	If rabbits eat brushwood next to snow or at its height in a standing position	Indicative of a lot of snow during the winter
Hyracoidea			
Procavia capensis (Pallas, 1766)—rock rabbit	Zimbabwe	When it gives out a typical squeak, it is a prediction of imminent rainfall in a particular place	Much water during the season
Rodentia			
Sciurus spp.—fox squirrels	Native American Tribes	Not storing nuts and corn in previous autumn	Indicative that the snowfall would not last long and that the squirrels will be more energetic in search for food
Cynomys spp.—Prairie dogs	Native American Tribes	Standing at their den entrance	Prediction of a long and hard winter
Ondatra zibethicus (Linnaeus, 1766)—muskrat	Native American Tribes	Construction of an unusually high and large house	Indicative of a severe winter
Castor canadensis (Kuhl, 1820)—American beaver	Native American Tribes	Construction of an unusually high and large house	Indicative of a severe winter
Marmota (*Marmota*) *monax* (Linnaeus, 1758)—groundhog	North America	Its behavior can predict if winter will be heavy or not	Attention to crops

Continued

TABLE 21.1 Animals Used as Weather and Climate Indicators in Folk Knowledge According to Surveyed Literature—cont'd

Animals	Region	Traditional Zoo Indicator Prediction	Decision Taken by People
Kerodon rupestris (F. Cuvier, 1825)—rock cavy; Mocó	Rio Grande do Norte—Brazil	Grow the tail; If it is skinny; mating during November/December predicts good winter	Attention to field fertilization and herds managing
Galea spixii (Wagler, 1831)—Spix's yellow-toothed cavy; Preá	Rio Grande do Norte—Brazil	Grow the tail; If it is skinny; mating during November/December predicts good winter	Attention to field fertilization and herds managing
Chiroptera			
Bats	Zimbabwe	Occurrence of *muremwaremwa* is an indication of erratic rainfall or good season, if it's seen flying or on the ground	Attention for much water or low water for the fields
Primates			
Howler monkeys	Santa Cruz do Sul—RS, Brazil	The monkeys are sensitive to atmospheric pressure, making it howl drastically and insistently	Prediction of heavy rain
Lemurs	Mount Kilimanjaro in Moshi rural district of Tanzania	Occurrence of lemurs around farmhouses signs rainfall onset	Crop preparations
Colobus sp.—colobus monkey	Tanzania	Presence of many groups of colobus monkeys in the fields is a prediction of long rainy season	Much water during the season
Chlorocebus pygerythrus (F. Cuvier, 1821)—baboon, vervet monkey	Tanzania	Appearance in the village is a sign of a good rainfall season	Preparation for rains
Cingulata			
Armadillo	Brazil	Occurrence of armadillo pregnant in the month of December is a good sign of rain	Preparations for crop plantation
Tolypeutes tricinctus (Linnaeus, 1758)—Brazilian three-banded Armadillo	Ceará, Brazil	During November, the occurrence of three or four armadillo pups housed in the den is a good sign of rain	Good winter season
Pholidota			
Pangolin/scaly anteaters sp.	Tanzania	Occurrence is a prediction of rainfall	Much water during the season

disasters, and found them to be key elements of their environmental management and conservation efforts. For example, invertebrates such butterflies, ants, and termites can indicate the immediate onset of precipitation.

The presence of cicadas and termites is considered a traditional weather indicator for the locals of Mberengwa in Zimbabwe (Shoko, 2012). Similarly, elders in Masvingo and Manicaland (also Zimbabwe) rely on

insect behavior (anthill and termite mound construction, leafcutter ants moving in line) to estimate the start and intensity of the rainy season (Muguti and Maposa, 2012; Risiro et al., 2012). Likewise, while exploring indigenous knowledge in the southwestern highlands of Tanzania, Changa et al. (2010) found that a considerable number of insects, such as grasshoppers, butterflies, armyworms, and termites, are used by local populations to predict the beginning of the rainy season. Furthermore, Mahoo et al. (2015) observed that locals of the Lushoto district in Tanzania forecast rains by observing the presence and migration of butterflies from south to north, especially black butterflies which are a sign of a good season. The appearance of large swarms of red ants from September to November and the occurrence of large swarms of butterflies is indicative of the imminent onset of rainfall and that the upcoming rainfall season will be good (Changa et al., 2010).

