ANIMAL BEHAVIOR

AS A WEATHER

PREDICTOR

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CHAPTER ONE

INTRODUCTION

This thesis examines the possibility that animal behavior can be used to indicate future weather. The literature review covers current and historical writing as well as anecdotes and traditional weather lore. Chapter Four presents the results of a study of bird activity at bird feeders as an indicator of winter storms.

Personal observations and anecdotes suggest that birds feed heavily a few hours before winter storms arrive in their area. Studies were conducted in Santa Fe, New Mexico, and Tulsa, Oklahoma, to examine the relationship between seed consumption at bird feeders and winter storms. Neither study demonstrated an observable relationship between winter storms involving precipitation and decreased time between feeder refills, the means by which increased seed consumption was measured.

These results do not justify dismissing all anecdotal information regarding animal behavior as an indicator of weather. Since this is a topic that has previously been overlooked by the scientific community, the appendix contains two model studies that can be used to examine the role of specific animal behaviors as indicators for weather events in the immediate future.

The Problem

There have been more federally-declared disasters in the United States in the 1990s than during any previous decade in which records were kept. Federally-declared disasters are events of a magnitude that overwhelm the resources of state and local governments and require financial and other assistance from the federal government (Federal Emergency Management Agency, September 6, 1999). By May 31, 1999, disasters for the 1990s numbered 425. This number exceeds the decade in second place, the 1970s, by almost 100 (Jaffe, 1999).

Although the disasters of the 1990s included events such as the bombings of the New York World Trade Center and the Murrah Federal Building in Oklahoma City, the majority were "natural disasters:" floods, storms, tornadoes, and earthquakes (Jaffe, 1999).

Most of the decade's natural disasters were weather-related. Forty percent of the declared disasters were caused by floods. The next highest category is tornadoes at 15%, then winter storms and hurricanes at 10% each (Jaffe, 1999).

In 1998, there were more than 400 weather-related deaths from droughts, hurricanes, tornadoes, floods, and ice storms (Jaffe, 1999). The Mayo Clinic (1998) reported the deadliest weather to be flash flooding, lightning, tornadoes, and hurricanes respectively.

Without current, increasingly accurate weather forecasting techniques, more fatalities would probably occur. Although more than 40 people died in the May 3, 1999, tornadoes in central Oklahoma and Kansas, early warnings of up to an hour before the storms struck probably saved many lives (National Climate Data Center/National Oceanic and Atmospheric Administration, May 28, 1999).

According to a spokesman for the National Severe Storms Laboratory, the cause behind the increase in disasters is not necessarily more disasters, but more people living in areas where disasters normally occur. Population growth and the resulting development of human habitat have created bigger and more vulnerable targets (Jaffe, 1999).

Effective weather warning systems such as those used during the May 3, 1999, tornado outbreak in Oklahoma and Kansas are dependent on rapid and widespread dissemination of information. Timely weather warnings require ready access to radio, television, the Internet or other electronic devices. For a variety of reasons, some people do not have such access.

Just a few decades ago, the lives and livelihoods of farmers, travelers, sailors and many other people depended on a personal ability to anticipate the weather. Ignorance of approaching storms resulted in shipwrecks and frostbite; disregarding the signs of a late freeze meant ruined crops and loss of livestock (Garriott, 1903).

By similar necessity, non-human animals have been forced to develop abilities to "predict" upcoming weather events to survive and reproduce, and thus pass on their weather-predicting skills, whether learned or innate (Tributsch, 1978). Animals often appear to react to a change in weather before it occurs, and humans can still use changes in animal behavior as a basis for weather prediction, just as they did for thousands of years before modern weather-forecasting technologies ("Animal weather prophets," 1920). Such information can be especially useful for people whose activities do not allow easy access to conventional weather warnings.

In some cases, animal behavior may actually prove to be a more immediately useful weather indicator than conventional forecasting technology. Sattler (1978) pointed out that animals constantly assess conditions in their immediate territories as a survival mechanism, while weather services tend to make long-range predictions for large areas. For farmers or others engaged in outdoor activities, early warning of a storm in the vicinity can be more helpful than information about statewide weather trends.

The purpose of this thesis is to investigate the validity of animal behavior as a weather forecasting tool. If certain types of animal behavior proved to be accurate indicators of certain types of weather, this information could be used by hikers, hunters, farmers, boaters and others whose activities often take them away from electronically-transmitted broadcasts.

Observing animal behavior to predict the weather requires a close look at nature. Such observation not only can produce the immediate benefit of accurate weather forecasting, but also a more intimate connection with the natural world and more interest in scientific processes.

CHAPTER TWO

REVIEW OF THE LITERATURE

Scientific Studies

An extensive search for scientific studies on animal behavior as an indicator of future weather produced virtually no information. Research was conducted at several university libraries, via Internet searches of Library of Congress records, and with the assistance of personnel at specialized libraries such as those of the National Park Service and National Oceanic and Atmospheric Administration. Other inquiries were made through university professors in natural sciences and meteorology and via queries posted on the National Park Service electronic bulletin boards for migratory bird studies, interpretation, education and natural resources.

These investigations yielded only two scientific discussions of animal behavior as a weather indicator: Garriott's 1903 USDA Weather Bureau Bulletin and a 1977 study published by Chen in China. Chen's work has been translated into English, but the translation was never published; the translator's review of the book was published in 1996 (Houghton, 1996).

Garriott (1903) pointed out that folklore has been the primary means of transmitting knowledge of animal behavior and its relation to future weather. He added that such information has sometimes lost its usefulness by transfer from one area to another, a point also noted by Ormond (1981) and Schmid (1986).

Garriott (1903) argued that animals are not reliable long-range weather forecasters but that their behavior can indicate certain weather changes from one to 12 hours in advance. He mentioned Dr. C.C. Abbott's twenty-year study of fall house construction by muskrats (*Ondatra zibethica*) and fall nut storage by squirrels as predictors of the following winter's weather. Abbott's conclusion that there was no correlation between these behaviors and the subsequent weather was reported in the February 13, 1883, meeting minutes of the Trenton Natural Historical Society.

Garriott (1903) and many other writers suggested scientific explanations for animal behaviors that seem to indicate changes in the weather. For example, birds flying high traditionally predict fair weather while birds flying low indicate a coming storm. Fair weather is associated with greater air pressure that provides a denser atmosphere more capable of sustaining flight; the lower pressure that often precedes a storm means birds must exert more effort when flying and encourages flight at lower altitudes. Flying insects are similarly affected, giving birds that catch insects on the wing additional incentive to "fly low" before a storm.

A change of one inch in a barometer's mercurial column means a change of about 70 pounds per square foot of surface. A change of one barometric inch during a 24-hour period means a change of about one-half ton in atmospheric pressure for the average human. Garriott (1903) argued that it is not difficult to accept that such a change could be discernible to living creatures able to associate it with a corresponding change in weather. Animal behavioral patterns "predicting" weather are simply attempts to take advantage of favorable conditions or to minimize harm from coming storms.

Wood (1996) noted that studies of the effects of weather on human populations have been frustrating and inconclusive due to the difficulty of separating possible causes from one another. Studies in artificial weather chambers have shown some success in this area and suggest that Garriott's idea of change as the crucial factor could be correct. Weather chamber studies demonstrate that rising humidity coupled with falling barometric pressure often produce a noticeable effect on human subjects, but it seems that it is the change itself, not a change to or from a specific range of humidity or air pressure, that produces the reaction.

Chen's 1977 book compares weather data from China to traditional Chinese weather forecasting proverbs. Houghton's (1996) review of the book pointed out that China's long history as an agricultural society provided ample need and opportunity for the development and transmittal of "folk" forecasting methods. Until at least the 1970s, weather proverbs were the chief forecasting tool of Chinese farmers.

Chen not only recorded weather proverbs, but also compared them with data from China's centuries-long weather records to discern their usefulness. Houghton (1996) states that Chen's comparisons found a reliability rate ranging from 75 to 95% for some proverbs, but does not describe Chen's method of comparison.

Historical Background

Although modern science has paid little attention to animal behavior as a means of weather forecasting, for thousands of years in China and elsewhere, it was considered a reliable tool. Sattler (1978) credited the Babylonians as the first people known to use nature systematically as a weather indicator and to write down signs and predictions.

Heninger (1968) wrote that the most influential ancient writer on weather signs was Aristotle. His *Meteorologica* provided the first record of an attempt to explain weather as part of a greater system and included references to previous authors who had studied various aspects of weather without developing general theories about the forces behind it.

The Historia Naturalis of Pliny the Elder described weather-predicting behaviors in animals ranging from cuttlefish to oxen (*Bos taurus*) (Tributsch, 1978). Virgil's Georgics, a poetic guide to agriculture, covered the topic in depth, noting that "Rain never need surprise us unprepared" (Virgil, 1956).

The meteorological observations of classical writers influenced medieval churchmen, including Thomas Aquinas, as well as early scientific thinkers such as England's Venerable Bede and Roger Bacon (Heninger, 1968). Almanacs containing weather lore became popular with farmers and sailors by 1600, and during the following decades the weather theories of many earlier writers were translated into English (Heninger, 1968).

Heninger explained that by the middle of the sixteenth century, two schools of thought had developed regarding meteorological phenomena and predictions. One was a theoretical "pure" science based on Aristotle's ideas; the other was the applied discipline of astrologers. This split was typical of Renaissance thinking in general: the ideas of the time were affected by influences as diverse as science, magic, Christian scripture and classical mythology. Heninger credits the development of dependable instruments of measurement as the turning point in scientific meteorological studies: Galileo's use of the thermometer in 1607 and Torricelli's invention of an accurate barometer in 1643 meant that subjective observations could be quantified and compared.

Over the following centuries, the acceptance of animal behavior as an indicator of future weather has become less evident in literature, in nature writing and certainly in scientific works.

In his essay, "A Sharp Lookout," American naturalist John Burroughs (1886) was unsure whether animal behavior was even a reliable short-term weather predictor. He agreed that swallows flying high generally indicated good weather but noted that he had seen bees leave their hives in the face of an imminent storm, behavior contrary to popular lore. Burroughs' essay also refuted his earlier belief that muskrats could predict an early or severe winter, noting that the time or location chosen for house construction by muskrats did not seem related to the weather that followed. Other important natural historians, including John Muir, Barry Lopez, Terry Tempest-Williams, and Aldo Leopold, seem equally uncertain or do not mention a possible connection between animal behavior and impending weather.

Modern Uses of Traditional Lore

There have been few serious modern attempts to consider animal behavior in light of the weather that folklore claims it predicts. In the United States, Groundhog Day provides the best-known weather prediction based on animal behavior. According to Freier (1992) and Watson (1993), the tradition of Groundhog Day originated with Candlemas Day in England. Candlemas falls on February 2, statistically about a week after the coldest days of winter. A clear day on Candlemas produces the shadow that frightens the groundhog (*Marmota monax*) back into its hole for six more weeks of winter. Clear weather also indicates a high-pressure system, which in early February in England is usually cold. The cloud cover of a low-pressure system encourages the groundhog to stay above ground; low-pressure systems usually mean warmer temperatures and perhaps an early spring.

"What kind of winter will we have?" (1998), an article in Countryside and Small Stock Journal, reported the results of an informal weather study from Mount Nebo, Oregon. Local lore promised fair weather if goats (*Capra* sp.) grazed high on the mountain, rain if they fed near its base. A radio personality from a neighboring town recorded goat grazing versus actual weather for a week in May 1971. When the goats' behavior predicted the weather accurately 90% of the time, goat weather forecasts began and a "Goat Observation Corps" formed. The goats ended their careers in the early 1990s when they were declared a traffic hazard and retired to a nearby farm (Reed, 1992/1993).

Leeches and frogs have long been kept in jars of water and used as barometers in southern and central Europe. The frog's croaking warns of rain; for fair weather, the frog climbs the little ladder provided in its jar and remains quiet. Leeches supposedly predict rain by climbing out of the water in their jars and forecast sunshine by remaining immersed (Sattler, 1978).

In 1850, an English doctor, George Merryweather, carried the idea of the animal barometer to extremes (Figure 1). Watson (1993) and Sattler (1978) described his Tempest Prognosticator, which Merryweather called "'an Atmospheric Electromagnetic Telegraph conducted by Animal Instinct.'" The barometer looked something like a carousel with 12 bottles at its base; at its top was a bell surrounded by 12 hammers. Each bottle had a metal tube in its neck that contained a piece of whalebone and a small wire attached to a golden chain, which in turned was attached to one of the hammers. Each bottle also held a leech and a little rainwater. When a storm approached, the leech responded to the change in atmospheric pressure by crawling to the top of the bottle where it dislodged the whalebone, disturbing the wire and causing the hammer to strike the bell.

Insects can serve as thermometers, according to Sloane (1952). Figure 2 illustrates the variety of katydid calls that signify different Fahrenheit temperature ranges as well as the behaviors of bees, ants and other insects at particular temperatures. More specific Fahrenheit temperature readings can be obtained by counting the chirps of the black field cricket (*Gryllus pennsylvanicus*) for 14 seconds and adding 40.

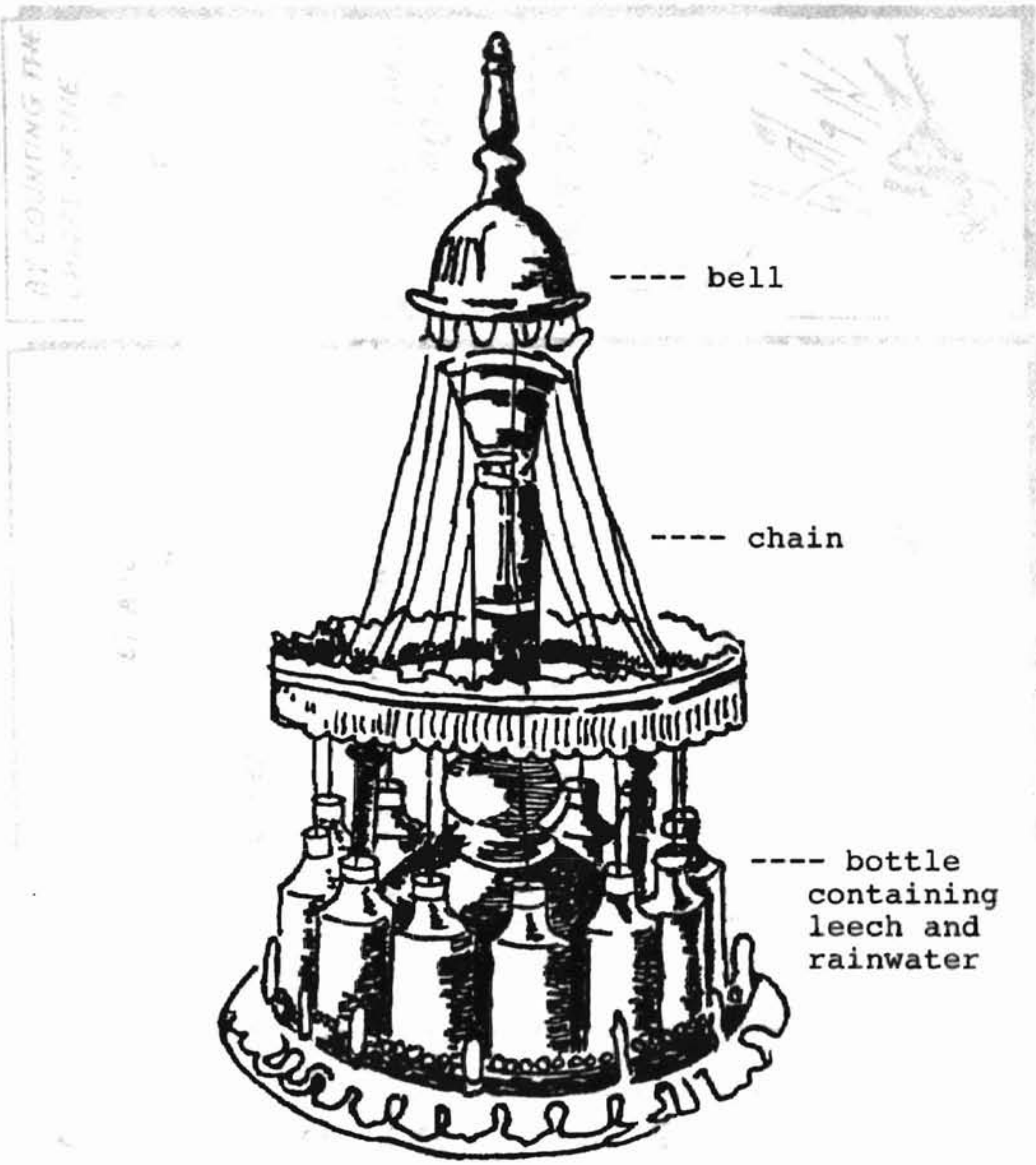


Figure 1. George Merryweather's 1850 barometer, the "Tempest Prognosticator." Each of the 12 bottles held rainwater and a leech. The leech reacted to the changing air pressure of an approaching storm by crawling to the bottle's top, thereby dislodging a piece of whalebone and wire attached to a chain. Movement of the chain caused a hammer to strike a bell. Based on a drawing in Acts of God: "The old farmer's almanac" unpredictable guide to weather and natural disasters by B.A. Watson and the editors of The old farmer's almanac. 1993. New York: Random House.

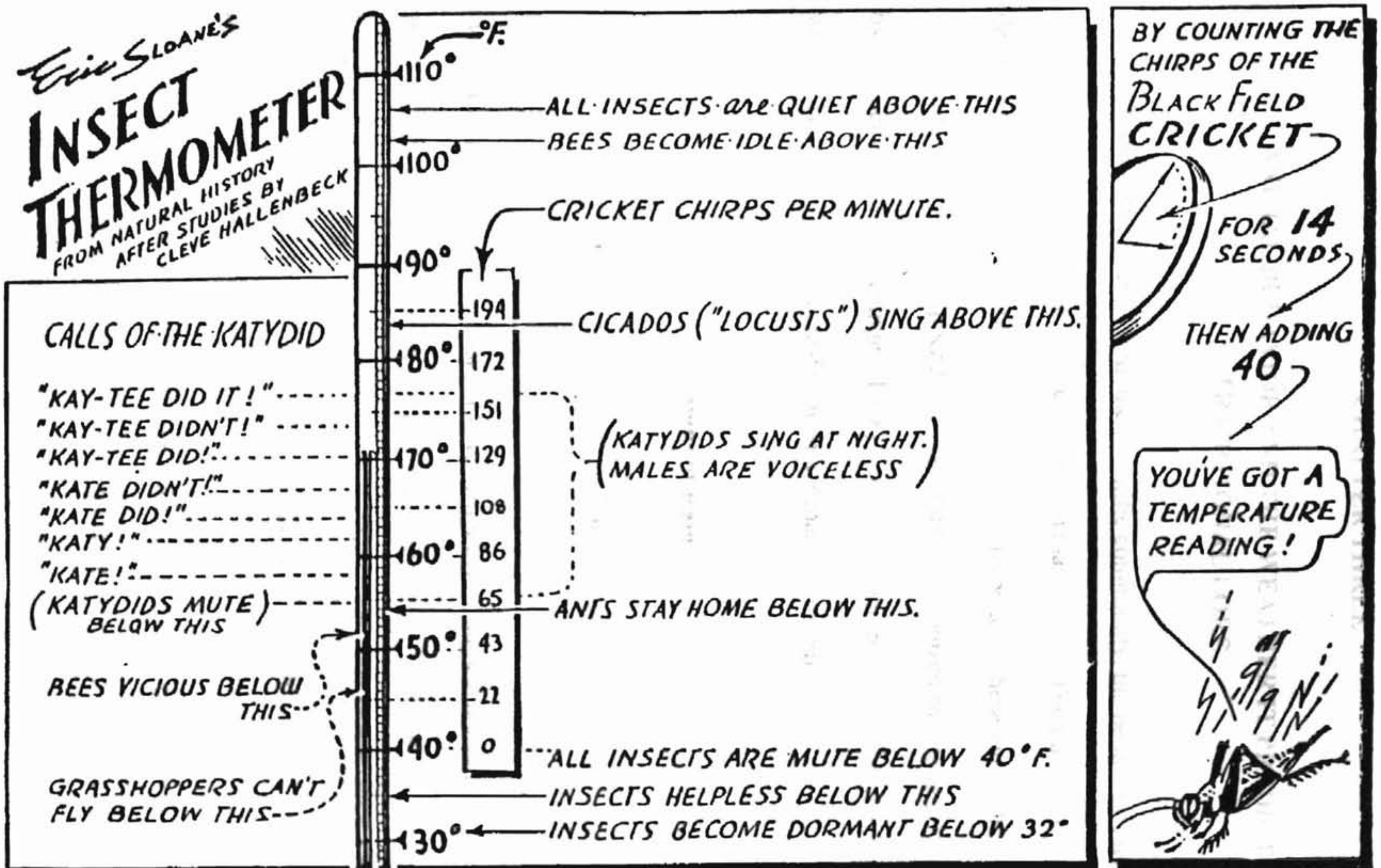


Figure 2. Eric Sloane's insect thermometer provides Fahrenheit readings based on insect calls and behavior. From Eric Sloane's weather book by E. Sloane. 1952. New York: Hawthorn Books.

CHAPTER THREE

ANIMAL BEHAVIOR AND THE WEATHER IT PREDICTS: TRADITIONAL LORE

Despite little interest from the scientific community, the belief that animal behavior can indicate future weather persists in many areas. The traditions described below demonstrate the prevalence of this belief. These indicators are provided in table form in Appendix C. One table is organized by animal; the other by weather predicted. Heninger (1968) provided a comprehensive list of animal weather signs from ancient, medieval, and Renaissance authorities.

Signs of Rain

Birds figure prominently as traditional indicators for rain: "If the goose honks high, fair weather/If the goose honks low, foul weather." Other couplets mention similar behavior by rooks (*Corvus frugilegus*), larks and swallows, or perching high or low rather than flying (Freier, 1992; Lee, 1998; Sloane, 1952; Tributsch, 1978). Sighting a swan (*Cygnus* sp.) flying against the wind is said to be a sure predictor of a hurricane within 24 hours, and most likely within 12 (Watson, 1993).

Bird songs are believed to be rain indicators, although traditions are contradictory. A change in song is the simplest clue. Before a rain, the chaffinch (*Fringilla coelebs*), American and Eurasian robin (American *Turdus migratorius*;

Eurasian *Erithacus rubecula*), and titmouse (*Parus* sp.) are said to sing from treetops and sing unusually long or differently constructed songs (P. Cooke, personal communication, September 19, 1998; Freier, 1992; Tributsch, 1978). Similarly, unusually loud calls have been attributed to peacocks (*Pavo* sp.), ravens (*Corvus* sp.), geese, ducks, owls, sparrows, and parrots before rain (Barnes, 1998; Freier, 1992; Watson, 1993).

Crows (*Corvus* sp.), swallows and gulls call and fly in circles before a rainstorm (Freier, 1992). The Zuni Indians say that chimney swallows circle and call before rain (Garriott, 1971). Roosters (*Gallus gallus*) reportedly indicate rain by crowing in the afternoon or at night (Freier, 1992; Schmid, 1986; Watson, 1993). A hen crowing predicts a flood (Watson, 1993). In Germany, the plover is called the rain piper, *Regenpfeifer*, for its habit of calling before a storm (Tributsch, 1978).

Falling barometric pressure appears to be the immediate cause of this behavior. The reduced air pressure outside the body encourages the formation of bubbles inside the body as dissolved gases are released to equalize pressure. The bubbles irritate nerve synapses and may encourage behavior such as erratic movement and territorial singing or crowing (Freier, 1992). However, these audible warnings of change and Freier's explanation are contradicted by the traditional wisdom that "When birds stop singing,/A storm is on the way" Freier (1992).

Aquatic animals may also react to decreased air pressure. Porpoises (*Phocaena* sp.) are thought to be more active, dolphins swim to windward, crabs emerge on the shore, and, as anglers from Europe to China have noted, fish rise and attempt to feed (Freier, 1992; Golad, 1991; Sattler, 1978; Tributsch, 1978; Watson, 1993). This last behavior may be related to the low-pressure center that usually develops as the barometer falls. Again, bubbles develop to equalize air pressure, this time occurring in decaying plant material in the water. The bubbles rise to the water's surface, carrying detritus with them and providing feeding opportunities for fish (Freier, 1992).

Iguanas hide in vegetation or among rocks before rain (M. Banuelos Connell, personal communication, January 20 1999). Desert tortoises (*Gopherus agassizzii*), on the other hand, emerge from their underground burrows prior to rain and move to depressions where rainwater may collect (K. Hawk, personal communication, January 27, 1999).

Before particularly violent storms, marine animals and sea and shore birds have been observed moving inland (Newman, 1996; Prince, 1974; S. Snyder, personal communication, January 27, 1999; Tributsch, 1978). Barnes (1998) wrote that in 1881, the Army's chief signal officer in Morehead City, North Carolina, noticed that "'the skies became blackened with seabirds of every kind, size, color, and description, moving rapidly towards the west.'" The officer also reported enormous schools of fish and numerous porpoises moving upriver, "'so thick that the river looked like a slowly moving stream of ink.'" The next day, the area was struck by a hurricane.

According to traditions from Europe, China and Australia, ants, crickets, earthworms and roaches become more active before a rain (Freier, 1992; Houghton, 1996; Lee, 1998; Tributsch, 1978). Ants will move eggs to higher ground, a phenomenon first recorded by the Greek writer Theophrastus in the fourth century B.C. (Freier, 1992; Lee, 1998). Ants will also increase the size of the cone of soil that surrounds the nest entrance or close off the entrance altogether (Freier, 1992; Watson, 1993). Ants are more likely to travel in a straight line before rain; increased humidity reduces the volatility of scents and pheromones and trails of these substances last longer, apparently reducing the need to cast about for the scent (Freier, 1992; Schmid, 1986).

Other insects also seem to be affected by approaching storms. Flies enter houses (Freier, 1992). Fleas bite more frequently (Elliot, 1996). Honey bees stay closer to the hive on cloudy days and during rainstorms: the polarized light they use for navigation is disrupted by the moisture contained in clouds (Freier, 1992; Schmid, 1986; Watson, 1993). Biting mosquitoes seem to be more numerous before a rain; the darker skies storms bring may trigger behavior usually reserved for the evening hours ("Six weird ways to predict the weather," 1998; Watson, 1993).

Increased activity by some insects before rain also encourages activity by birds that catch and eat insects while in flight; more opportunities for prey outweigh the difficulties of flying in denser, more humid air. Because of those difficulties, however, both insects and the birds pursuing them generally fly closer to the ground (Lee, 1998; Tributsch, 1978; Watson, 1993).

Spiders are thought to be highly sensitive to changes in weather because of the effect on their webs. Many American Indian groups hold that spiders enlarge and repair their webs before bad weather. Freier (1992) explained that since increased humidity results in denser air, flying becomes more difficult for tiny insects and they are more likely to fall victim to a spider's web. Web threads also tend to absorb moisture when the air is humid, causing them to tighten and break and requiring increased maintenance.

Mammals are also affected by coming storms. Before a storm, wild and domestic sheep (*Ovis* sp.), deer, elk (*Cervus canadensis*), and cattle (*Bos* sp.) will move to lower elevations (Barnes, 1998; Freier, 1992; Newman, 1996; Watson, 1993). In Germany, red (*Cervus etaphus*) and roe (*Capreolus capreolus*) deer browsing in clearings during daylight hours are considered a sure indicator of rain; fallow deer (*Dama dama*) on the other hand, hide in thickets before a storm (Tributsch, 1978).

Tributsch (1978) noted that the storm survival strategies of deer seem effective. After a particularly violent windstorm in 1972 in Germany, a survey of forestry officers and district hunt managers revealed that on the evening and morning preceding the storm, rabbits and red, roe and fallow deer were seen in clearings and open fields, avoiding wooded areas. A few of the smaller animals were seen hiding in thickets, which presumably might afford some protection from falling trees. Some animals even hid under bridges or approached humans or their buildings. Although over 211,000 hectares of forest were affected by the storm, only 37 dead animals were found.

Cows are thought to exhibit a variety of weather-predicting behaviors: they will huddle together and may lay down, the latter perhaps explainable as a reaction to arthritic discomfort brought on by increased humidity (Freier, 1992; Schmid, 1986; "Six weird ways to predict the weather," 1998). Before a storm cows are also said to sniff the air, lie on their right sides, lick their forefeet, act playfully, and quit giving milk (Pancake, 1983; Watson, 1993).

Sheep become frisky, goats butt aggressively, and horses (*Equus caballus*) shy for no apparent reason before rainstorms (Barnes, 1998; Freier, 1992). Mules (*Equus* sp.) display unusual behavior such as laying back their ears and general agitation before violent storms (M. Crooks, personal communication, January 25, 1999). In Italy, common wisdom is that before a rain chickens, cattle and goats eat more than normally and refuse to enter their shelters (Tributsch, 1978). Donkeys (*Equus asinus*) bray more, hang their ears down and forward, and rub against walls (Freier, 1992; Watson, 1993).

Dogs (*Canis familiaris*) roll on their backs and straighten their tails before a storm; although dogs are generally considered to show signs of drowsiness before rain, the Swiss believe that spaniels are especially sleepy (Freier, 1992; Schmid, 1986; Watson, 1993). On the other hand, mice, squirrels and rabbits become active, even frolicsome (Freier, 1992; Sattler, 1978). Freier (1992) explained many of these behaviors by falling barometric pressure and the equalizing but irritating release of gases in the body. Thus dogs and cats (*Felis catus*) may eat grass before rain to induce vomiting and relieve pressure.

As with ants rain-proofing their nests, many mammals attempt to protect their homes from rain or rising water. Before a rain, squirrels can be seen reinforcing their nests (Sattler, 1978). Pigs carry sticks and straw in their mouths and sometimes pile them up in a nest (Freier, 1992; Watson, 1993). Prairie dogs (*Cynomys* sp.) cover their burrow entrances with grass (Barnes, 1998). Bats are affected in much the same way as birds: they can be heard crying out and seen flying low to seek shelter before a storm (Sattler, 1978, Sloane, 1952; Watson, 1993).

Sattler (1978) wrote that small mammals often head for higher ground before a heavy rain; consequently, large numbers of hawks can often be seen in the same vicinity, reversing their usual pattern of solitary hunting to take advantage of the greater numbers of prey. Raccoons (*Procyon lotor)* and opossums (*Didelphis marsupialis*) living in riparian areas will also head for higher ground, abandoning low-lying homes near the water.

Signs of Fair Weather

Judging by the comparatively few behavior predictors for fair weather, either sunshine is more difficult to forecast than rain or it is the norm against which other weather is measured. Cats and dogs are thought to lick themselves more in fair weather, perhaps to relieve the charges of static electricity that build up in their fur during periods of low humidity (Freier, 1992). However, high temperatures during fair weather might also encourage animals to lick themselves as an evaporative cooling strategy.

English physician Edward Jenner, creator of the first smallpox vaccine, noted that if spiders crawl out on their webs while it is raining, the rain is sure to be short and light (Lee, 1998). Web-spinning by spiders is an indicator of fair weather, since spiders will not spin before a rain that might spoil their work (Lee, 1998). This of course seems a direct contradiction to the previous assertion that spiders enlarge and repair their webs before bad weather (Freier, 1992), but perhaps close observation reveals a difference between spinning new webs and repairing old ones.

Several indicators for rain when it is sunny are also said to indicate a change to fair weather when it is raining. Increased croaking by frogs indicates rain when it is fair; croaking at night indicates that it will be fair tomorrow if it is raining (Freier, 1992, Newman, 1996; Watson, 1993). Similarly, loud hooting and screeching by owls means rain if it is fair and sunshine if it is raining (Barnes, 1998; Freier, 1992; Watson, 1993).

Signs of Snow and Winter Weather

Woolly caterpillars are the classic predictors of weather for the upcoming winter. Most traditional wisdom relies on caterpillar coloring rather than behavior, but caterpillar coloring anecdotes are included here because they are so pervasive.

Biologists insist that the stripe colors designate different species of insects that most people lump together as woolly caterpillars. The stripe width is related to the caterpillar's age and to how wet the fall has been (Kauffman, 1998; "What kind of winter will we have?", 1998)

Traditions on the subject of caterpillar colors are often contradictory. One holds that a narrow middle band of color on woolly caterpillars means a severe winter (Freier, 1992). Another states that the wider the caterpillar's black band, the worse the winter ("What kind of winter will we have?", 1998). Traditional weather forecaster Helen Lane of Crab Orchard, Tennessee, said that caterpillar band patterns predict when snow will fall. A black-brown-black pattern indicated a winter that will start and end with severe weather, while a brown-black-brown pattern suggested a winter with a snowy middle but a mild beginning and end (Kauffman, 1998).

Lane predicted an unusually cold, snowy winter for 1998-1999 because woolly caterpillars were scarce and the few seen were solid black. The 1998-1999 winter weather in Knoxville, some 60 miles east of Crab Orchard, proved to be average in temperature although nearly twice as much precipitation fell. Precipitation November through February totaled 47.19 cm; the National Weather

Service average for precipitation for those months is 25.44 cm (National Weather Service, personal communication, June 1, 1999; Wood, 1996).

Lane stated that spider webs built close together are indicators of a severe winter ahead (Kauffman, 1998). Lane also said that hornet nests built close to the ground predict a cold winter, although other traditional wisdom holds that hornet nests built higher than usual predict deep snow (Golad, 1991; Kauffman, 1998).

Mud daubers are said to build their nests in sheltered areas before cold winters and birds will migrate unusually early. Few squirrels will be seen in the fall before a severe winter (Freier, 1992). Deer will eat more than usual and squirrels will gather unusually large numbers of nuts and store them unusually high in trees (Golad, 1991; Marshall 1998).

Immediately before a snowstorm, many animals will seek warmth and shelter. Cats will sit with their backs to the fire (Freier, 1992). Deer head to lower elevations, and coyotes (*Canis latrans*) will move in closer to areas occupied by humans (Sattler, 1978). Turkeys, on the other hand, will perch in trees and refuse to descend (Hardy, 1996).

Cameraman Frank Hurley took footage of an early and enormous northward migration of crab-eater seals (*Lobodon carcinophagus*) in May, 1915. As he and the other members of Ernest Shackleton's Antarctic expedition were later informed, sailors familiar with far southern waters saw this as a sign of an unusually cold winter and an early freeze, which did occur (Hurley, 1919).

One of the hardest winters on record occurred in Montana, with snow beginning on Christmas Eve 1886, and continuing nearly without a pause through early March of 1887. Although hot, sunny days and mild nights continued well into October in 1886, cattlemen along the Missouri River noticed wild geese and songbirds migrating earlier than usual and beavers storing large amounts of willow brush near their lodges. Cowboy E.C. "Teddy Blue" Abbott wrote that rancher Granville Stuart saw "arctic owls" in the area and reported that the older Indians said this was a sign of a very bad winter. The signs were right: by spring 60% of the cattle in Montana had died from exposure or starvation (Watson, 1993; White, 1991).

Unusually high numbers of unusually active hairy caterpillars of several species were noted at Pecos National Historical Park in New Mexico in September 1998. According to some longtime area residents, this predicted a hard winter, although others thought the increased activity meant a milder winter than usual (personal communications, September, 1998). Weather records favor the latter interpretation.

According to the weather records at Pecos National Historical Park, the average winter precipitation for November through February, 1994-1995 through 1997-1998, was 4.7 cm. Total precipitation for November through February 1998-1998 was 3.78 cm, 20% less than during the previous four winters.

The park weather records also show that the average winter temperatures for winter 1998-1999 were slightly higher than in the previous four winters: 12.36

degrees (C) versus 10.37 degrees. The average low for winter 1998-1999 was –4.99 degrees versus the previous winters' lows that averaged –5.31 degrees.

CHAPTER FOUR

STUDY: SEED CONSUMPTION AT BIRD FEEDERS AS AN INDICATOR OF WINTER STORMS

Discussions with birdwatchers and personal observations that birds can be seen at bird feeders in great numbers eating large amounts of food a few hours before winter storms suggested that seed consumption might be used as an indicator of approaching winter storms (personal communications W. Lauritzen, October 1998; S. Walden, November 1997). To test these observations, studies were conducted in Santa Fe, New Mexico, and Tulsa, Oklahoma, during early 1999.

Food Consumption and Winter Survival Strategies

Birds employ a variety of strategies to survive cold temperatures. Strategies include migration, microclimate selection, shivering, increased activity and increased insulation through plumage or body fat (Dawson & O'Connor, 1996).

A wide variety of bird species employ metabolic strategies and demonstrate regulated decreases in body temperature. These strategies include nocturnal hypothermia, shallow depression of body temperature, and torpor. Although such regulated decreases are not necessarily related to the availability of food, a temporarily slowed metabolic rate reduces the amount of food required and thus also reduces both energy required to find food and exposure to predators while searching (Reinertsen, 1996).

Some studies indicate that eating is a major heat-producing mechanism for birds. The heat increment of feeding is the heat produced by the energy expended while food is assimilated. This suggests a reason behind the concentrated eating done by birds at feeders before winter storms: if digestion is a prime source of body heat, an increased food intake would provide increased heat from digestion and an increased possibility of surviving snow and cold (Dawson & O'Connor, 1996).

Similar eating behavior before storms is seen in other animals. "Animal weather prophets" (1920) noted that more rabbits are caught in baited traps before winter storms than at other times and that the more rabbits trapped, the more likely the storm is to be long and severe. Cows and goats have also been observed eating more before storms (Tributsch, 1978).

Studies have shown that whitetail deer have definite activity patterns throughout the day, with predictable periods for feeding and resting in cover. Hunters say that variations from these patterns are usually followed by severe weather and that the variations are caused by animals feeding throughout the day in preparation for the upcoming storm (Tinsley, 1977).

Research Questions

Anecdotal accounts and metabolic studies suggest that animal survival strategies might include increased feeding before winter storms involving precipitation, decreased temperatures, or both. A field study of seed consumption at bird feeders was created to examine this possibility. The assumption was that increased seed consumption at a feeder would more quickly empty the feeder of seed. If feeders were checked frequently and refilled when empty, the number of refills could indicate the extent of seed consumption at the feeder. Increased seed consumption would serve as an indicator of an upcoming storm, since birds would increase seed consumption as a survival strategy.

Research Limitations

Field observations are intrinsically flawed by lack of control over variables. In this study, many factors could have affected the number of birds at the feeders and the amount of food eaten. For example, an abundance of available natural food or the presence of other feeders in the area could provide other opportunities for feeding. Disturbances caused by humans or other animals could discourage birds from feeding, as could the presence of particularly aggressive or territorial birds.

Definitively determining whether a small or a large number of birds were responsible for emptying a feeder was outside the scope of this study. Such information would have required a means of positively identifying birds by sight. To provide some answers to this question, observers noted the number of birds at feeders. A relatively small number of birds consistently appearing at a feeder and a relatively large amount of food being eaten would have suggested the presence of a particularly aggressive or hungry bird, but such a relationship was not apparent.

Regional and species differences in food preferences could influence feeder visits. The Cornell Laboratory of Ornithology's national Seed Preference Test found that nearly 30 bird species showed distinct preferences for specific types of seeds (Rosenberg & Bonney, 1994). There were also regional differences in seed preference within single species (Rosenberg & Dhondt, 1995; Rosenberg 1996). The seeds provided in the feeder could thus influence the types and number of birds feeding and how much food was eaten.

The feeder study was a fairly informal one. Because volunteers collected some of the data, a study that was too formal or too work-intensive would probably not be done as willingly or accurately as a simpler study. This also provided an opportunity to test the study's suitability for use by people not ordinarily considered part of the scientific community.

The study's informality and ease of use and the collection of data by unsupervised amateurs may be seen as research problems in themselves. However, effective use of animal behavior as a weather indicator requires just such ease and informality, so a study reflecting actual conditions of use seemed most appropriate and most useful.

Methodology and Data Collected

A simple calendar format was used to record daily high and low temperatures and amount and type of precipitation. Feeders were to be refilled only when empty and refill dates and times marked on the calendar. The feeders were refilled with the same amount and same type of birdseed each time.

Bird counts were taken at about the same time each day. The number of birds on and around the feeder was recorded on the calendar, since many ground-feeding birds scrape birdseed out of feeders so that they may eat on the ground.

Individuals conducting the studies made several decisions: what kind of birdseed to feed, what kind of feeders to use, when to check feeders to see if a refill was warranted, and when to count birds.

Appendix A contains a sample of the study instruction sheet and calendar for recording data. Raw data from the studies is contained in Appendix B. Appendix B also contains Figures 9 through 32, which present raw data in graphic form. For each month at each site, graphs illustrate high and low temperatures, precipitation, feeder refills, and numbers of birds observed and times.

Figures 3 through 8 show cumulative data for all three months by site. These figures follow discussions of results. Statistical analyses used Pearson product-moment correlation and were performed on Microsoft Excel Office 97 Professional Edition.

Results: The Santa Fe Study

The author conducted the Santa Fe feeder study. Birds on and around the feeder were counted once a day, usually (64% of the time) between 6:55 a.m. (0655 hours) and 7:00 a.m. (0700 hours). Three times birds were counted after 8:00 a.m. (0800 hours).

Feeders were checked about 7:00 a.m. (0700 hours) and between 5:30 p.m. (1730 hours) and 6:00 p.m. (1800 hours) to see if more feed should be added. Other random feeder checks also occurred. Feeder checks were accomplished by observing from house windows so birds feeding were not disturbed.

Two feeders were used. Both were general-purpose feeders with flat trays, appropriate for feeding a variety of species. Birdseed was also sprinkled on the horizontal fence rail near the feeders.