In various provinces of India, Anandaraja et al. (2008) recorded several local climate and weather forecasts linked to the folk practices that farmers and pastoralists use in their agricultural systems, which included the behaviors of some invertebrates, such as ants, dragon flies, and termites. The appearance and behavior of some insects, for instance, butterflies, red caterpillars, western honey bees, and bush crickets, are considered traditional indicators of the approach of the dry season in some districts of Uganda (Okonya and Kroschel, 2013). In northern Kenya, traditional communities of pastoralists make use of indigenous weather forecasting methods, such as the increased presence of crickets, butterflies, and other insects, in predicting the start of monsoons (Kagunyu et al., 2016).

Most traditional people in Africa also evaluate time based upon the behavior of several insects. For instance, the presence of black beetles is commonly related to the beginning of planting crops; according to tribal elders, these insects only occur during the harvest time (Mapara, 2009). Another example is the continuous singing of *mandere* (*Eulepida* sp.), which signals the imminence of precipitation (Pareek and Trivedi, 2011). Similarly, the singing of *nyenze* (cicadas) predicts the start of rains in 2–3 weeks. Other insects that inform some traditional African people about when to plant crops include *makugwe*, *Brachytrupes membranaceus* (Drury, 1770), and *mopani* worms (Emeagwali and Shizha, 2016). Muguti and Maposa (2012) found parallel patterns in their study of indigenous weather forecasting among the Shona people in Zimbabwe. Richards (1980) observed that farming groups in southern Nigeria used nature-based knowledge of the multicolored grasshopper *Zonocerus variegatus* (Linnaeus, 1758) to predict the severity and geographical extent of monsoon outbreaks. According to a traditional weather forecaster from the Philippines, a flood is believed to be coming when wasps build their honeycombs high in the tops of trees, and strong winds are anticipated when they build them near the ground (Galacgac and Balisacan, 2009).

The behavior of insects in relation to climatic parameters is not unknown to science. In a study conducted in Brazil, Pellegrino et al. (2013) observed variation in mating behaviors of three taxonomically unrelated insects, the curcurbit beetle, *Diabrotica speciosa* (Coleoptera), the true armyworm moth, *Pseudaletia unipuncta* (Lepidoptera), and the potato aphid, *Macrosiphum euphorbiae* (Hemiptera), when exposed to natural or experimentally manipulated alterations in atmospheric pressure. They demonstrated that insects, in fact, have the ability to detect changes in time by sensing reductions in atmospheric pressure, thus seeking shelter to protect themselves in anticipation of unfavorable climatic conditions such as thunderstorms and windstorms (Acharya, 2011). Similarly, it has been observed that most crabs react to certain environmental signals that accompany

weather changes, and not to the weather itself. Sometimes the crabs, which live in sand hills, block the entrance to their home in anticipation of rainy weather. Other times they exhibit the behavior of scratching the sand, which is a signal of incoming strong winds (Alsaiari, 2012; Dudde and Apte, 2016; Hines et al., 2010). According to Chengula and Nyambo (2016), traditional weather forecasters of the southeastern slopes of Mount Kilimanjaro perceived that the migration of crabs from watercourses and rivers to higher land indicates probable flooding or heavy rainfall. Galacgac and Balisacan (2009) mentioned that Philippine people used crustaceans, such as shrimps and crabs, as indicators of upcoming typhoons, by observing them exhibit the behaviors of migrating from rivers to brackish water or crawling out of the water to riverbanks.

VERTEBRATES

Vertebrates stand out as the group of animals most widely used for evidence of climate change by traditional and local populations across the globe. Our review revealed that at least 158 species of vertebrates are used to predict weather conditions. Of these, birds were the most referenced, followed by mammals. Amphibians and reptiles have also been used as climate ethnozooindicators, in many cases inspiring beliefs associated with climatic factors.

In many folk beliefs, amphibians, including frogs and toads, are frequently related to rainstorms and blizzards. In India, for example, frogs were assumed to echo the thunder, and even the name frog in ancient Sanskrit means "cloud" (Sherman, 2008). In Mesoamerica, most amphibians were thought to be rain deities and were included in several rituals to bring precipitation. The *Aymara* natives of Bolivia and Peru placed small statues of toads on hilltops to call for the rainy season. If rains failed to arrive, such statues were usually broken because of their perceived failure (Pinch, 1995). In Australia, ancient aborigines also considered frogs to call upon rain (Robbins, 1996). Other local traditions, including those found in the Appalachian Mountains of the United States, hold that if someone kills a frog or toad, a downpour will ensue. It was even thought that frogs fell with the rain (Sherman, 2008).