The feeders were filled with 50% Pennington Sunflower Seed, a commercial feed containing sunflower seed, Vitamin A supplement, Vitamin D-3 supplement, potassium iodide, and vegetable oil, and 50% Kaytee Wild Bird Food, a commercial feed containing millet, milo, sunflower seeds, cracked corn, wheat, ground corn, salt, calcium carbonate, Vitamin A palmitate, and Vitamin D supplement. When feeders were empty, 5.56 dl of seed was added.

Weather data were obtained from the local newspaper, The Santa Fe New Mexican. Temperatures and precipitation shown in the figures are for the 24-hour period ending at 4:00 p.m. (1600 hours) each day.

The study's measure of seed consumption was how often feeders were refilled. As previously noted, if winter survival strategies for birds include increased feeding before storms involving precipitation, seed consumption should increase before storms, causing more frequent feeder refills.

Figure 3 from the Santa Fe study shows that feeder refills were not more frequent before winter storms involving precipitation. Feeder refills before precipitation are included in all feeder refills in the figure, as well as shown separately.

The line in Figure 3 that represents the relationship between number of hours between feeder refills before precipitation and amount of precipitation indicates that the number of hours between feeder refills increased before precipitation occured. Not only does seed consumption not increase before winter storms including precipitation, it may decrease before such events.

Figure 4 shows the distribution of hours between feeder refills in Santa Fe. Again, feeder refills before precipitation are included in all feeder refills, as well as shown separately. The number of hours between all feeder refills approaches a normal curve; the mean of all refills is 68.70 hours with a standard deviation of 36.67. In comparison, the mean number of hours between feeder refills before precipitation is 90.58 hours with a standard deviation of 43.14. Again, feeder refills before winter storms involving precipitation are less frequent than all feeder refills recorded.

Finally, Figure 5 illustrates that there is no correlation between daily average temperature and the average number of birds observed each day. No relationship is demonstrated: only 2.37% of the variance in the average number of birds observed can be explained by temperature.

Based on the data collected, the study conducted in Santa Fe indicates that no relationship exists between approaching winter storms and increased seed consumption by birds. On the contrary, time between feeder refills increased before storms including precipitation, indicating that seed consumption decreased before storms. The Santa Fe study demonstrates that increased seed consumption at bird feeders cannot reliably be used as an indicator of winter storms.

Figure 3. Santa Fe January through March 1999
Relationship between Precipitation and Number of Hours between Feeder Refills

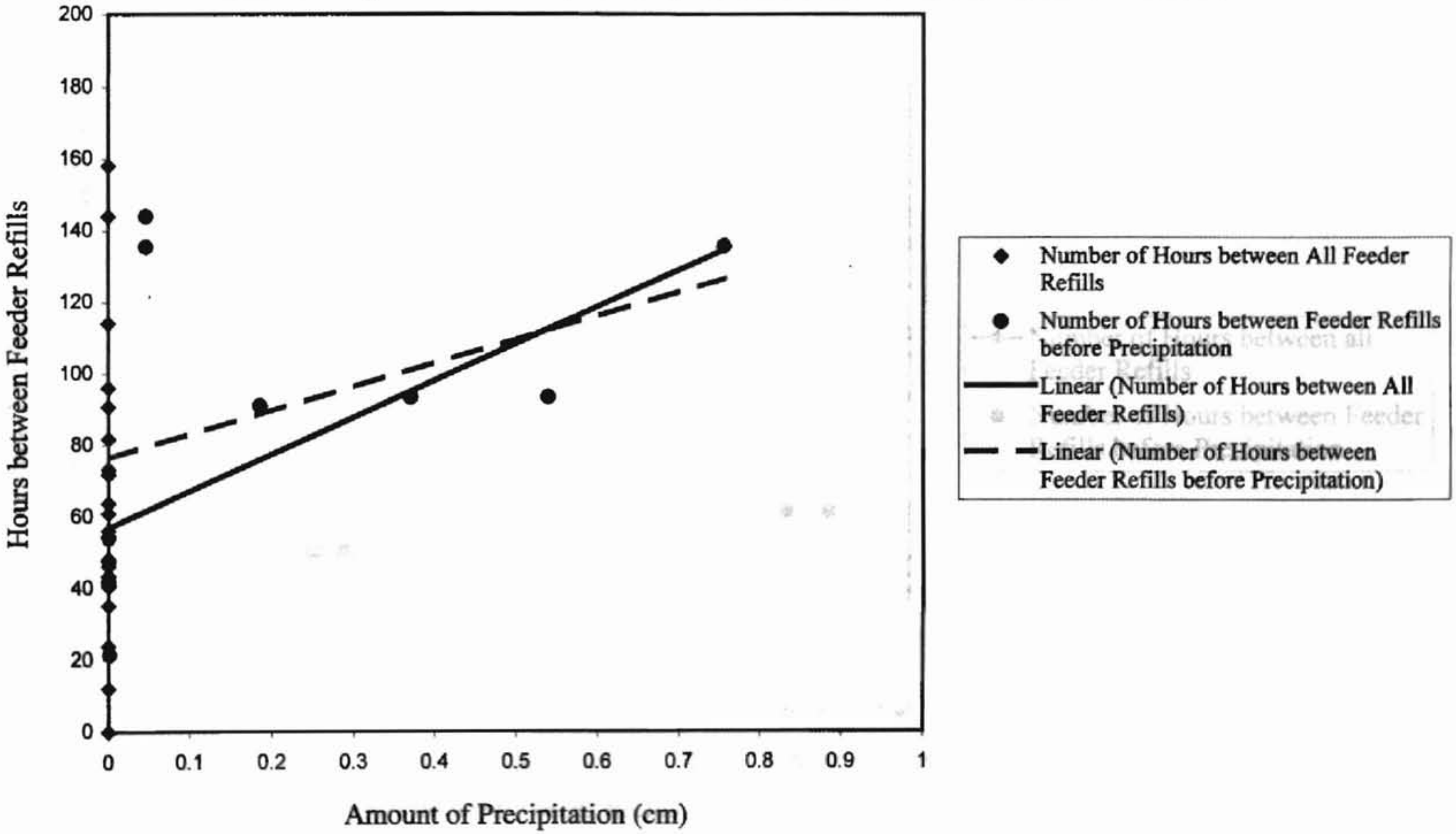


Figure 4. Santa Fe January through March 1999
Distribution of Hours between Feeder Refills

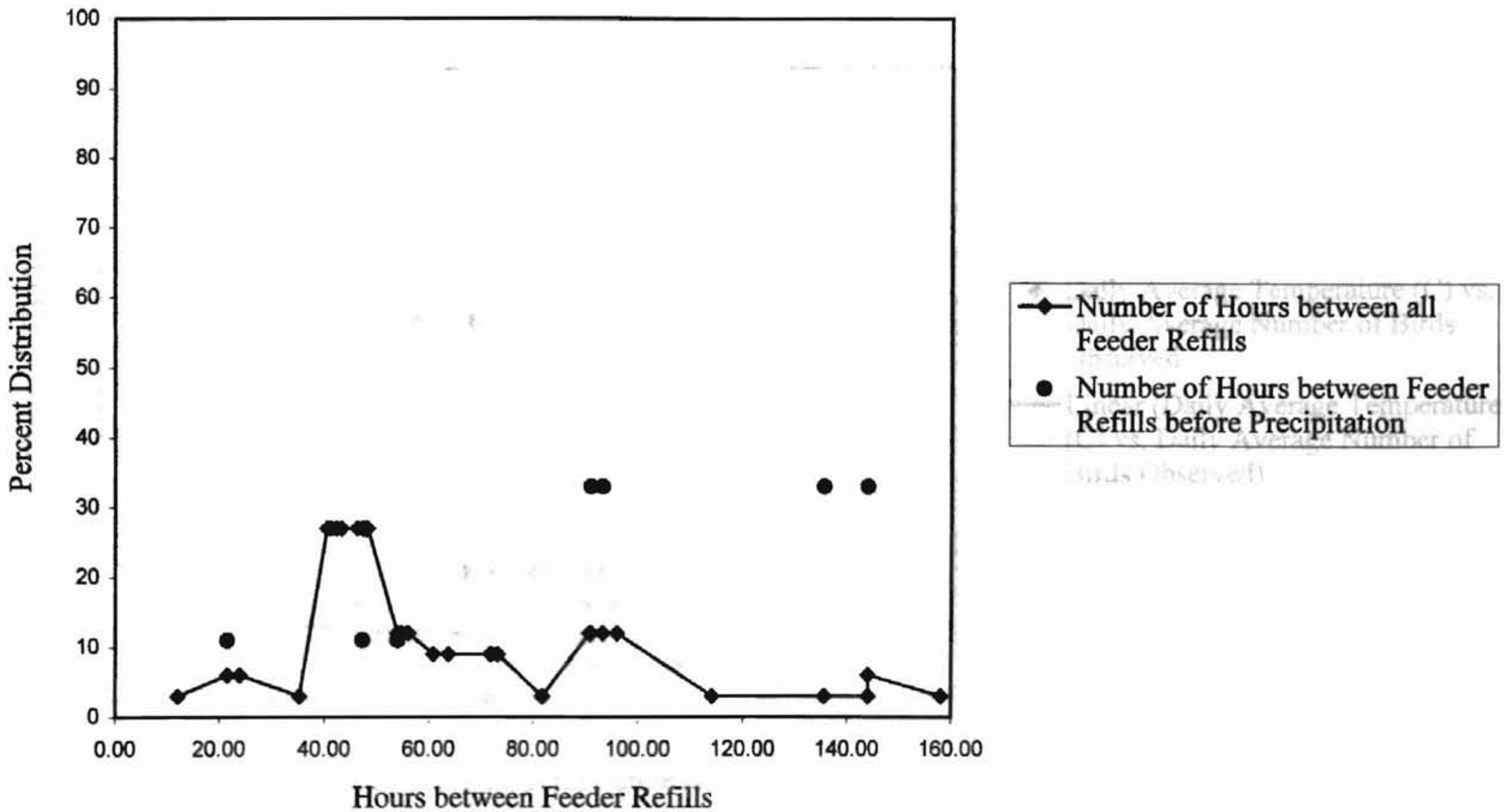
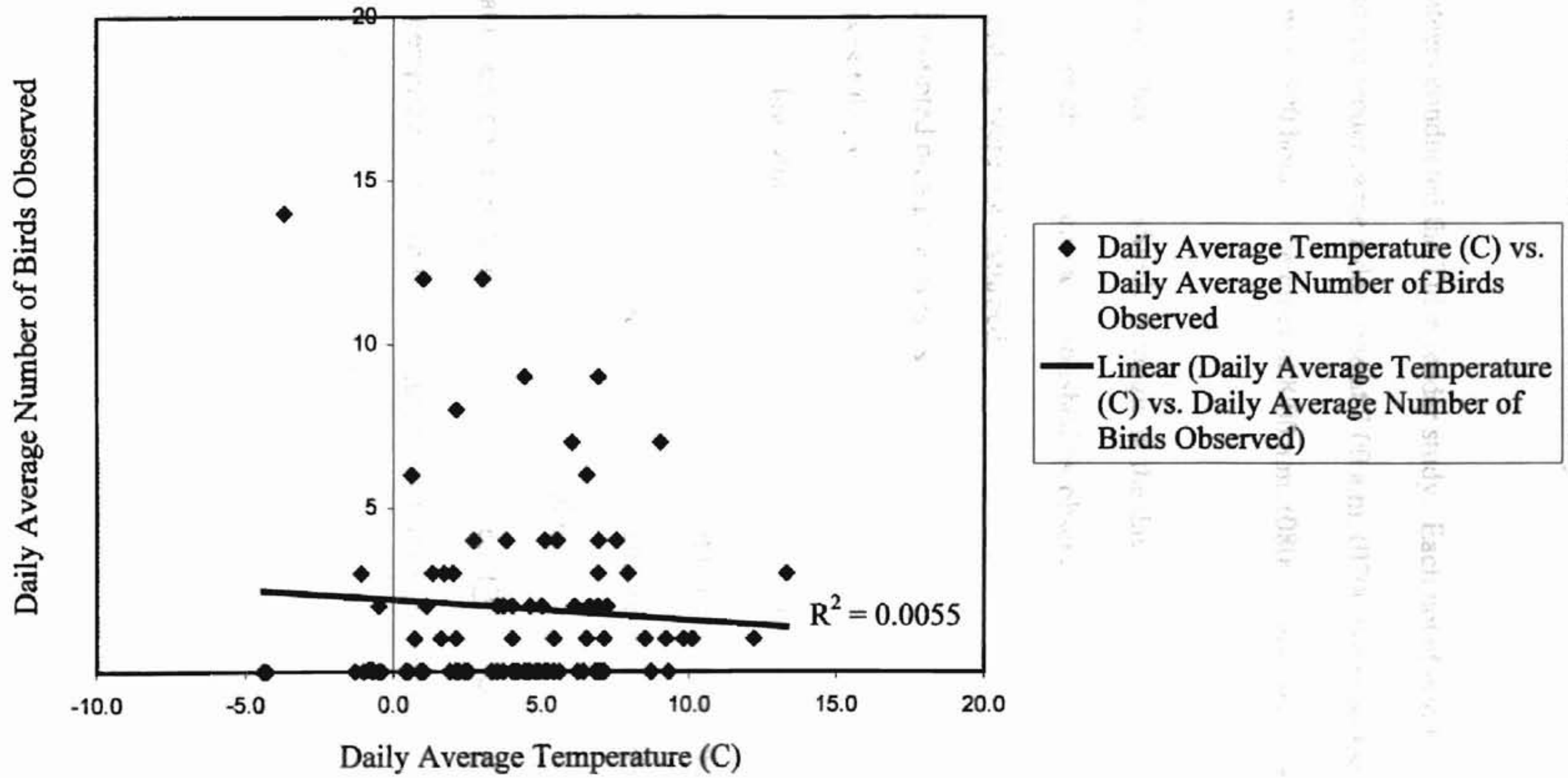


Figure 5. Santa Fe January through March 1999
Correlation between Daily Average Temperature (C)
and Daily Average Number of Birds Observed



Results: The Tulsa Study

Two volunteers conducted the Tulsa feeder study. Each noted number of birds at and around the feeder twice a day: one at 7:00 a.m. (0700 hours on the graph) and 3:00 p.m. (1500 hours), the other at 8:00 a.m. (0800 hours) and 4:00 p.m. (1600 hours).

The feeder was checked randomly throughout the day to see if more feed should be added. Feeder checks were accomplished by observing from house windows so birds feeding were not disturbed.

One feeder, mounted on a pole, was used.

The feeder was filled with Pennington's Pride Wild Bird Feed, a commercial feed containing white proso millets, milo, wheat, sunflower seed, calcium carbonate, Vitamin A supplement, Vitamin D-3 supplement, potassium iodide, and vegetable oil. Cracked corn and crushed egg shells were added to the seed. When the feeder was empty, 16.68 dl of seed was added.

Weather data were obtained from the local newspaper, The Tulsa World. Temperatures and precipitation shown in the figures that follow are for the 24-hour period ending at 6:00 p.m. (1800 hours) each day.

The study's measure of seed consumption was how often the feeder was refilled. More frequent feeder refills would indicate more seed consumption by birds; increased seed consumption would indicate an approaching storm.

Figure 6 shows that there is no relationship between precipitation and the number of hours between feeder refills in Tulsa. Feeder refills before precipitation are included in all feeder refills, as well as shown separately. The nearly horizontal line representing the correlation between precipitation and feeder refills before precipitation occurred demonstrates that no significant relationship exists between the two.

The curve in Figure 7 that represents the distribution of hours between feeder refills in the Tulsa study is nearly a normal curve for both all feeder refills and feeder refills before precipitation. Again, feeder refills before precipitation are included in all feeder refills, as well as shown separately.

For all feeder refills, the mean number of hours between refills is 21.40; standard deviation is 7.10. For feeder refills before precipitation, the mean number of hours is 25.17 and standard deviation is 1.03. Although feeder refills before precipitation show less variance in the number of hours between refills than do all feeder refills, this does not indicate that precipitation affects the number of hours between feeder refills. At most, the lesser variance demonstrates more consistency in the number of hours between feeder refills and therefore more consistent seed consumption before precipitation occurs. Increased seed consumption has not been demonstrated.

Figure 8 illustrates that there is no correlation between daily average temperature and the average number of birds observed each day. In Tulsa, 5.69% of the variance in the average number of birds observed can be explained by temperature. Although this is more than twice the variance shown in the Santa Fe study, where the variance was 2.37%, the Tulsa rate is still insignificant.

As in the Santa Fe study, the Tulsa study demonstrates no relationship between approaching winter storms and increased seed consumption by birds. Again, increases in the number of hours between all feeder refills increased as precipitation increased, and no relationship was demonstrated between precipitation and feeder refill periods before precipitation occurred. A more consistent pattern of feeder refills before precipitation was seen, but a shorter period of time between refills before precipitation was not. The Tulsa study, like the Santa Fe study, does not support the use of seed consumption at bird feeders as an indicator of approaching winter storms.

Figure 6. Tulsa January through March 1999
Relationship between Precipitation and Number of Hours between Feeder Refills

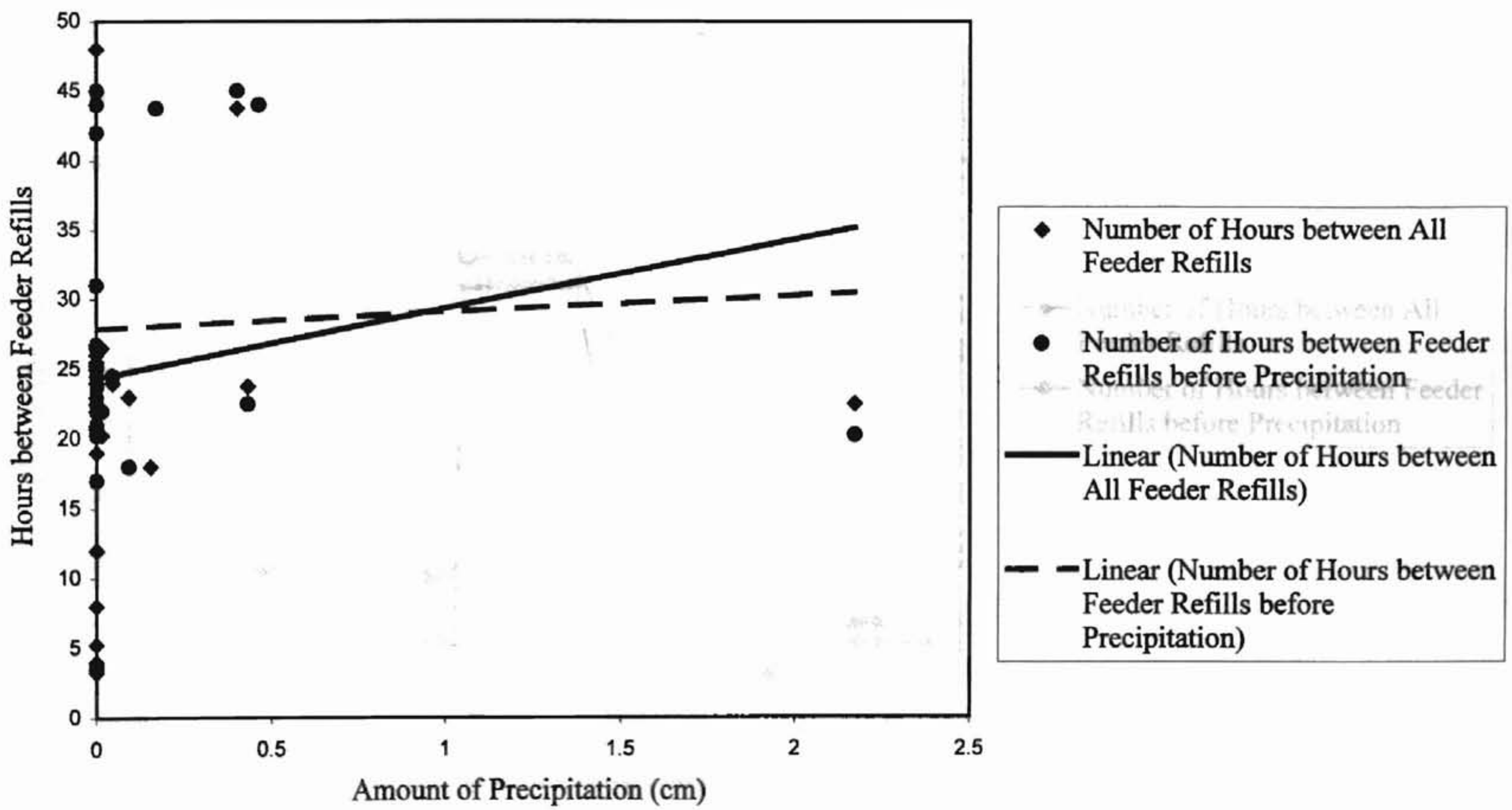


Figure 7. Tulsa January through March 1999
Distribution of Hours between Feeder Refills

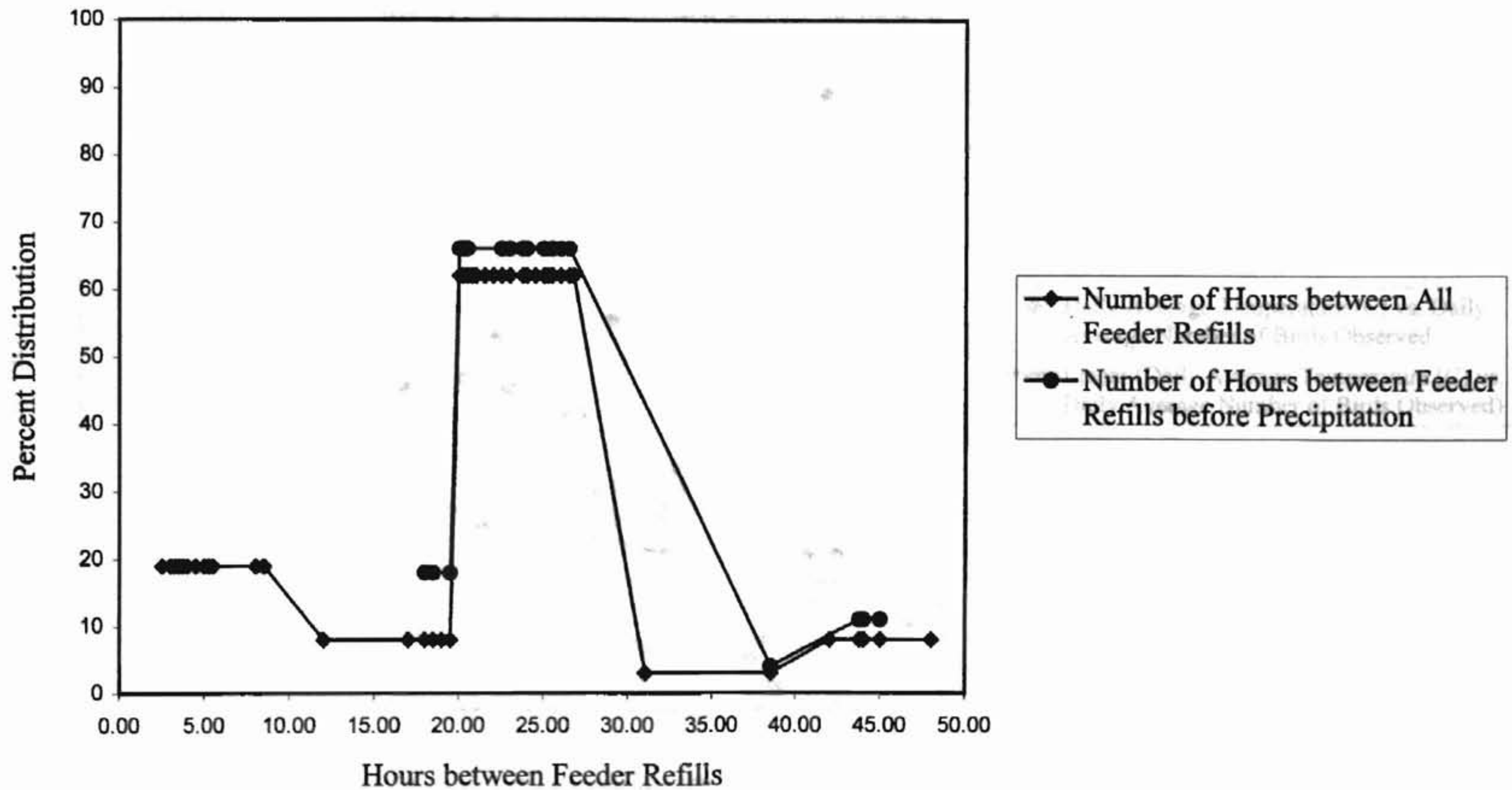
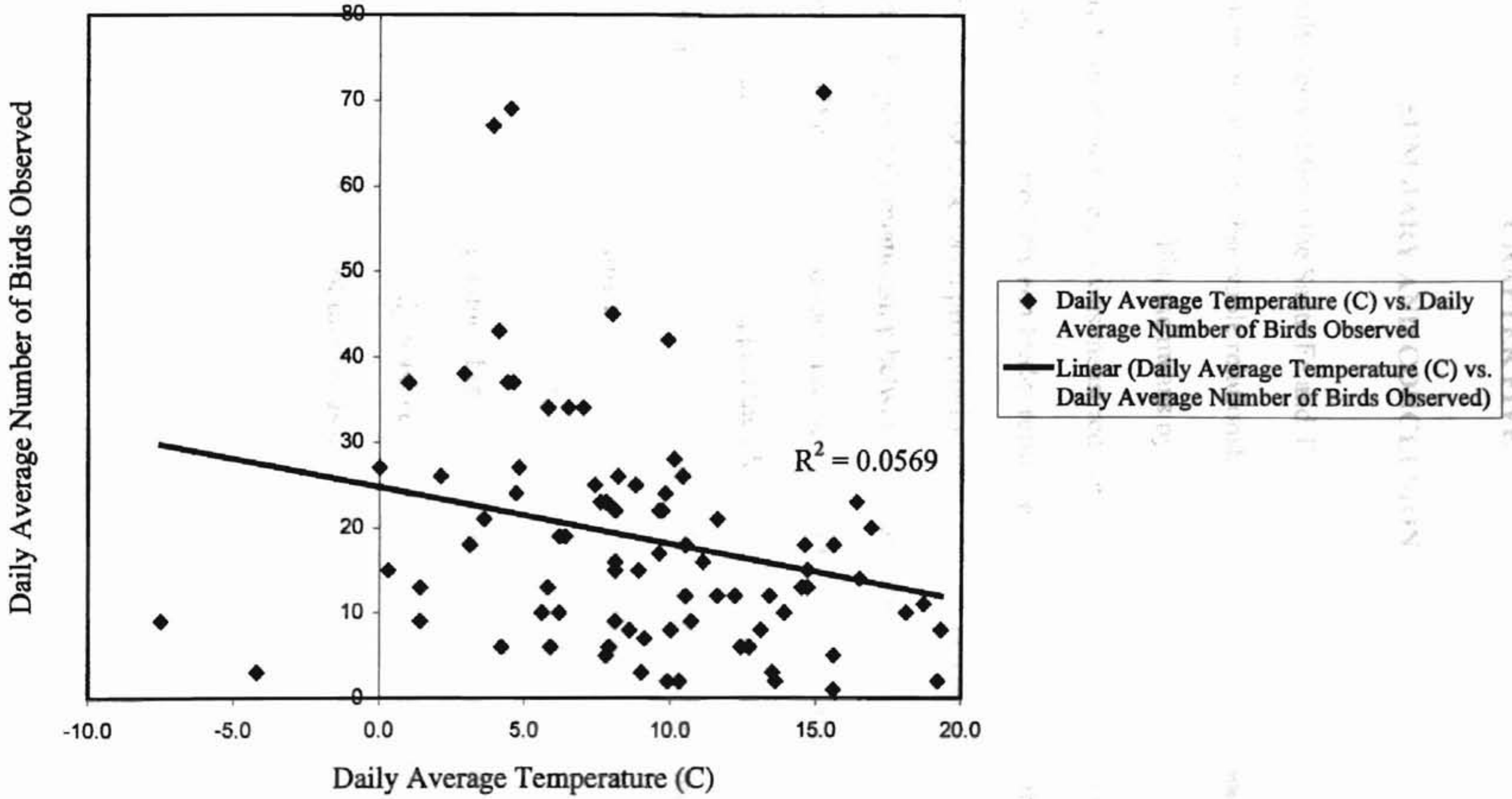


Figure 8. Tulsa January through March 1999
Correlation between Daily Average Temperature (C)
and Daily Average Number of Birds Observed



CHAPTER FIVE

SUMMARY AND CONCLUSIONS

The results derived from the Santa Fe and Tulsa studies were very similar. Neither study demonstrated an observable relationship between precipitation and decreased time between feeder refills, the means by which increased seed consumption by birds at bird feeders was measured. Instead, one study showed an increase in the number of hours between feeder refills before precipitation and the other showed no relationship between precipitation and time between refills.

Similarly, the possible relationship between daily average temperature and the average number of birds observed each day was shown to be unimportant.

Although these studies did not support the idea that increased seed consumption by birds at feeders can serve as a indicator of an approaching winter storm, the results do not justify dismissing all anecdotal information regarding animal behavior as a weather predictor. Chen's research found a high rate of successful weather forecasts among some of the Chinese weather proverbs she studied (Houghton, 1996). It is certainly feasible that all traditional lore on the subject is inaccurate, but the results of thousands of years of observation and tradition from cultures from around the world should not be accepted or rejected on the basis of one study.

Because of its long history, and because of the possible applications of an informal method of weather prediction not based on electronic technology, this seems to be a problem that merits further study. Appendix D contains two model studies for the use of non-scientists, appropriate for use at home, school, or in other informal settings.

Amateur efforts such as the Cornell Laboratory of Ornithology's national Seed Preference Test and the National Audubon Society's annual Christmas bird counts have demonstrated that very useful information can be collected by people not traditionally considered part of the scientific community. In the same way, informal studies on animal behavior as a weather predictor could provide more evidence on its effectiveness, its limitations, and its uses.

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APPENDIX

APPENDIX A

SAMPLE INSTRUCTIONS AND CALENDAR

USED BY VOLUNTEERS

Guidelines for Bird Feeder Study

Every day, please

- Record high and low temperatures and amount and kind of any precipitation as reported in your newspaper.
- Observe your feeder for a few minutes about the same time every day. Record observation time and how many birds are at or around the feeder. If you like, you can record more than one observation per day.

Refill your feeder only when it is empty (this lets me keep track of how fast birds are emptying the feeder). Mark refill days on the calendar. Always refill with the same amount and the same kind or mix of birdseed. On the bottom of the calendar, write how much and what kind of seed you use for refills.

If something unusual happens at your feeder, please make a note on your calendar.

I've enclosed a sample calendar with examples of the information I need for my study. Please let me know if you have any questions: you can call me collect most evenings at XXX-XXX-XXXX. Many thanks for your help!!!

DECEMBER – BIRD FEEDING STUDY

Sun	Mon	Tues	Weds	Thur	Fri	Sat
		1	2	3	4	5
6	7	8	9	10 37-22-Ø refill 7am 7am Ø birds	11 43-11-Ø 7am Ø birds	12 51-13-Ø refill 4pm 7:30am Ø birds
13 54-20-Ø 7:30am Ø birds	14 52-20-Ø 7am 1 bird	15 53-22-Ø 7am 1 bird	16 55-20-Ø 7am 3 birds	17 53-17-Ø refill 7am 7am 4 birds	18 55-17-Ø 7am 3 birds	19 57-20-Ø refill 8:30am 7am Ø birds
20 55-30-Ø 7am Ø birds	21 38-26-Ø refill 10am 7am 3 birds	22 29-7-Ø refills 7am, 10:30 pm 7am 14 birds	23 38-8-Ø 7am 3 birds	24 40-8-Ø refill 8am 7am 12 birds	25 44-19-Ø refill 3pm 7am 2 birds	26 49-26-Ø 7am 3 birds
27 49-24-Ø refill 7am 7am 1 bird	28 52-22-Ø 7am 3 birds	29 55-27-Ø refill 7am 7am 15 birds	30 7am 7 birds	31		

← 1st number is high
2nd number is low
3rd number is precipitation

refill: 2 cups (mixture of half black sunflower seeds, half wild bird seed mix)

APPENDIX B

DATA FROM SANTA FE AND TULSA STUDIES:

TEMPERATURES, PRECIPITATION,

NUMBER OF BIRDS OBSERVED, FEEDER REFILL TIMES

Table 1.

SANTA FE DATA - JANUARY 1999										
JAN	**TEMPERATURE(C)**			**PRECIPITATION**	**NUMBER OF BIRDS SEEN/TIME**					**REFILL**
date	**high**	**low**	**daily avg**	**cm**	**0700 hrs**	**0730 hrs**	**0800 hrs**	**0830 hrs**	**daily avg**	**time**
1	8.9	0.0	4.5	0.0015				0	0	1000
2	8.0	-10.0	-1.0	0.0000	0				0	
3	4.0	-12.8	-4.4	0.0000				0	0	
4	6.0	-13.3	-3.7	0.0000	14				14	
5	12.0	-9.4	1.3	0.0000	3				3	700
6	11.0	-7.2	1.9	0.0000	0				0	
7	12.0	-7.8	2.1	0.0000	8				8	
8	9.0	-5.6	1.7	0.0000	3				3	700
9	8.0	-10.6	-1.3	0.0000			0		0	
10	11.0	-4.4	3.3	0.0000	0				0	1630
11	12.0	-7.8	2.1	0.0000	1				1	
12	13.0	-6.1	3.5	0.0000	0				0	
13	11.0	-2.8	4.1	0.0000	0				0	
14	9.0	-8.3	0.4	0.0000	0				0	
15	13.0	-3.9	4.6	0.0000	0				0	1800
16	9.0	-7.2	0.9	0.0000		0			0	
17	14.0	-6.1	4.0	0.0000		1			1	
18	14.0	-2.8	5.6	0.0000	0				0	
19	15.0	-1.1	7.0	0.0000	0				0	1845
20	12.0	-1.1	5.5	0.1848	4				4	
21	6.0	0.0	3.0	0.0000	12				12	1800
22	6.0	-3.9	1.1	0.0000	2				2	
23	10.0	-5.6	2.2	0.0000				0	0	1315
24	14.0	-3.3	5.4	0.0000	0				0	
25	13.0	0.6	6.8	0.0000	0				0	1130
26	8.0	3.9	6.0	0.0015	7				7	

SANTA FE DATA - JANUARY 1999										
JAN	TEMPERATURE(C)			PRECIPITATION	NUMBER OF BIRDS SEEN/TIME					REFILL
date	high	low	daily avg	cm	0700 hrs	0730 hrs	0800 hrs	0830 hrs	daily avg	time
27	8.0	-6.7	0.7	0.0000	1				1	1730
28	8.0	-6.1	1.0	0.0000	0				0	
29	7.0	-7.8	-0.4	0.0000	0				0	
30	12.0	-7.8	2.1	0.0000					0	1840
31	12.0	-8.9	1.6	0.0000	1				1	

Table 2.

SANTA FE DATA - FEBRUARY 1999										
FEB	TEMPERATURE(C)			PRECIP	NUMBER OF BIRDS SEEN/TIME					REFILL
date	high	low	daily avg	cm	0700 hrs	0730 hrs	0800 hrs	0830 hrs	daily avg	time
1										
2	10.0	-8.9	0.6	0.0000	6				6	730
3	13.0	-5.6	3.7	0.0000	0			0	0	
4	11.0	-6.1	2.5	0.0000	0				0	700
5	11.0	2.2	6.6	0.0000	2				2	
6	9.0	-5.0	2.0	0.0000	3				3	
7	13.0	-5.0	4.0	0.0000	0				0	1645
8	14.0	-3.9	5.1	0.0000	0				0	
9	16.0	-2.2	6.9	0.0000	2				2	2330
10	18.0	-5.6	6.2	0.0000	0				0	
11	2.0	-10.6	-4.3	0.0000	0				0	1745
12	9.0	-11.1	-1.1	0.0000	3				3	
13	17.0	-7.8	4.6	0.0000			2		2	
14	16.0	-7.2	4.4	0.0000				9	9	930
15	12.0	-6.7	2.7	0.0000	4				4	
16	9.0	-10.0	-0.5	0.0000	2				2	1600
17	14.0	-5.6	4.2	0.0000		0			0	
18	14.0	-3.3	5.4	0.0000			1		1	
19	16.0	-2.2	6.9	0.0000	3				3	
20	12.0	-4.4	3.8	0.1848	4				4	1100
21	13.0	-5.6	3.7	0.0000		2			2	2300
22	9.0	1.1	5.1	0.0000	4				4	
23	13.0	-6.1	3.5	0.0000	2				2	2000
24	17.0	-2.8	7.1	0.0000	1				1	
25	16.0	-1.7	7.2	0.0000	2				2	2000
26	15.0	-2.8	6.1	0.0015	2				2	1730
27	16.0	-7.2	4.4	0.0000		0			0	
28	18.0	-0.6	8.7	0.0000		0			0	1045

Table 3.

SANTA FE DATA - MARCH 1999										
MAR	**TEMPERATURE(C)**			**PRECIP**	**NUMBER OF BIRDS SEEN/TIME**					**REFILL**
date	**high**	**low**	**daily avg**	**cm**	**0700 hrs**	**0730 hrs**	**0800 hrs**	**0830 hrs**	**daily avg**	**time**
1	19.0	-1.1	9.0	0.0000	7			0	7	
2	17.0	-3.9	6.6	0.0000	2				2	620
3	17.0	-3.3	6.9	0.0000	4			0	4	615
4	17.0	-3.3	6.9	0.0000	0				0	1745
5	15.0	0.0	7.5	0.0000	4				4	
6	8.0	-3.3	2.4	0.0000	0				0	
7	9.0	0.6	4.8	0.0000	0				0	1730
8	11.0	-0.6	5.2	0.0000	0				0	
9	14.0	-6.1	4.0	0.0000	2		0		2	1745
10	16.0	-6.1	5.0	0.0000	2				2	
11	12.0	-2.2	4.9	0.0000	0				0	
12	3.0	-1.1	1.0	0.3696	12				12	
13	9.0	-10.0	-0.5	0.5390	0				0	1500
14	16.0	-3.3	6.4	0.0000	0				0	
15	18.0	-2.2	7.9	0.0000	3				3	
16	19.0	-1.7	8.7	0.0000	0	0			0	
17	9.0	3.9	6.5	0.0000	0	1			1	
18	2.0	-1.1	0.5	0.7546	0				0	
19	3.0	-4.4	-0.7	0.0462	0				0	630
20	16.0	-2.2	6.9	0.0000		9			9	
21	18.0	0.6	9.3	0.0000	0				0	
22	19.0	-0.6	9.2	0.0000	1				1	
23	18.0	-0.6	8.7	0.0000	0			0	0	
24	17.0	0.0	8.5	0.0000	1				1	
25	17.0	-2.8	7.1	0.0000	0				0	2030
26	14.0	-1.1	6.5	0.0000	6				6	

SANTA FE DATA - MARCH 1999														
MAR		**TEMPERATURE(C)**				**PRECIP**		**NUMBER OF BIRDS SEEN/TIME**						**REFILL**
date		**high**	**low**	**daily avg**		**cm**		**0700 hrs**	**0730 hrs**	**0800 hrs**	**0830 hrs**	**daily avg**		**time**
27		18.0	2.2	10.1		0.4620		1				1		
28		18.0	-0.6	8.7		0.0000		0				0		
29		19.0	0.6	9.8		0.0000				1		1		
30		21.0	3.3	12.2		0.0000		1				1		
31		21.0	5.6	13.3		0.0000		3				3		