Unsurprisingly, amphibians are commonly used as weather predictors in many regions. In Zimbabwe, for example, traditional communities use frogs to predict the intensity of rains (Mapara, 2009). Whenever they begin to produce an incessantly "*hiss*" sing, natives realize that the rainy season is "around the corner." Likewise, the congregation of huge, brownish bullfrogs, locally known as *machesi*, at a particular lake is interpreted as a prediction for much rain at that locality. Similarly, Emeagwali and Shizha (2016) explain how elders from African tribes identify frog sounds and celebrate the arrival of rainfall; they are able to associate rainfall patterns with the calls of certain species of frogs. For example, the croaking of bullfrogs with a high tone indicates that rains will arrive the following day. Their observations of the way other living organism behave are used to predict the quality of the impending season (Emeagwali and Shizha, 2016). Among the elders of the Mfereji village in the Monduli district of Tanzania, amphibian behaviors, in most cases frogs (*Africana* spp.) and toads (*Bufo* spp.), are clear indicators of seasonal variation. The absence of these animals is also used to indicate the coming of the dry season. According to the elders, when frogs stop croaking during the rainy season, even if it is still raining, it is an indication that the rains would soon cease (UNEP, 2008).

Reptiles play an important role in several cultures, including in mythology associated with climate and weather. In Australian aboriginal culture, Wollunqua is sanctified as the rainbow snake, a massive snake united with the rainbow

and the entirety of creation itself. Another creature is *Eingana*, an aboriginal snake goddess who created the land–water living beings, and brought all seasons to the earth (Sherman, 2008). Many hunters become alert and cautious when snakes are seen more frequently while they hunt for prey, as it is an indication of the onset of the growing season. Abundant movements of snakes and tortoises are interpreted as a seasonal prediction of ensuing good rainfall (Changa et al., 2010; Gardner, 2011).

According to Marais (2008) and Zuma-Netshiukhwi et al. (2013), snakes normally come out of hibernation and descend mountains looking for prey and breeding partners early in the summer. In Tanzania, native tribes rely on snakes to predict the length of the fall, and if they hibernate later, the fall will be longer than normal (UNEP, 2008). On the other hand, in many areas of Kenya, the presence of snakes and other reptiles around homesteads in search of water and food indicate the prevalence and continuity of drought (UNEP, 2008). According to a peasant community in Tlaxcala, Mexico, water snakes indicate the arrival of good rains (Rivero-Romero et al., 2016). Lizards also are considered weather predictors in some places. For example, Ahmed et al. (2016) recorded that people of Tharparkar, Pakistan, believe that if chameleons climb trees and shake their heads, it is indicative of good rainfall. Furthermore, when another type of chameleon, which the Tharparkar people claim lives underground, senses imminent rainfall, as it emerges (Ahmed et al., 2016).

Perhaps, no other animal group is more famous for weather forecasting than birds. Birds are the group most cited by numerous traditional communities worldwide, and one of the most reliable with regard to the influence of climate change on behavior. Examples involving birds as climate ethnozooindicators are abundant. Zuma-Netshiukhwi et al. (2013) pointed out that South African farmers use the appearance of cape sparrows, *Passer melanurus* (Müller, 1776), as an indication of the onset of good rain in the next day or two, which stimulates farmers to prepare for field activities (De Swardt et al., 2004). Eastwood (1967) stressed that flocks of sparrows were commonly observed in southwestern Free State during the growing season, feeding on seeds and insects. Therefore, their presence flying around in the sky, along with scattered clouds, indicates that rain is coming in the afternoon (Koistinen, 2000). A group of sparrows over grayish clouds predicts heavy rainfall for the next hour (Kopij, 2002). Migration of certain bird species is associated with the change in seasons in response to temperature and rainfall (De Swardt et al., 2004; Koistinen, 2000; Kopij, 2002; Zuma-Netshiukhwi et al., 2013).

The behavior of animals, including the appearance and movements of birds and insects, is frequently used by Hehe and Nyakyusa elders in Tanzania to predict the weather and climate of their communities. In both Kilolo and Rungwe districts of Tanzania, the appearance of large swarms of Yangiyangi birds is indicative of a good rainfall season and the imminent onset of rainfall (Chang'a et al., 2010; Gissila et al., 2004). Peppler (2010) reported that Native American tribes were known for their long-term climate predictions, as a 1950–52 letter by Senator Robert S. Kerr explains. According to Peppler (2010), native Indians seemed to base their forecasts on natural phenomena, such as the flight altitude of wild geese or even eagles hovering over lakes.

Welty (1982) stressed that perhaps the most famous advantage provided by the observation of the migration of birds is the prediction that better weather is assured. It is well known that birds display different behaviors as weather fronts approach. Furthermore, birds are able to sense infrasonic frequencies (at least down to 0.05 Hz), which can travel hundreds of kilometers, thus permitting birds to orient to remote locations (e.g., distant mountains, canyons, or even shorelines). According to Anderson and Eriksson (2007), the appearance of birds and insects can assist in detecting meso-scale

meteorological phenomena such as gust fronts. In fact, birds do have some ability to forecast weather over the short term. A very complex inner ear structure known as the Vitali or paratympanic organ is sensitive to variations in air pressure, which provides birds a warning of advancing "bad" weather, thus inducing them to indulge in feeding frenzies or short migrations to safe regions (Miller et al., 2016; Stach et al., 2016). Additionally, some bird species become very noisy or make mournful sounds when rainfall is forthcoming. According to Welty (1982), one of the functions of bird vocalization is to advertise an individual's sensitive state or mood, discharge anxious energy, and provide emotional release. For example, one of the behaviors of *Cacomantis merulinus* (Scopoli, 1786) involves expressing a call late in the day during cloudy and rainy days (Galacgac and Balisacan, 2009).

Numerous bird species are said to sing or call in advance of a windy day or a rainstorm. For centuries, many cultures worldwide believed that peacocks display a dance behavior prior to the arrival of rain, essentially foretelling when a place might experience rainfall (Ahmed et al., 2016). In Swaziland, Africa, where sporadic floods and drought are usual catastrophes, traditional communities would take particular caution in predicting such events. For instance, the agitation and noisy behavior of peacocks and ducks was interpreted to indicate an imminent heavy storm (UNEP, 2008). In many countries of Asia and Africa, the Jacobin cuckoo, *Clamator jacobinus* (Boddaert, 1783), is known by traditional communities to predict the arrival of rain (Ahmed et al., 2016). A 16th-century English antiquarian noted that the green woodpecker (*Picus viridis*, Linnaeus, 1758) was used by the druids for divination (Warren-Chadd and Taylor, 2016) due to its laughing vocal sound that supposedly heralds rain (the bird is laughing at the sun). In Orkney, among archipelagos located in the North Sea and near the north of Scotland, and in Shetland, locals named *Gavia stellate* (Pontoppidan, 1763) the "rain goose" because its drawn-out wailing vocalization indicates imminent rain, while a different, more exuberant, kind of call is a prediction that the clouds will clear (Warren-Chadd and Taylor, 2016). In Delaware Indian folklore, the red-throated loon plays a key role because it helped survivors of a great flood by finding them land, and has since served to predict rain (Trail, 2007). The marbled teal, *Marmaronetta angustirostris* (Ménétriés, 1832), is thought to indicate early monsoons by exhibiting a distinct agitated behavior during different periods of the day (Ahmed et al., 2016). In many traditional African cultures, the booming vocalization of the southern ground hornbill, *Bucorvus leadbeateri* (Vigors, 1825), is an assured predictor of precipitation, and due to its large size and loud calls, it has become a target of hunters (Warren-Chadd and Taylor, 2016). The same is true for the shouts of the yellow-tailed black-cockatoo, *Zanda funereal* (Shaw, 1794), in Australia (Warren-Chadd and Taylor, 2016). According to Shoko and Shoko (2013), the Australian aborigines consult the masked lapwing, *Vanellus miles* (Boddaert, 1783), by looking to see whether it lays its eggs or not on the upper part of a field. By doing so, the natives know if it will be a good rainy season or heavy drought. Pigeons have also served as a source of prediction for many cultures, but especially in Asia where people recognize that when a pigeon sings from morning to evening, it will rain in around 15 days (Ahmed et al., 2016). Interestingly, the slaty-breasted wood-rail, *Aramides saracura* (Spix, 1825) is considered a good predictor of heavy rain because of its vocalization behavior (Ruoso, 2012). Indians and Pakistanis consider crows and owls to be an omen or a sign of luck, depending on their behavior, bringing a good rainy season or bad luck (Ahmed et al., 2016).