Figure 9. Santa Fe January 1999
Daily High and Low Temperatures

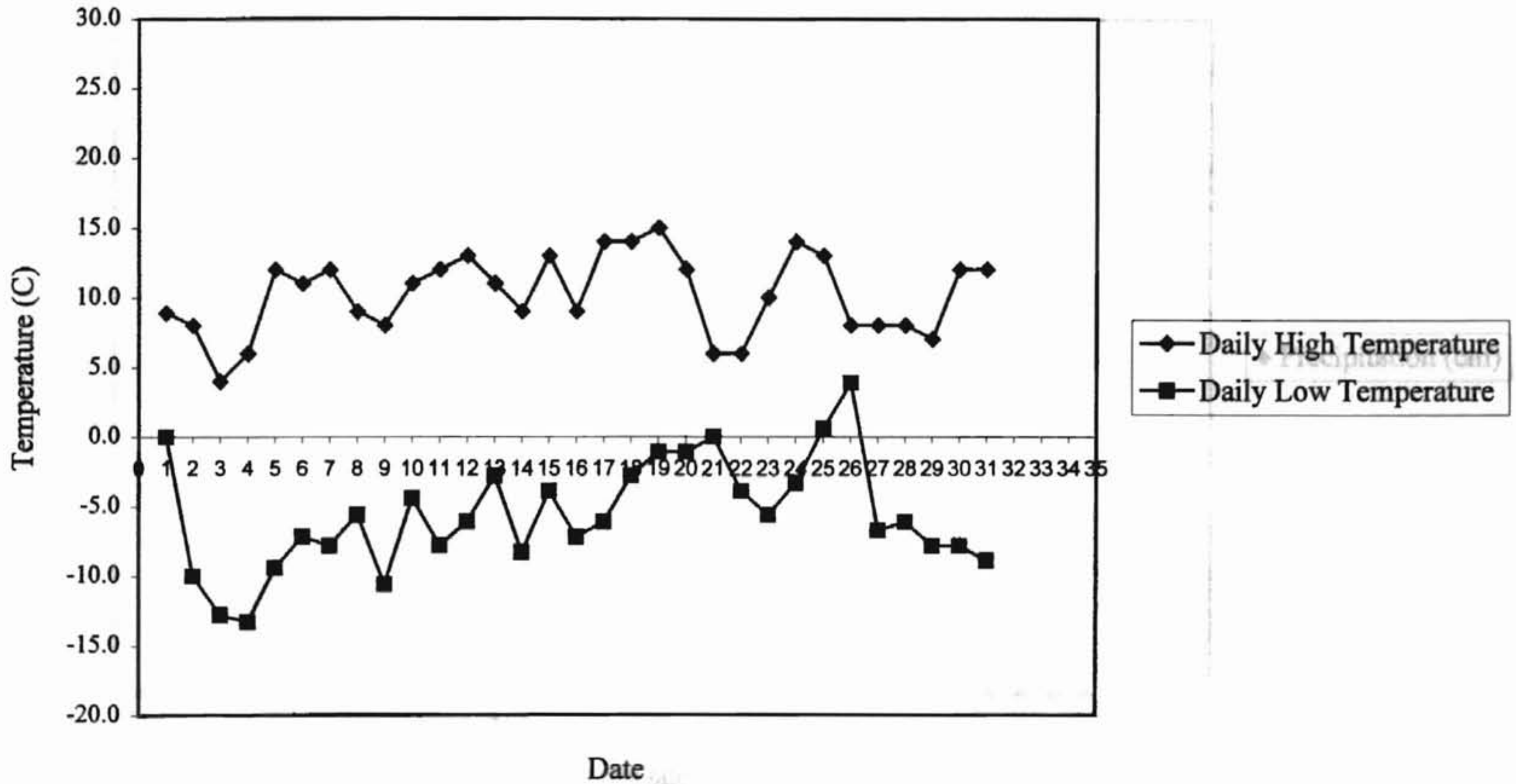


Figure 10. Santa Fe January 1999
Precipitation

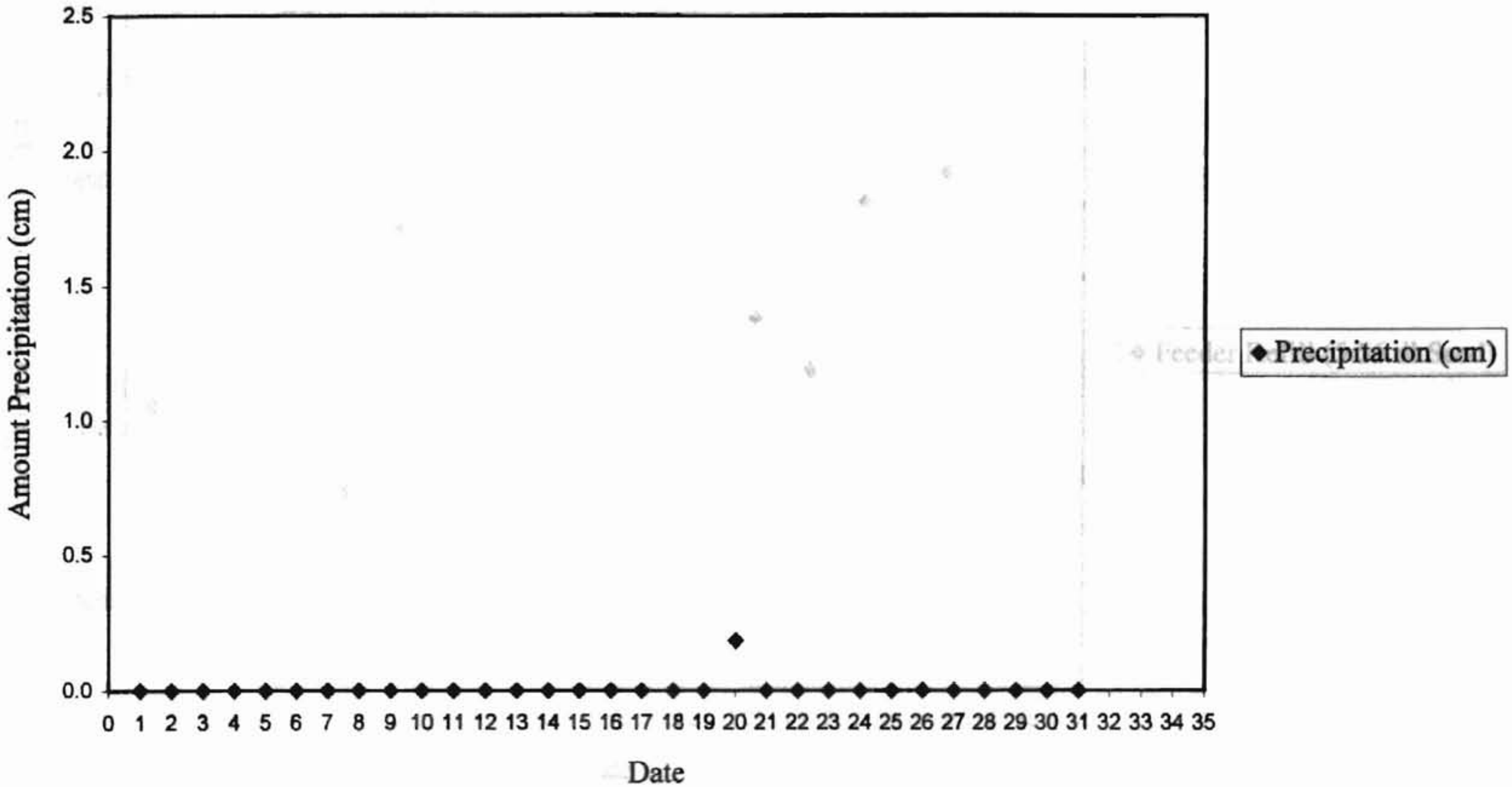


Figure 11. Santa Fe January 1999
Feeder Refills

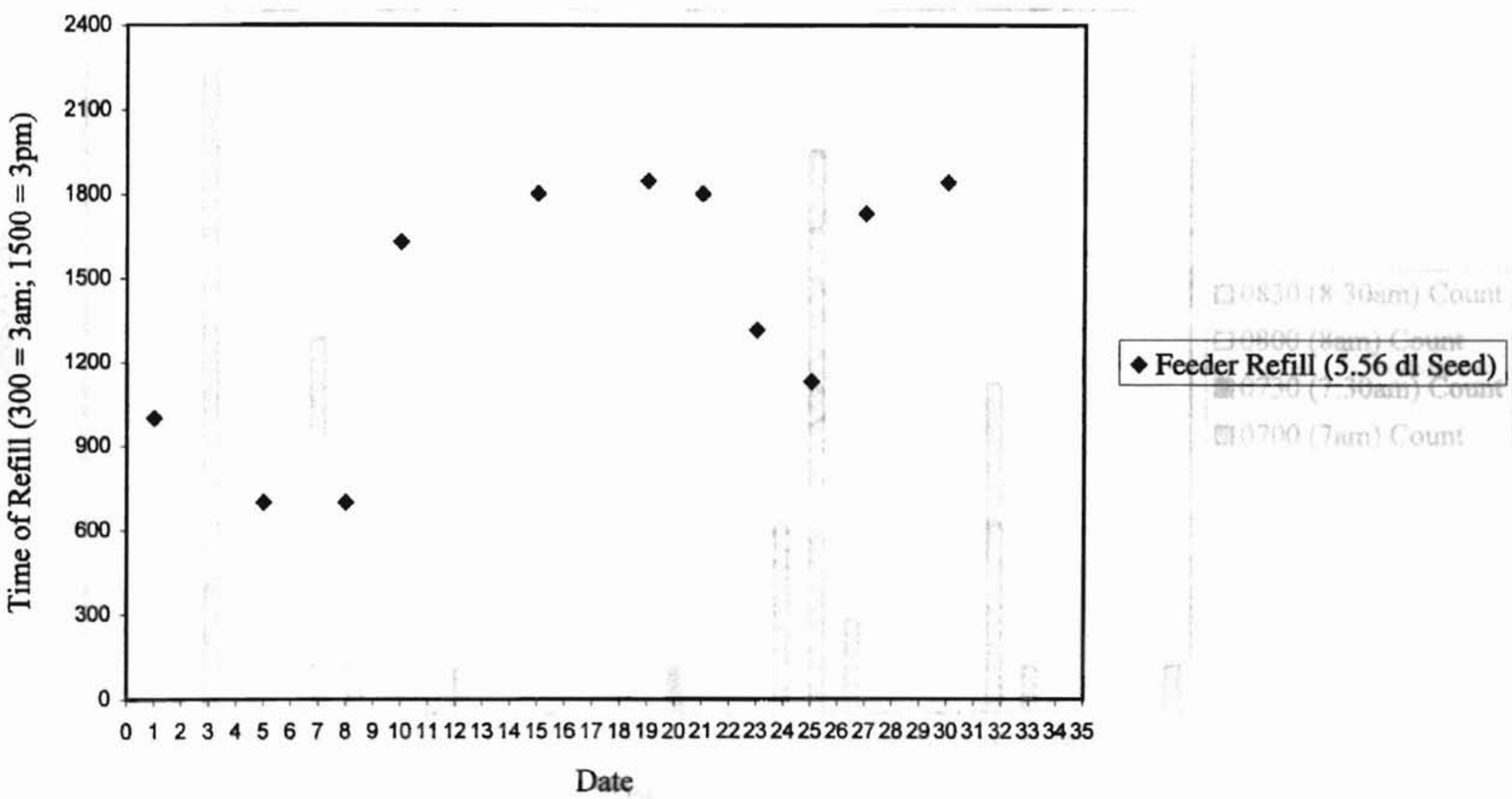


Figure 12. Santa Fe January 1999
Number of Birds Observed/Time

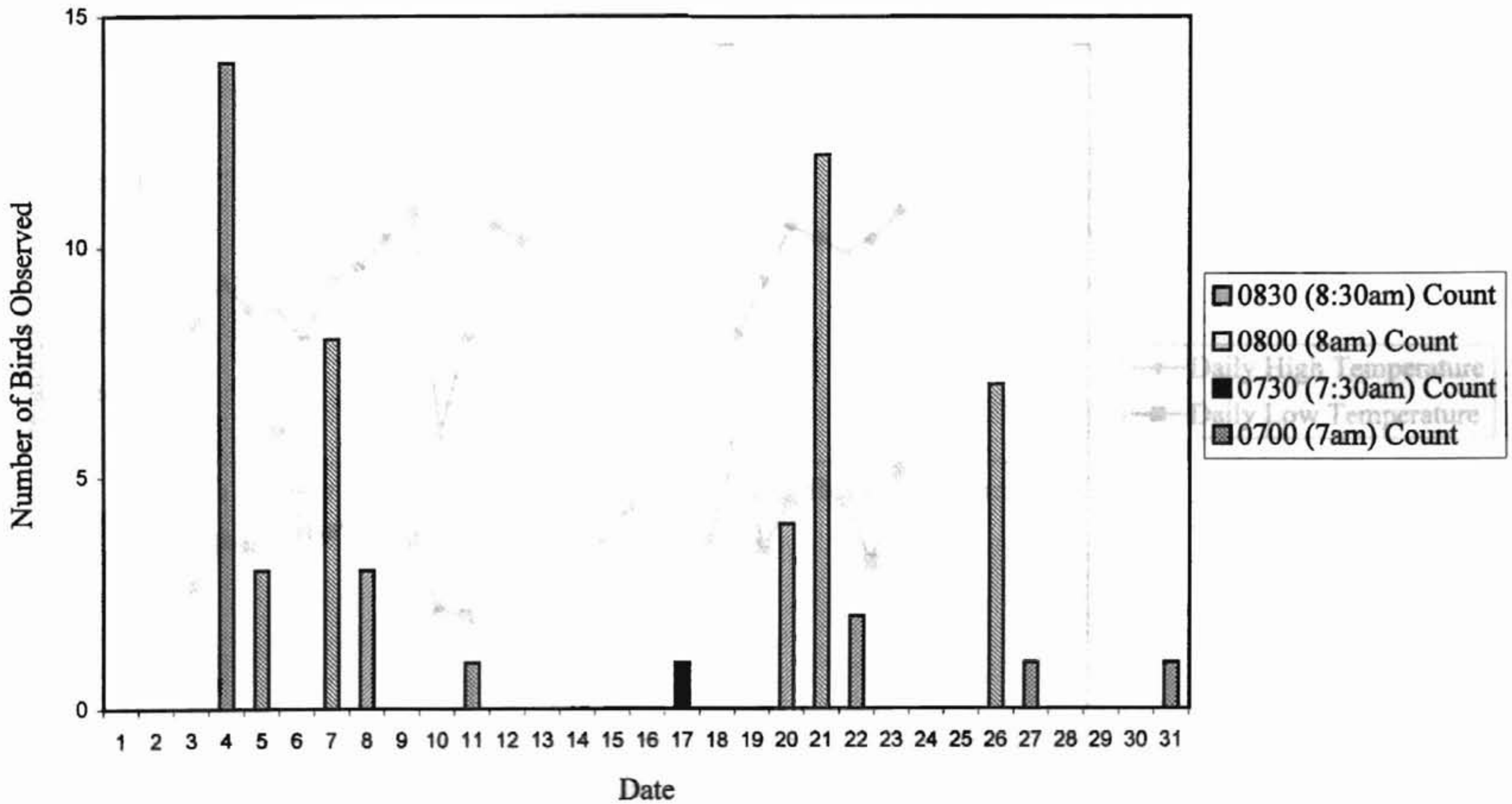


Figure 13. Santa Fe February 1999
Daily High and Low Temperatures

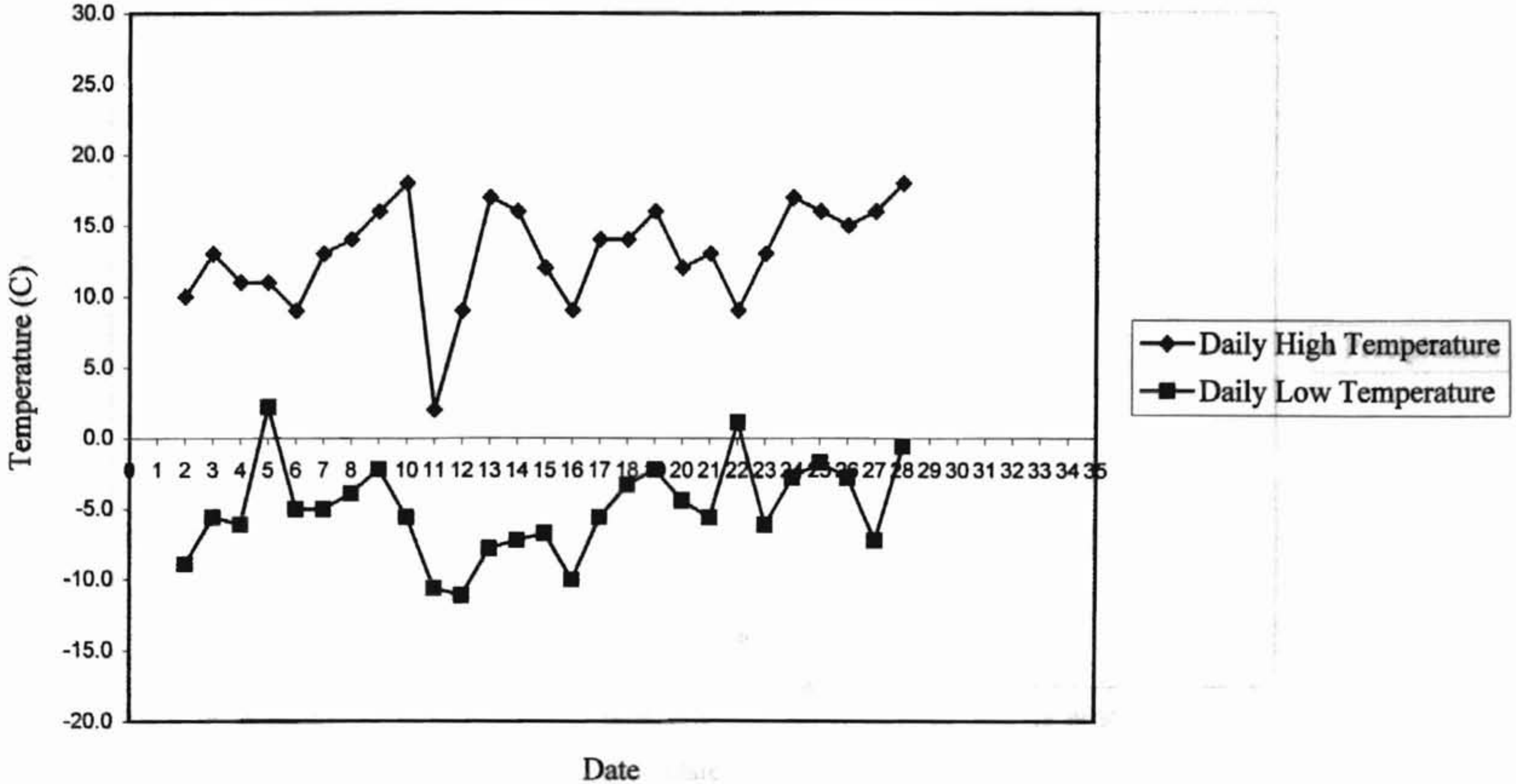


Figure 14. Santa Fe February 1999
Precipitation

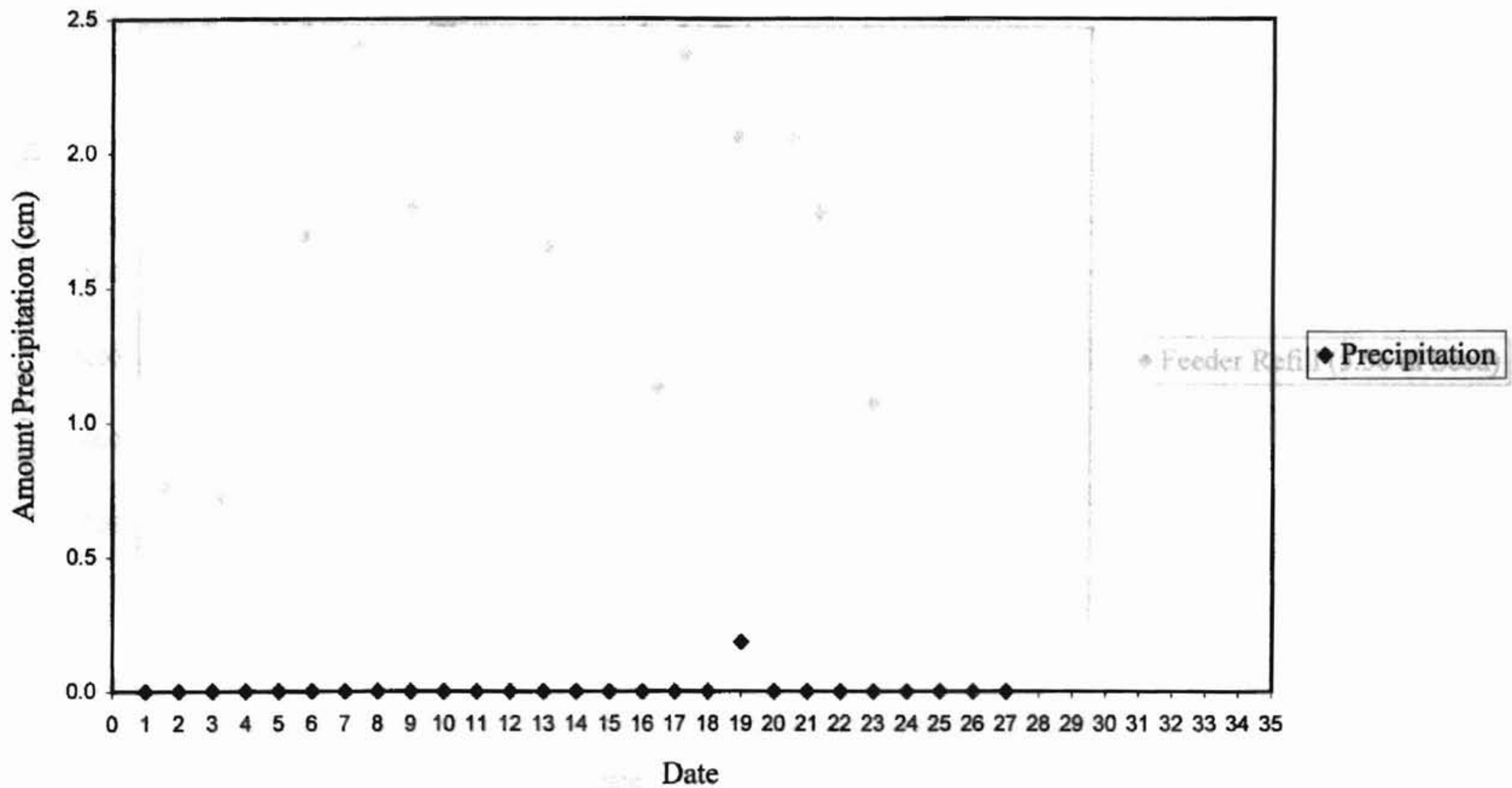