According to some Scottish mythology, when an owl frequently whoops loudly, it is deemed, by most, as a sign of pleasant weather (Saxby and Clouston, 1892). The cry of the owl, like that of the raven, is also significant to the weather-lore

of several districts of England. According to a local statement, when the owl screeches during foul weather it is a sign of fair weather ahead; others state that the owls cry is sometimes taken as an indication of approaching hail or rain, accompanied by lightning. Because of this link between owls and bad weather, it was a custom, until the twentieth century to nail the body of an owl to a barn door to ward off lightning (Sherman, 2008). The Chinese associate owls with the prediction of thunder and lightning, and owl effigies are placed in each corner of a home to protect it from lightning strikes (Sherman, 2008; Weinstein, 1988).

In an old chapbook entitled *The Shepherd's Prognostication for the Weather*, printed in 1573, it is said that "if ravens be seen to stand gaping toward the sun, it is a manifest sign of extreme heat to follow" (Godfridus, 1983). In some districts of ancient Scotland, ravens build their nests in sea-cliffs, and it was believed that if they make short flights inland, it is an indication of stormy weather, but if they make a strong flight inland for a considerable distance, it is a token of fair weather (Gregor, 1881).

Freeland (2006) observed that agricultural workers of 19th century United Kingdom, relied on typical rhymes and sayings about animals to forecast the weather. For instance, "*An early cuckoo heralds a fine summer*" predicts a good summer if one hears a cuckoo before St George's Day on 23 April, and "*Seagull, seagull, stay on the sand; it's never fair weather if you're over land*," means that in calm weather seagulls obtain their food from the sea and shoreline; therefore, seagulls are believed to predict good weather when hovering over coastal areas (Freeland, 2006). The early coming of other migratory birds in late April, May, and June, such as swallows and martins, was taken as a promising omen, which assured dry, warm conditions throughout their nesting seasons (Giles, 1990). Simpson (1973) stressed that nonmigratory or solitary species, such as crows, wood pigeons, and thrushes, were rarely observed by peasants of northeastern United Kingdom during the nesting season, and according to local folklores, the higher these birds built their nests, the greater the probability that the summer would occur. Another example according to the local peasants would be if swallows and martins were seen in groups of 10 or more flying high and repeatedly making circular flights, they were said to be "wheeling" or "drawing water from the well," a typical sign that rain was on the way.

In Brazil, many bird species are recognized as indicators of coming rainfall in the dry northeast region (Araujo et al., 2005; Bezerra et al., 2013; Marques, 1999). One example is *Turdus rufiventris* (rufous-bellied thrush), whose vocalization is believed to have the power of predicting weather and climatic events. The call of this species, as well as others, have been cited by Araujo et al. (2005) and Marques (1999) as being used by local populations to predict rainfall.

Similar to birds, wild mammals constitute a key group of predictors of weather conditions for many societies. The behavior of livestock animals, for example, is considered to forecast weather and the onset of seasons. Observation of the behavioral and/or morphological characteristics of mammals, whether domestic or wild, yields basic information used in the construction of weather forecasts in various locations. For example, some mammal species have the ability to change color to blend into their environments. Rabbits, for instance, change the color of their fur from white to brown prior to the beginning of snowmelt (Sandoval Salinasa et al., 2016). Indeed, some European cultures have used animal oracles to predict weather for centuries, such as watching hibernating animals, including bears, badgers, and hedgehogs, for signs of spring (Ring, 2008). Medieval Germans often relied on the shadow of a badger to make predictions about the coming spring. If the badger saw his shadow on a particular day, it meant that more winter would be forthcoming; if he did not see his shadow, there would be an early onset of spring. The Europeans brought this type

of weather forecasting to North America, and replaced the badger with the groundhog in a tradition celebrated every February 2nd in the state of Pennsylvania, United States (Ring, 2008). Still today, North Americans observe the way muskrat, *Ondatra zibethicus* (Linnaeus, 1766), and beaver, *Castor canadensis* (Kuhl, 1820), build their huts and how rabbits feed during autumn (Klemm and McPherson, 2017; Peppler, 2010). According to Huntington et al. (2005), native settlements of the Arctic observed that some species of deer and reindeer would seek cover among low-branched trees, such as hemlocks and pines, in advance of a rain or snow storm. Some American tales predict that when squirrels gather a large supply of nuts, a cold winter can be expected (Mallery, 2000).