Figure 15. Santa Fe February 1999
Feeder Refills

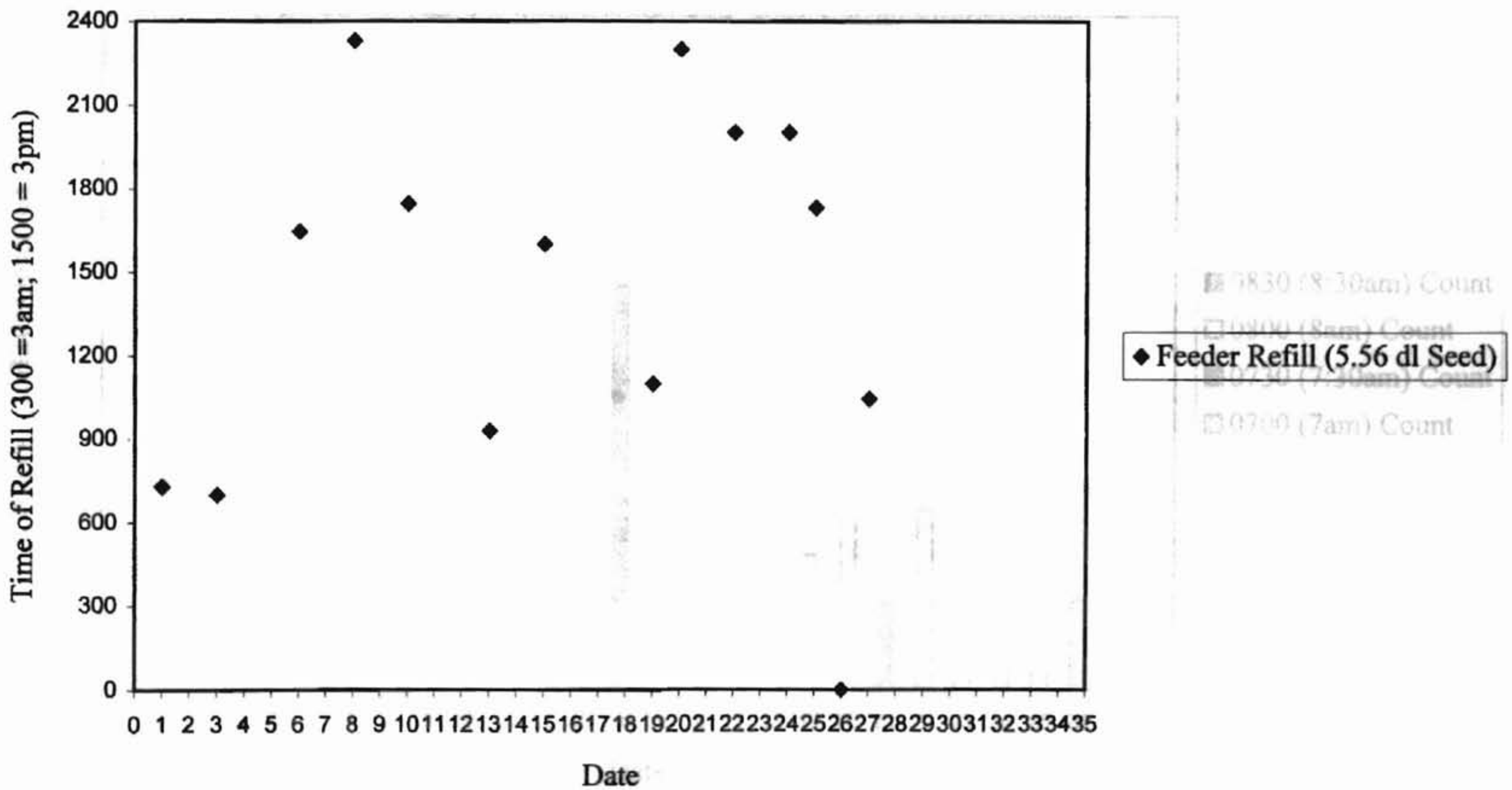


Figure 16. Santa Fe February 1999
Number of Birds Observed/Time

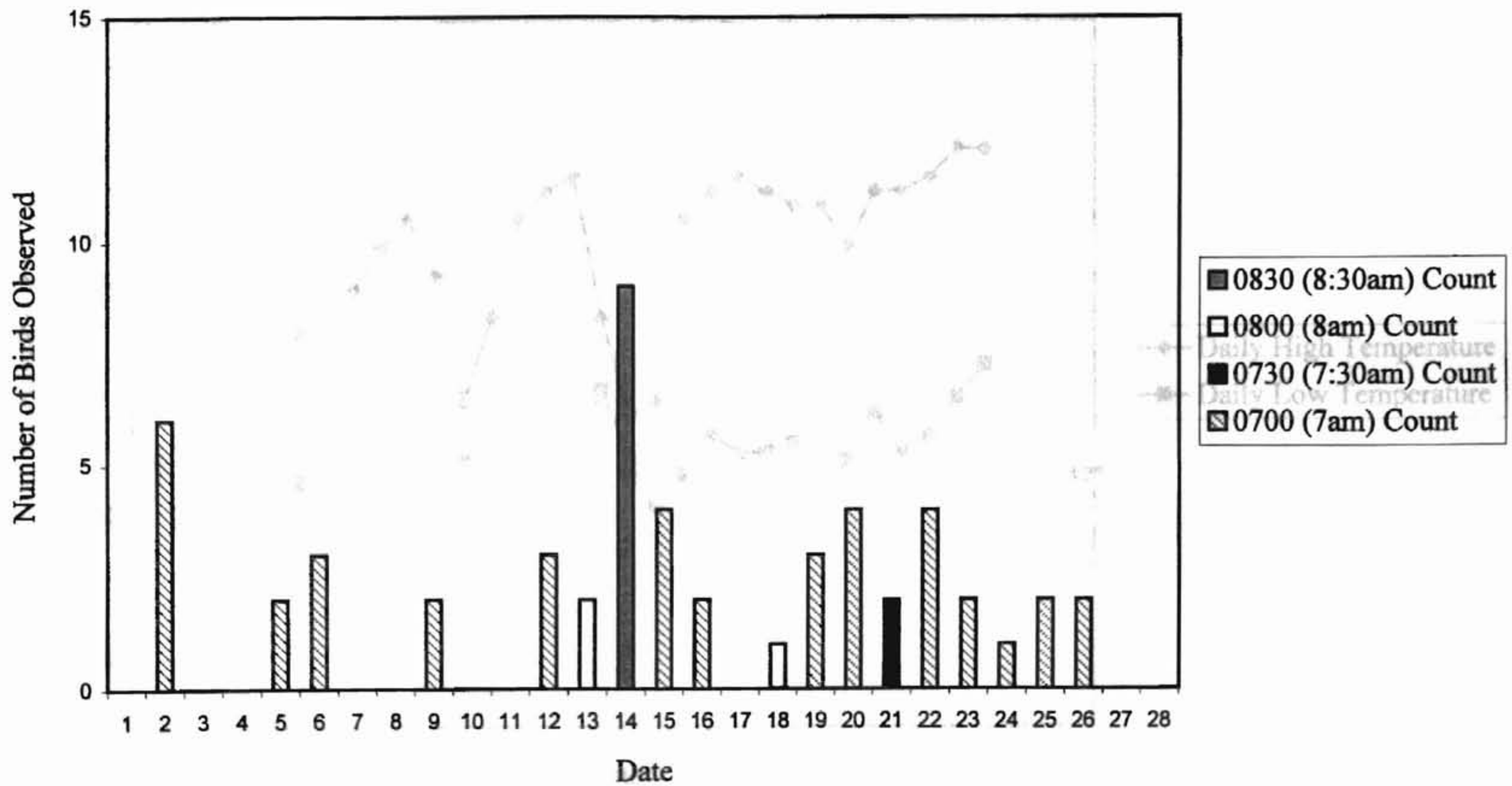


Figure 17. Santa Fe March 1999
Daily High and Low Temperatures

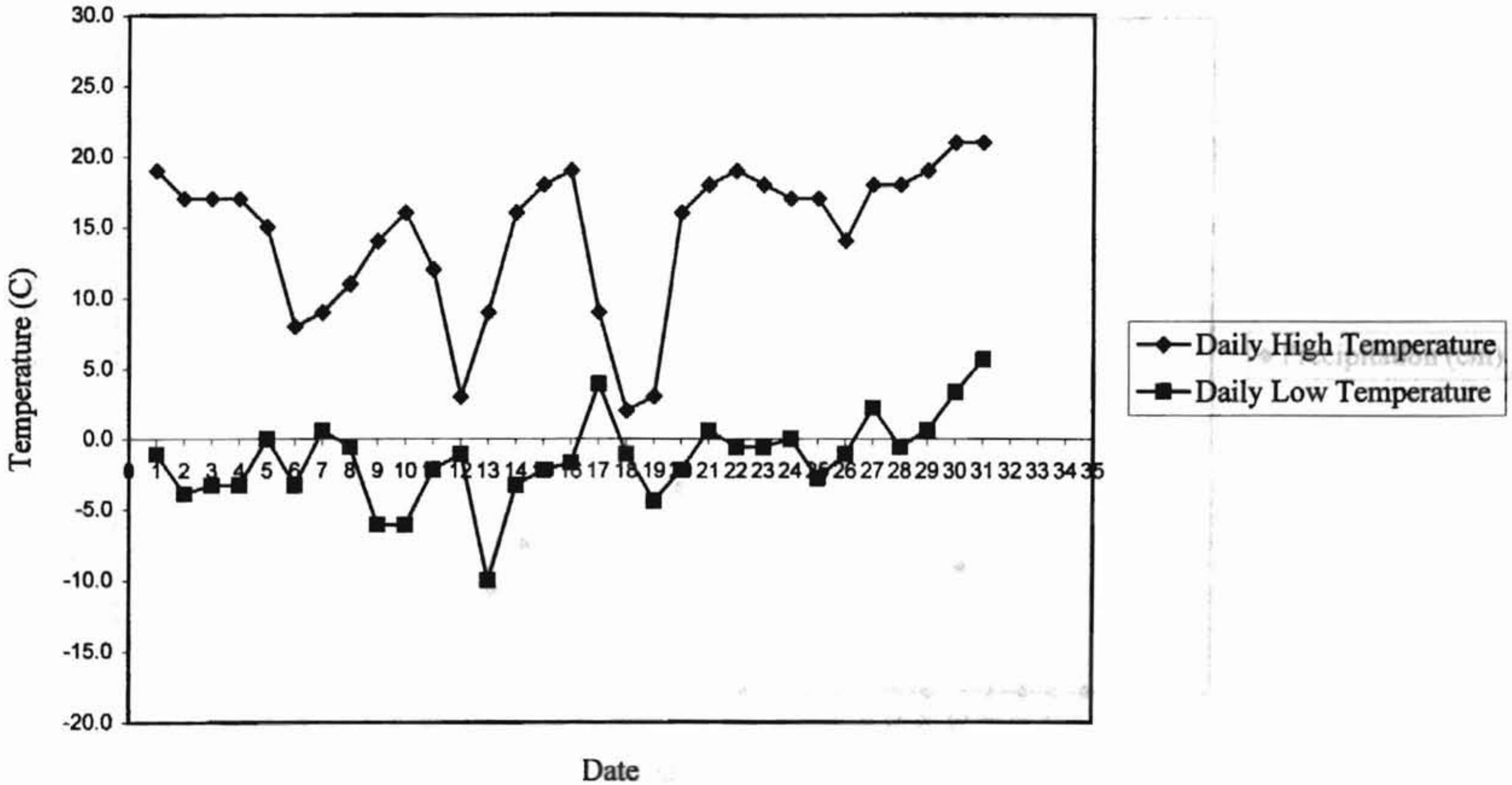


Figure 18. Santa Fe March 1999
Precipitation

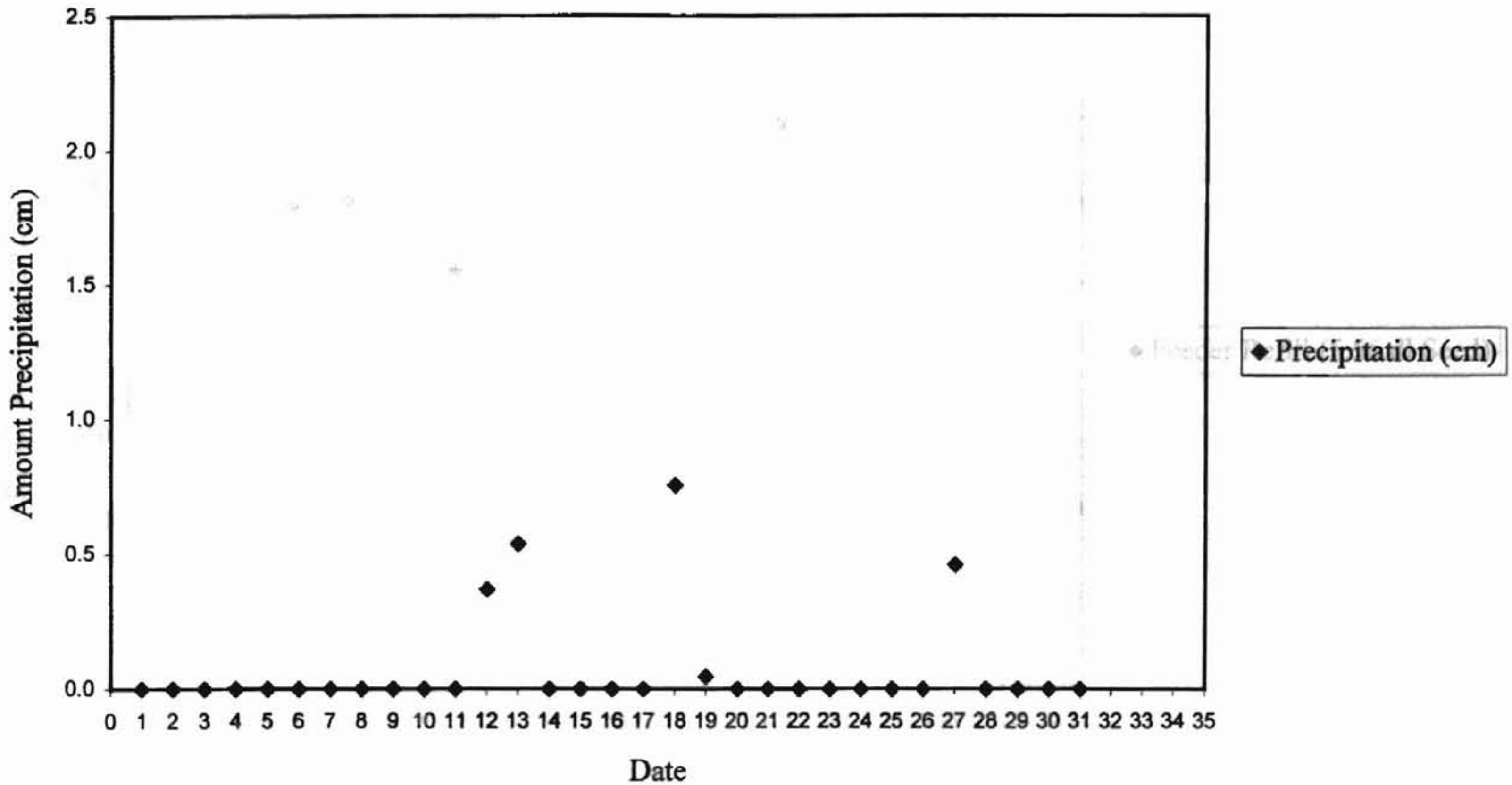


Figure 19. Santa Fe March 1999
Feeder Refills

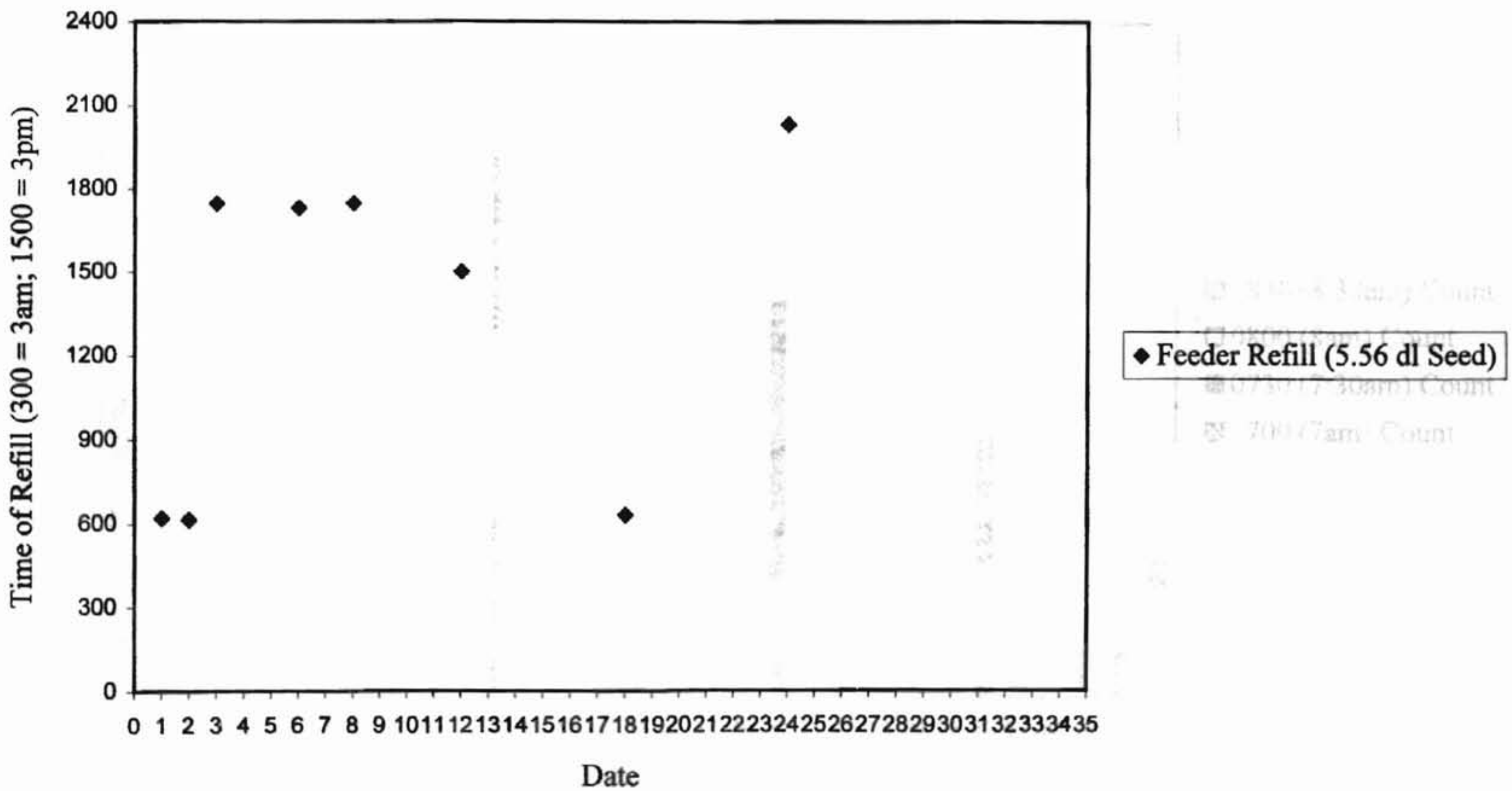


Figure 20. Santa Fe March 1999
Number of Birds Observed/Time

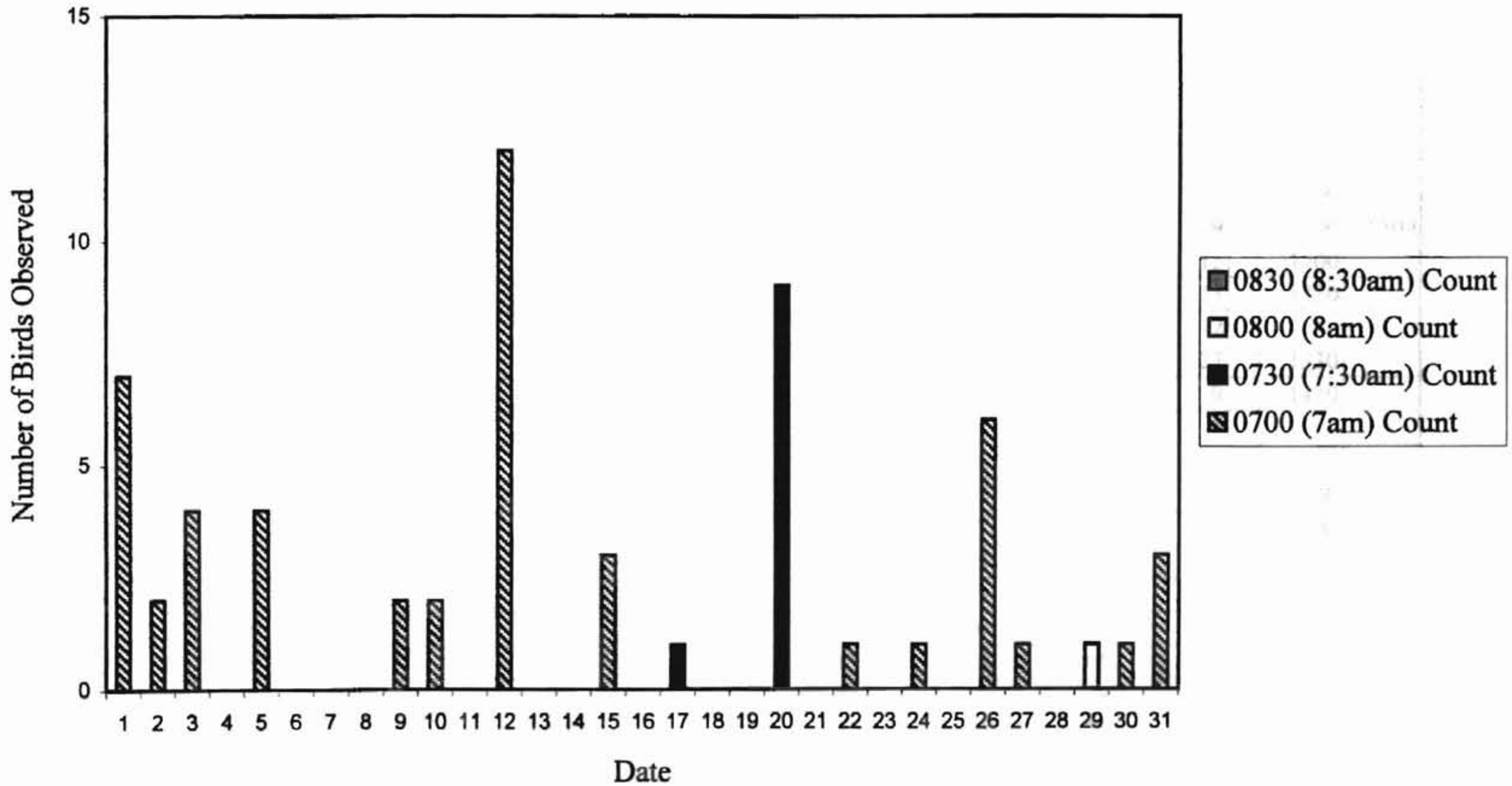


Table 4.

TULSA DATA - JANUARY 1999											
JAN	TEMPERATURE(C)			PRECIPITATION	NUMBER OF BIRDS SEEN/TIME					REFILL	
date	high	low	daily avg	cm	0800 hrs	1200 hrs	1500 hrs	1600 hrs	daily avg	time	time
1											
2											
3											
4											
5											
6											
7											
8	-3.3	-5.0	-4.2	0.0000	4	4		5	3	1200	
9	-2.8	-12.2	-7.5	0.0000	5	14	5	12	9	700	1500
10	6.7	-6.1	0.3	0.0000	6	12	17	25	15	1500	
11	14.4	-2.8	5.8	0.0000	4	22	7	17	13	1730	
12	17.8	9.4	13.6	0.0000	0	7	0	0	2		
13	5.0	-5.0	0.0	0.0000	34	19	43	11	27	1330	
14	7.2	-4.4	1.4	0.0000	8	0	27	0	9	1430	
15	15.6	0.0	7.8	0.0000	0	9	11	0	5		
16	13.9	-2.8	5.6	0.0000	6	5	18	9	10	1430	
17	16.1	1.1	8.6	0.0015	19	6	5	0	8	1100	
18	14.4	1.7	8.1	0.0000	5	3	7	19	9	1300	
19	18.9	7.2	13.1	0.0000	8	4	15	3	8	1330	
20	20.0	-2.2	8.9	0.0000	2	7	3	46	15	1400	
21	21.7	9.4	15.6	0.0000	3	14	0	53	18	1515	
22	8.3	3.3	5.8	0.0924	0	13	78	43	34	1415	1730
23	7.8	0.0	3.9	0.1540	166	45	7	48	67	1130	1515
24	15.6	0.0	7.8	0.0000	0	27	6	58	23	1200	
25	6.1	1.1	3.6	0.0000	0	23	27	35	21	1000	1515
26	18.3	1.7	10.0	0.0015	0	0	33	0	8	1130	

TULSA DATA - JANUARY 1999

JAN	TEMPERATURE(C)			PRECIPITATION	NUMBER OF BIRDS SEEN/TIME					REFILL	
date	high	low	daily avg	cm	0800 hrs	1200 hrs	1500 hrs	1600 hrs	daily avg	time	time
27	18.3	12.8	15.6	0.0000	0		3	2	1	1300	
28	15.6	5.0	10.3	0.0015	0	6	0	0	2	1530	
29	5.6	3.3	4.5	0.4312	0	48	63	163	69	1515	
30	7.8	6.1	7.0	2.1714	87	0	31	18	34	1345	1745
31	5.6	3.9	4.8	0.0154	11	11	38	49	27	1400	1730

Table 5.

TULSA DATA - FEBRUARY 1999											
FEB	**TEMPERATURE(C)**			**PRECIP**	**NUMBER OF BIRDS SEEN/TIME**					**REFILL**	
date	**high**	**low**	**daily avg**	**cm**	**0800 hrs**	**1200 hrs**	**1500 hrs**	**1600 hrs**	**daily avg**	**time**	**time**
1	13.0	5.0	9.0	0.0000	0	0	11	1	3		
2	13.0	2.8	7.9	0.0000	0	6	11	7	6	1130	
3	17.0	3.9	10.5	0.0000	0	18	31	0	12	1830	
4	15.0	1.1	8.1	0.0000	6	9	27	21	16	1445	
5	19.0	7.8	13.4	0.0000	0	32	5	11	12	1730	
6	23.0	14.4	18.7	0.1694	0	11	17	16	11		
7	12.0	6.1	9.1	0.4004	7	11	8	0	7	1315	1830
8	23.0	1.7	12.4	0.0000	0	19	5	0	6		
9	23.0	10.0	16.5	0.0000	2	0	6	49	14	1530	
10	25.0	11.1	18.1	0.0000	0	10	14	16	10	1630	
11	21.0	4.4	12.7	0.4620	0	11	3	11	6		
12	10.0	-1.7	4.2	0.0000	0	0	23	1	6	1230	
13	9.0	-2.8	3.1	0.0000	5	51	9	8	18	1030	1830
14	18.0	1.7	9.9	0.0000	1	0	6	0	2	1130	
15	19.0	10.0	14.5	0.0000	7	0		43	13	1030	
16	14.0	5.6	9.8	0.0154	1	7	19	67	24	1300	
17	16.0	0.0	8.0	0.0000	106	17	0	58	45	1000	
18	9.0	7.2	8.1	0.0462	53	7	29	0	22	1000	1800
19	7.0	1.7	4.4	0.0000	96	19	17	17	37	1830	
20	14.0	2.2	8.1	0.0000	47	5	2	6	15	1830	
21	7.0	2.2	4.6	0.0000	16	31	76	23	37	1700	
22	6.0	-3.3	1.4	0.0000	0	3	27	21	13	1730	
23	13.0	2.2	7.6	0.0000	31	27	21	13	23	1430	1830
24	21.0	-1.7	9.7	0.0000	0	7	3	76	22	1830	
25	23.0	3.9	13.5	0.0000	2	7	1	0	3	1530	
26	24.0	14.4	19.2	0.0000	0	5	3	0	2	1530	
27	19.0	12.2	15.6	0.0000	2	7	5	6	5	1530	
28	21.0	2.2	11.6	0.0000	52	1	17	12	21	1330	

Table 6.

TULSA DATA - MARCH 1999											
MAR	**TEMPERATURE(C)**			**PRECIP**	**NUMBER OF BIRDS SEEN/TIME**					**REFILL**	
date	**high**	**low**	**daily avg**	**cm**	**0800 hrs**	**1200 hrs**	**1500 hrs**	**1600 hrs**	**daily avg**	**time**	**time**
1	26.0	3.3	14.7	0.0000	12	5	18	17	13	1030	1830
2	16.0	8.3	12.2	0.0154	12	19	15	0	12	1830	
3	11.0	-1.7	4.7	0.0000	29	17	21	27	24	1830	
4	18.0	1.1	9.6	0.0000	27	25	21	16	22	1830	
5	23.0	15.6	19.3	0.0000	19	0	12	1	8	1830	
6	9.0	3.3	6.2	0.0000	12	5	22	0	10	1630	
7	8.0	-2.2	2.9	0.0000	7	27	90	29	38	1500	
8	17.0	2.2	9.6	1.5554	0	14	27	27	17	1630	
9	13.0	0.1	6.5	0.0000	93	11	27	3	34	1630	
10	11.0	1.7	6.4	0.0015	14		47	16	19	1830	
11	13.0	1.7	7.4	0.0000	0	4	77	19	25	1630	
12	6.0	2.2	4.1	1.4476	0	57	68	47	43	1630	
13	2.0	0.0	1.0	0.3080	0	33	88	27	37	1300	1830
14	7.0	-2.8	2.1	0.0154	23	53	29	0	26	1300	
15	15.0	-3.3	5.9	0.0000	0	1	11	11	6	1400	
16	22.0	7.2	14.6	0.0000	13	8	26	23	18	1630	
17	21.0	12.8	16.9	0.0000	27	11	7	33	20	1330	
18	17.0	4.4	10.7	0.0015	0	14	8	13	9	1430	
19	13.0	6.7	9.9	0.0616	13	49	67	39	42	1330	1830
20	14.0	6.1	10.1	0.0770	17	63	20	12	28	1300	
21	17.0	3.9	10.5	0.0000	25	14	18	15	18	1500	1830
22	25.0	4.4	14.7	0.0000	6	10	21	22	15		
23	8.0	4.4	6.2	0.0015	18	22	19	17	19	900	1730
24	16.0	7.2	11.6	0.0000	4	19	16	7	12	1730	
25	13.0	3.3	8.2	0.0000	52	6	0	44	26	1730	
26	16.0	6.1	11.1	0.0000	29	13	18	3	16	1800	

TULSA DATA - MARCH 1999											
MAR	**TEMPERATURE(C)**			**PRECIP**	**NUMBER OF BIRDS SEEN/TIME**					**REFILL**	
date	**high**	**low**	**daily avg**	**cm**	**0800 hrs**	**1200 hrs**	**1500 hrs**	**1600 hrs**	**daily avg**	**time**	**time**
27	12.0	5.6	8.8	0.0770	29	21	30	19	25	1330	
28	14.0	6.7	10.4	0.0462	31	12	47	12	26	1000	1400
29	21.0	9.4	15.2	0.0015	21	8	221	32	71	1000	1500
30	21.0	6.7	13.9	0.0000	13	19	3	5	10	1230	1500
31	21.0	11.7	16.4	0.0015	26	35	27	2	23	900	1200