Local communities of the Lushoto district of Tanzania use the occurrence of wild animals in villages to predict weather and climate. For example, baboons entering a village during the dry season indicates a good forthcoming rainy season (Mahoo et al., 2015). Even the sight of lemurs foraging around farmhouses in villages near Mount Kilimanjaro, in the Moshi rural district of Tanzania, is considered a good predictor of the onset rainfall (Chengula and Nyambo, 2016). Remarkably, in Santa Cruz do Sul, Brazil, the vocal behavior of howler monkeys is considered a predictor of good heavy rain (Ruoso, 2012). Even though they are used by Tanzanian natives for multiple purposes, pangolins are recognized as rainfall indicators by locals of the Mahenge and Ismani wards of the Morogoro and Iringa regions (Kijazi et al., 2013). Some traditional communities of the Caatinga biome, a semiarid region of Brazil, believe that if a pregnant armadillo was seen during the month of December, there would be good rains ahead (Abrantes et al., 2011). In some regions of England and the United States, it is believed that a bat circling a house at least three times is a warning of impending death. However, a bat flying playfully is a good omen, forecasting fair weather; the latter contains a bit of truth, since better atmospheric conditions mean easier flying for bats (Sherman, 2008). According to Muguti and Maposa (2012), when Zimbabweans see bats, locally known as muremwaremwa, flying in a certain area, it indicates that rainfall will be irregular. On the other hand, if they occasionally land on the ground, particularly as a swarm, it signifies good rainfall throughout the season (Muguti and Maposa, 2012). Carnivores, such as the leopard, *Panthera pardus* (Linnaeus, 1758), and the spotted hyena, *Crocuta crocuta* (Erxleben, 1777), are considered climate ethnozooindicators by some traditional cultures in Tanzania. Mahoo et al. (2015) observed that locals of the Lushoto district considered the appearance of leopards as a prediction of a good rainy season. In the village of Maluga, in central Tanzania, subsistence farmers commonly distinguish and use certain calls produced by hyenas to foretell the rainy season (Elia et al., 2014).

It is worth mentioning that the behavioral displays of some mammal species in response to changes in weather are scientifically demonstrated to be accurate climate forecasters around the globe. For example, Bartlam-Brooks et al. (2013) observed that zebras in Botswana heed subtle weather and vegetation clues when choosing when and how to move to greener pastures. The animals seemed to anticipate food and water availability at their annual migration destination and fine-tune their movements accordingly, for example, by delaying departure or reversing direction when rainfall was unseasonably late (Bartlam-Brooks et al., 2013).

In many traditional cultures worldwide, domestic animals are widely used for climate prediction. For example, cattle are symbols of fertility and worship, as well as predictors of climate (Egeru, 2012; Nyong et al., 2007; UNEP, 2008). In Pakistan, the way a cow sits is used as a weather predictor, such that having three legs under itself and one leg out, or even if it sits on the sand, is taken as an indication that rain is forthcoming. In India, the smell of cow urine can predict rain, while if cows lick each other it is an indication of drought (Ahmed et al., 2016). Berkeley and Linklater (2010) pointed

out that in some provinces of Africa, farmers rely on some sort of behavior by cattle herds for predicting the weather. For instance, an ox hesitant to go into a veld for grazing indicates the onset of rains within a few hours, as does the suddenly lying down in a field by cows. Goats and sheep can predict the weather by exhibiting a similar behavior. For example, in some Pakistani communities, goats entering properties at night time and roaming toward the eastern side is taken as a prediction of rainfall in the next week or two (Ahmed et al., 2016). Locals of the Lushoto district of Tanzania interpret the frequent flapping of ears of sheep, goats, and cattle, at any time during the dry season, as indicative that the onset of rain is near, and that there are good prospects for the coming season (Mahoo et al., 2015). Shoko and Shoko (2013) observed that in the Mberengwa district of Zimbabwe, locals believe that injuries, such as swellings, on the lower extensions of a camel's leg are indications that rainfall is ahead, and water must be stored as quickly as possible. Mapara (2009) stresses that by simple observation of the behavior of fowl, including chickens, people are able to predict whether rains are going to stop or not. If fowl continue to feed when it is raining, it is expected that it will rain for the next few days. For traditional cultures in regions of southwestern Africa and Tanzania, goats and domestic dogs circling around themselves give signs of onset of rains and also their mating and doing much noise during night time is a typical sign of coming rain (Chengula and Nyambo, 2016).

In contrast to most local communities, who observe environmental indicators for the prediction of weather and climate, some ethnic groups use divination and other spiritual prophesies. In the province of Namcntenga in Burkina Faso (Africa), *Tengsoba* is the eldest descendant of an ancient clan and is considered by the locals to be a shaman authority. Furthermore, other traditional experts similarly receive forecast insights from deities via dreams. Traditionally, animal sacrifices are made to appease earth spirits and influence the occurrence of rains. Predictions are drawn from the behavior of slaughtered animals, including the length of time it takes for a slaughtered animal to fall, which direction it falls, and where the blood spills (Roncoli et al., 2001). Rain fall after a ritual is considered to be well-accepted offering by the deities. Among the Hausa people in some pastoral areas of northern Nigeria, offerings and sacrifices, by means of slaughtering bulls are performed to ward off events of famine, drought, plague, and unproductive fields (Musa and Omokore, 2011; Musa, 2006). Peppler (2010) stated that during autumn, some American Indian tribes slaughtered pigs to look at their spleen, and if it was thick and rugose, the natives would believe a harsh winter was ahead that year. Similarly, the pastoralists of northern Kenya developed their sense of predicting the weather by observing the intestines of slaughtered animals (wild and domestic), and if their color was dark, it was taken as a sign of coming drought or war (Kagunyu et al., 2016). Also in Kenya, and northern Tanzania, the elders of Maasai regularly predict weather using the behavior of certain livestock animals. Goat intestines would be examined by an expert Maasai and if watery cysts were found on them during the month of August it was considered a sign of an imminent rainy season, but if the stomach was found partially or completely empty, it indicated drought, famine, hostility or war (UNEP, 2008). Risiro et al. (2012) pointed out that rain-making ceremonies are performed in sacred forests of some districts of Manicaland, Zimbabwe. These not only involved the brewing of beer, roasting meat, singing, and dancing, but the prohibition of killing sacred animals, such as cuckoo birds and frogs under circumstances of drought, so as not to displease ancestral spirits. In the Teso subregion of eastern Uganda, the killing of an Abyssinian hornbill, *Bucorvus abyssinicus* (Boddaert, 1783), is considered a fault and brings severe droughts to villagers by deities;

the offender would then be "buried" in the mud of a wetland in a ritual ceremony to bring back the rainy season (Egeru, 2012).

FINAL REMARKS

Since the beginning of human history, variation in climate has always received special attention, especially considering its influence on the life of plants and animals on which humankind depends. Human activities linked to these resources, such as hunting, fishing, agriculture, and the raising of livestock, depend directly on climate, and so attempts to predict weather to coexist with natural adversities has always been part of human history.

Therefore, animals have provided a fundamental service to humans since they are sensitive to variations in climate, which influences their behavioral, physiological, and reproductive characteristics. Human populations worldwide have come to appreciate the particularities of animals through observations from daily interactions. The result has been an accumulation of knowledge that helps humans develop climatic predictions, which influence various aspects of human life.

In this chapter we proposed the term "climate ethnozooindicators" in reference to animals that are used by humans to predict climatic events. There is a considerable richness of species that are used as ethnozooindicators, according to the peculiarities of the fauna of a given region or country. Species of invertebrates (mainly arthropods), and vertebrates, especially amphibians and birds, are taxa that are, as we have seen, widely used as ethnozooindicators. The predictions these animals provide are important to a great variety of human activities, and provide insight into the understanding of wildlife and ecology by local peoples. From an ethnozoological perspective, the use of animals as ethnozooindicators represents one of the oldest and most widespread forms of interaction between humans and nonhuman animals. However, the need for additional studies that seek to document this knowledge is urgent, especially considering that in many cases this knowledge has been lost, either due to a lack of interest on behalf of younger generations, or due to the extinction of important ethnozooindicator species.

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