Figure 21. Tulsa January 1999
Daily High and Low Temperatures

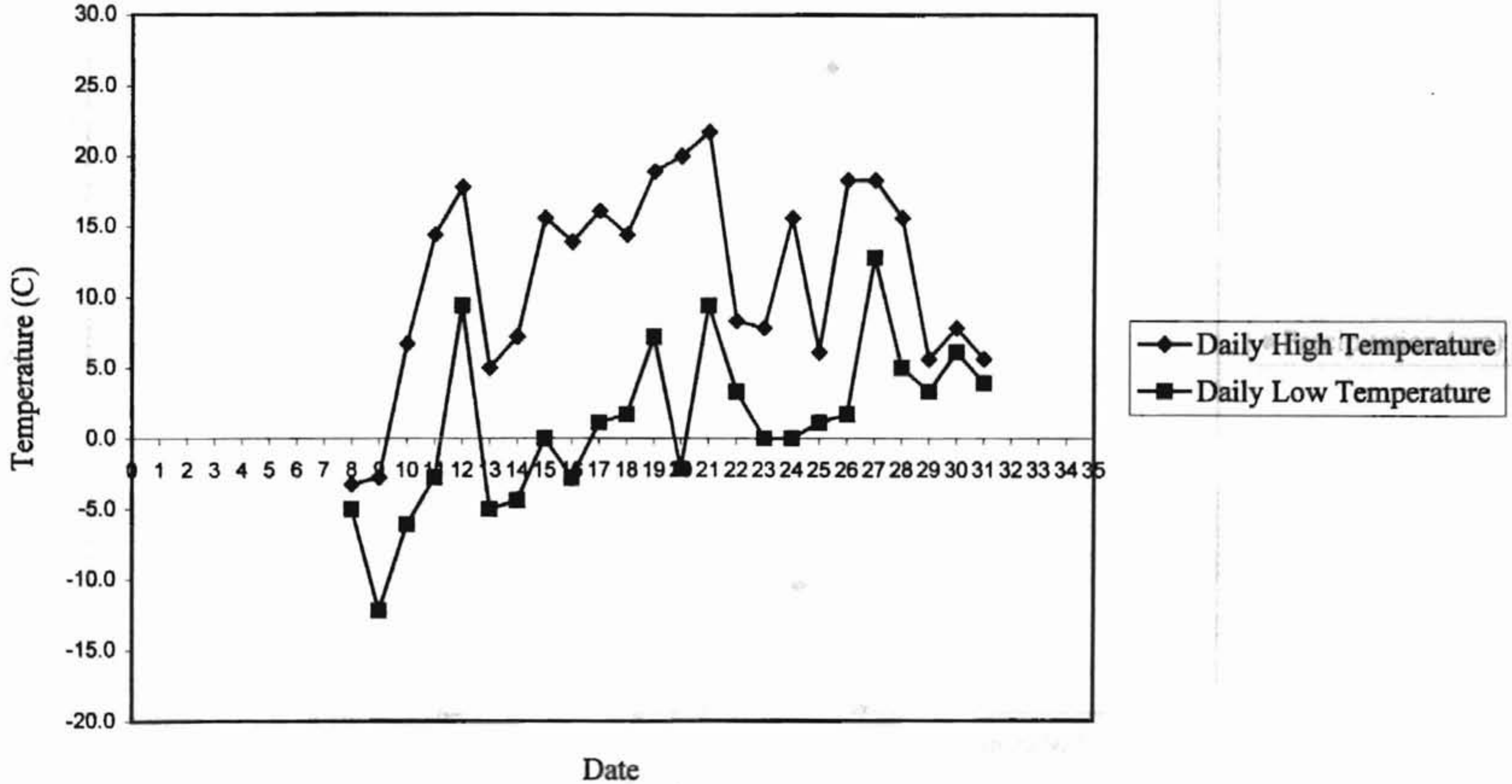


Figure 22. Tulsa January 1999
Precipitation

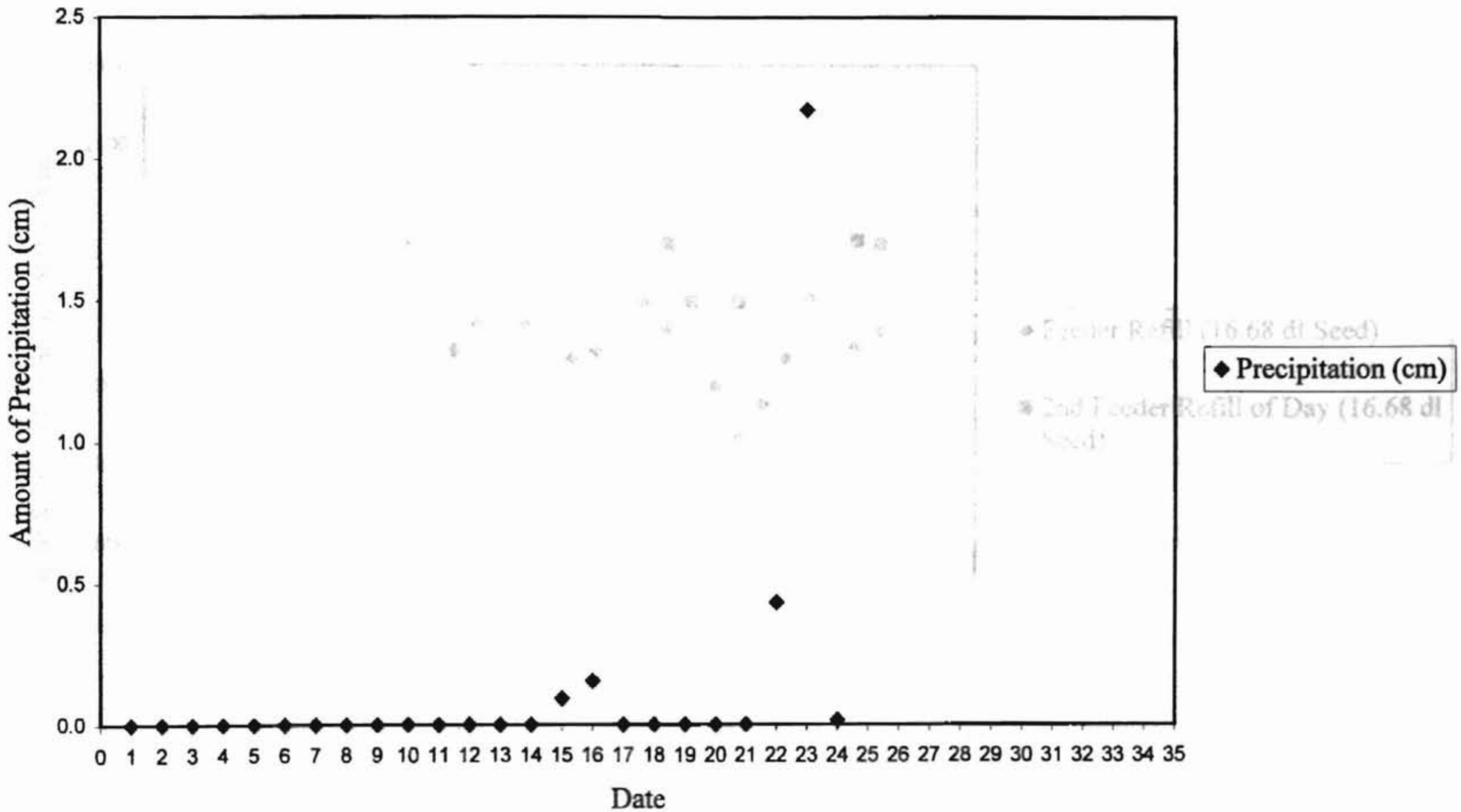


Figure 23. Tulsa January 1999
Feeder Refills

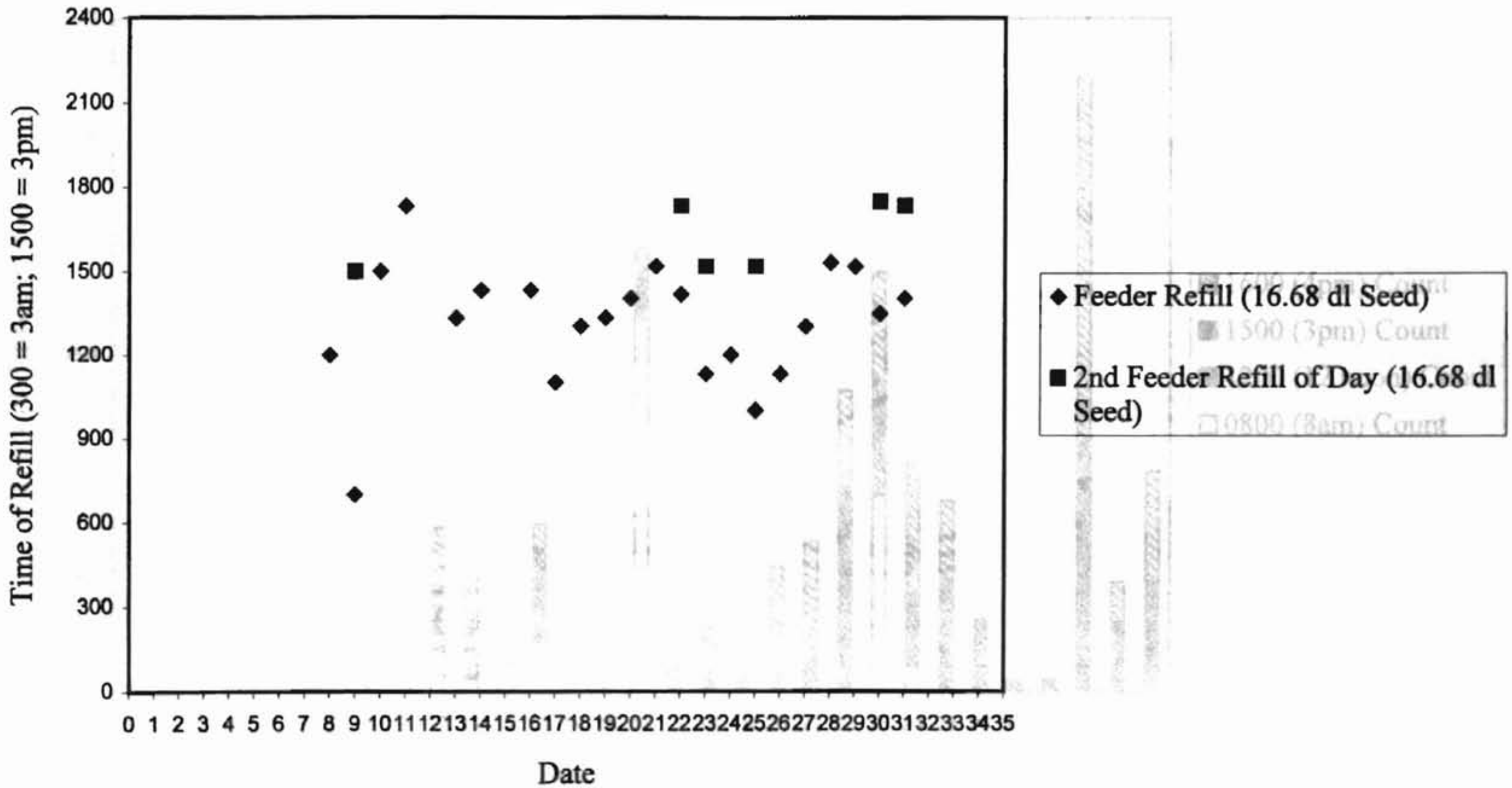


Figure 24. Tulsa January 1999
Number of Birds Observed/Time

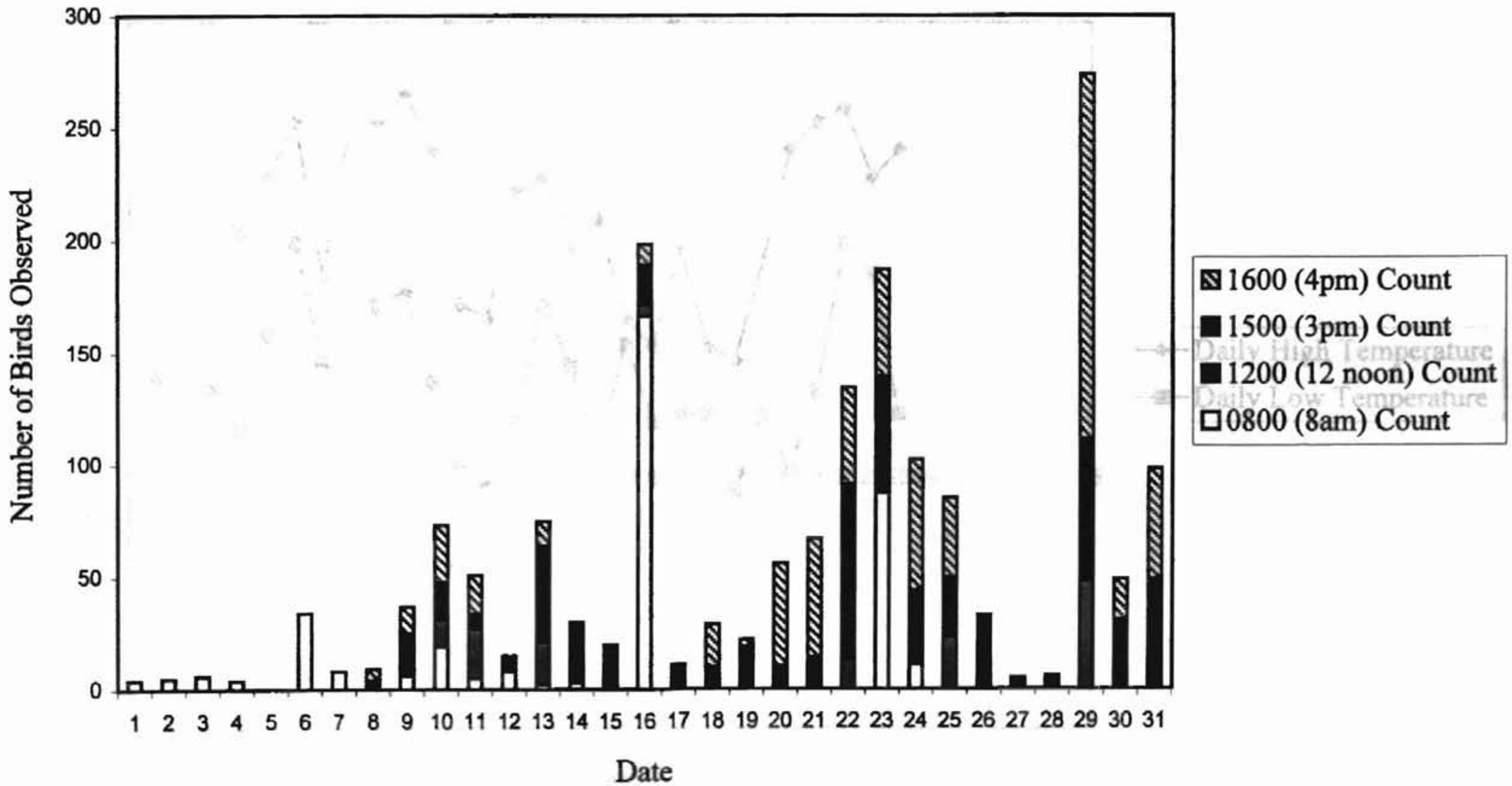


Figure 25. Tulsa February 1999
Daily High and Low Temperatures

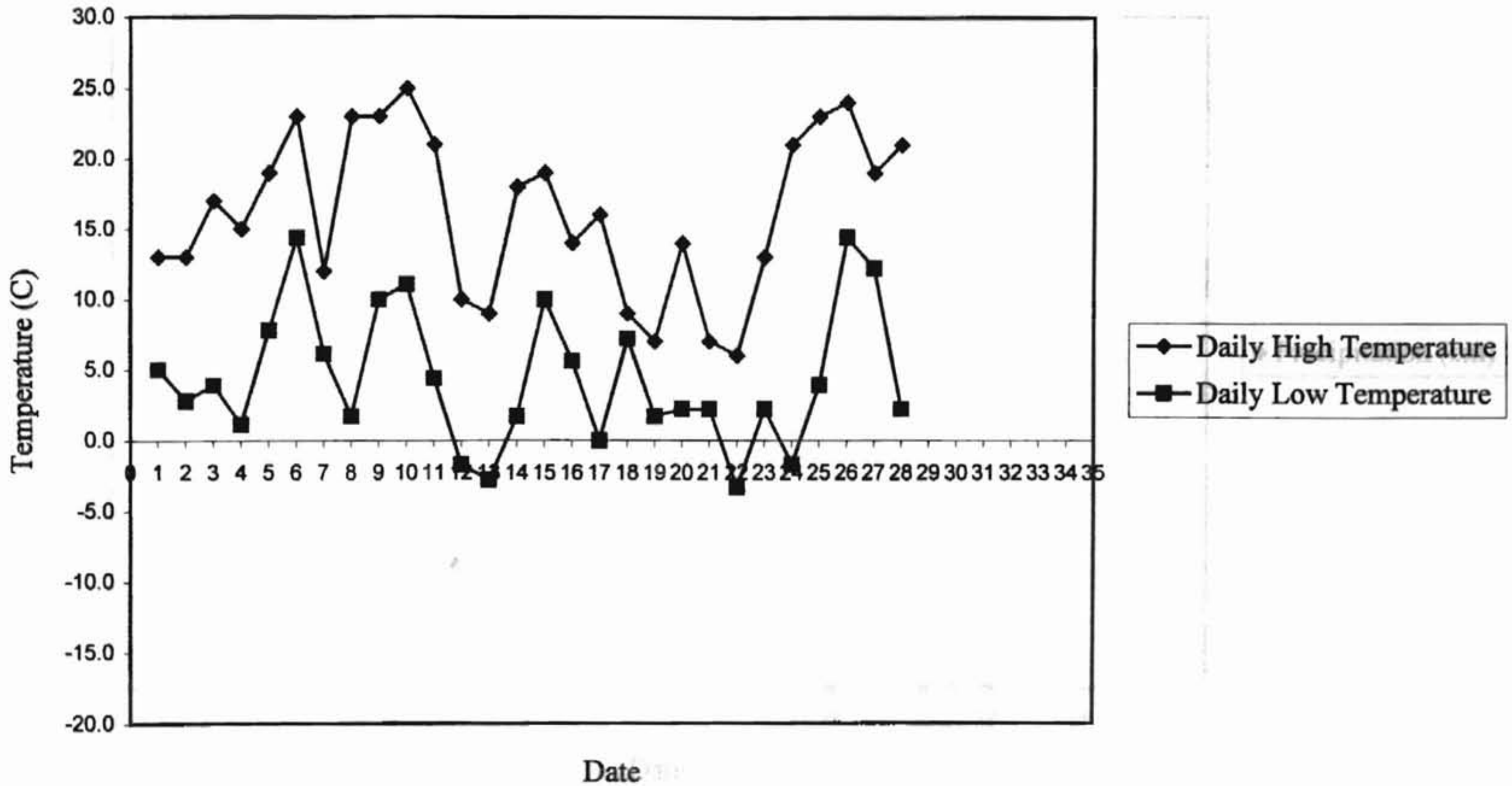


Figure 26. Tulsa February 1999
Precipitation

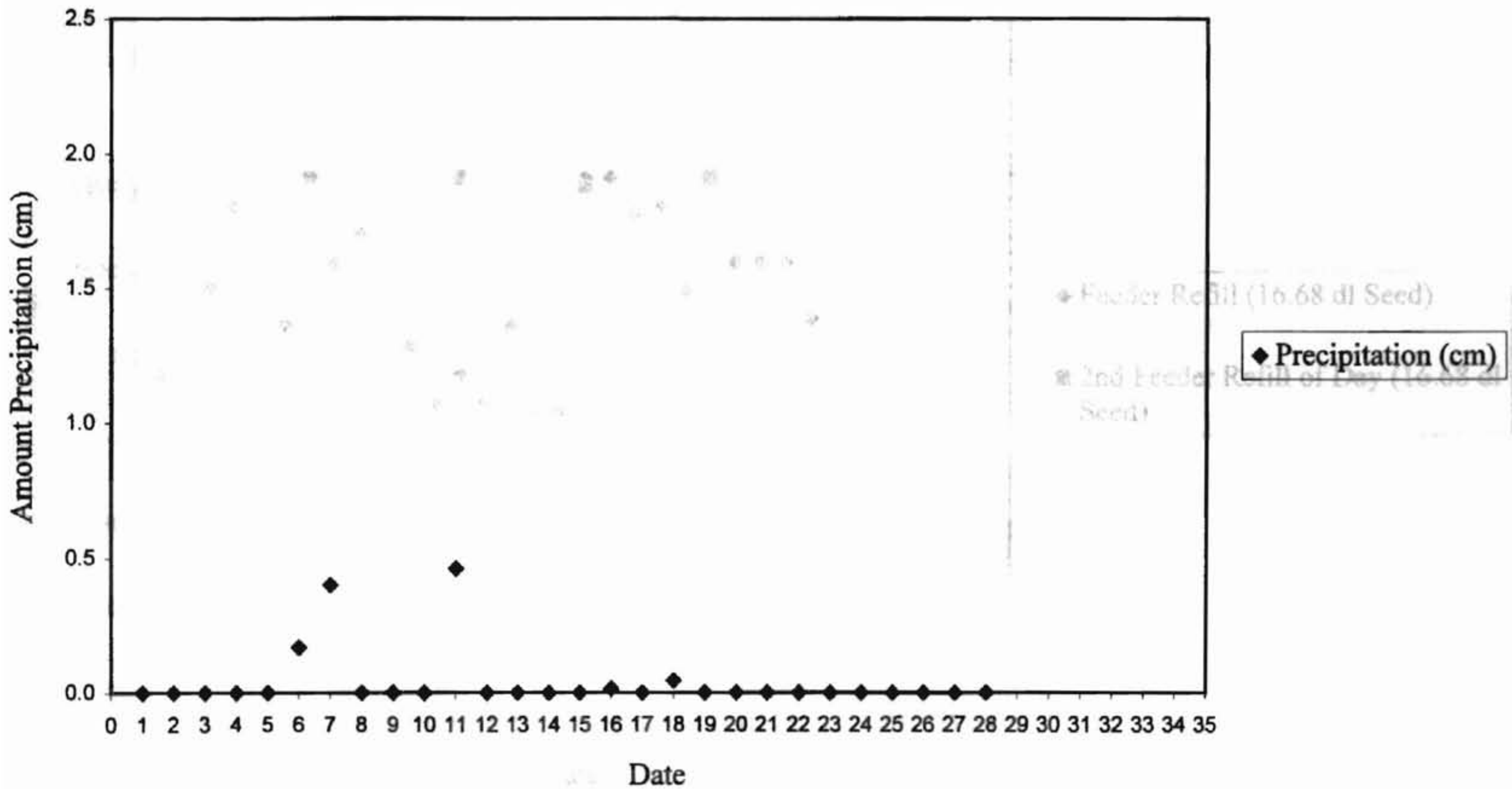


Figure 27. Tulsa February 1999
Feeder Refills

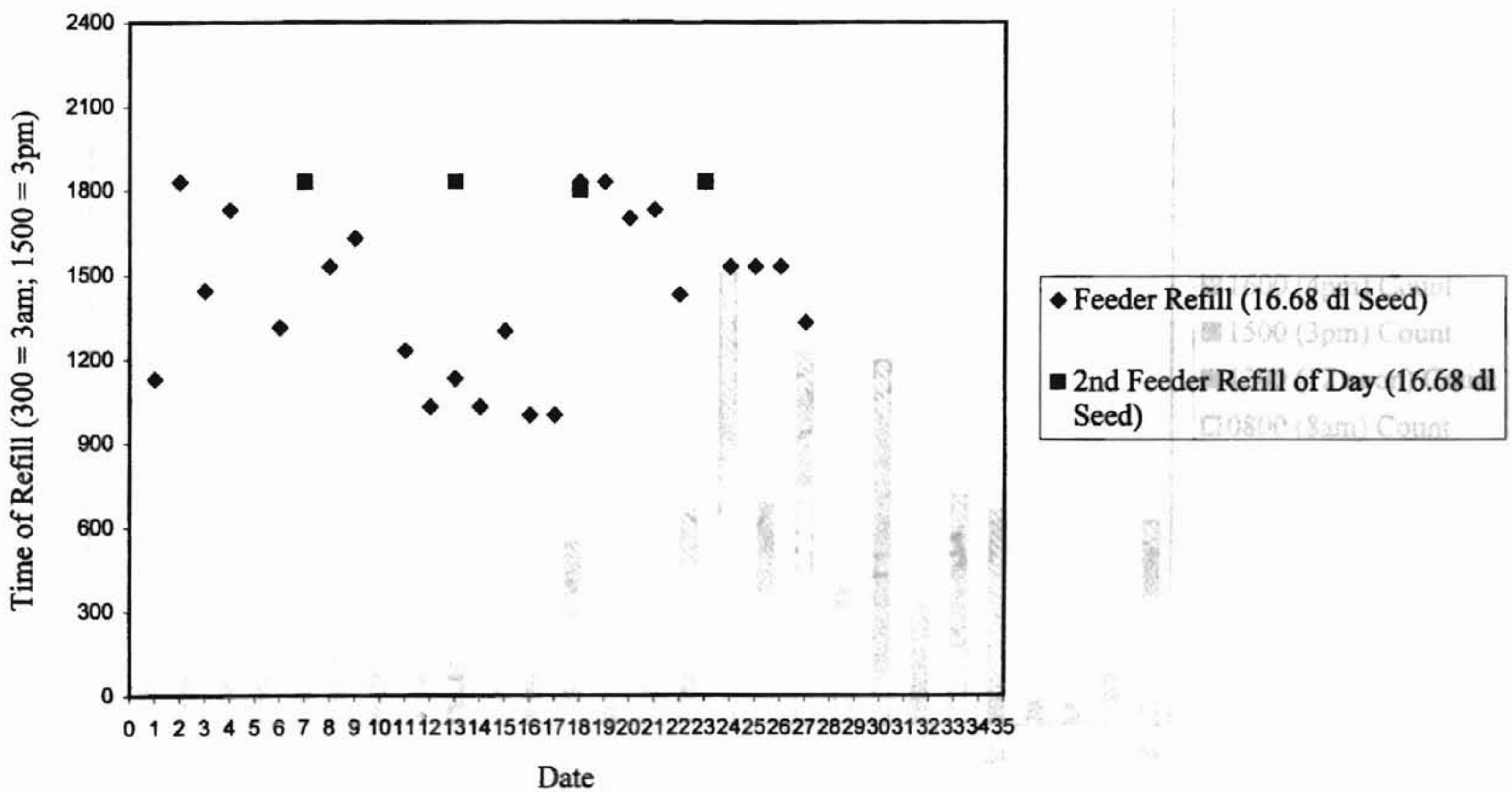


Figure 28. Tulsa February 1999
Number of Birds Observed/Time

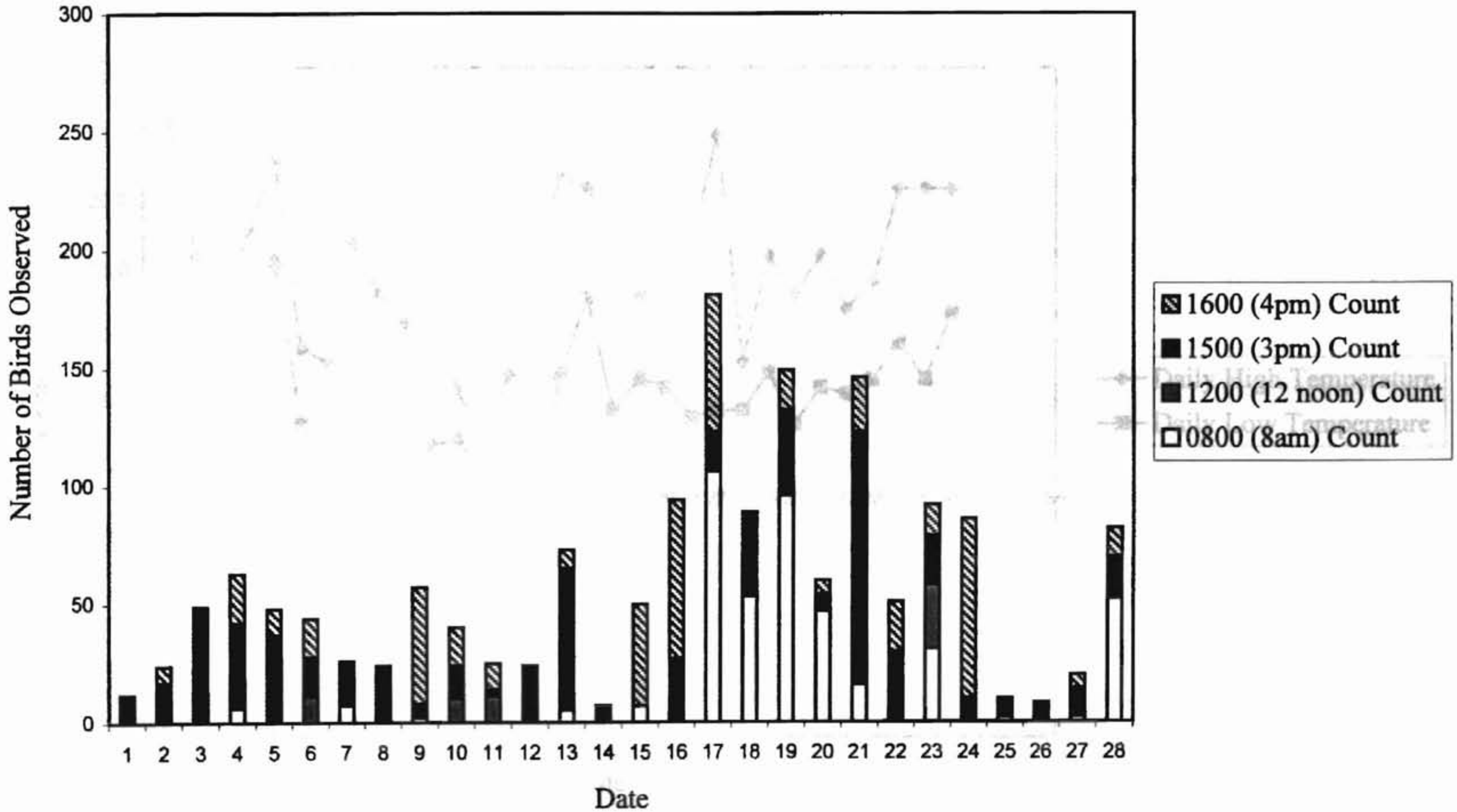


Figure 29. Tulsa March 1999
Daily High and Low Temperatures

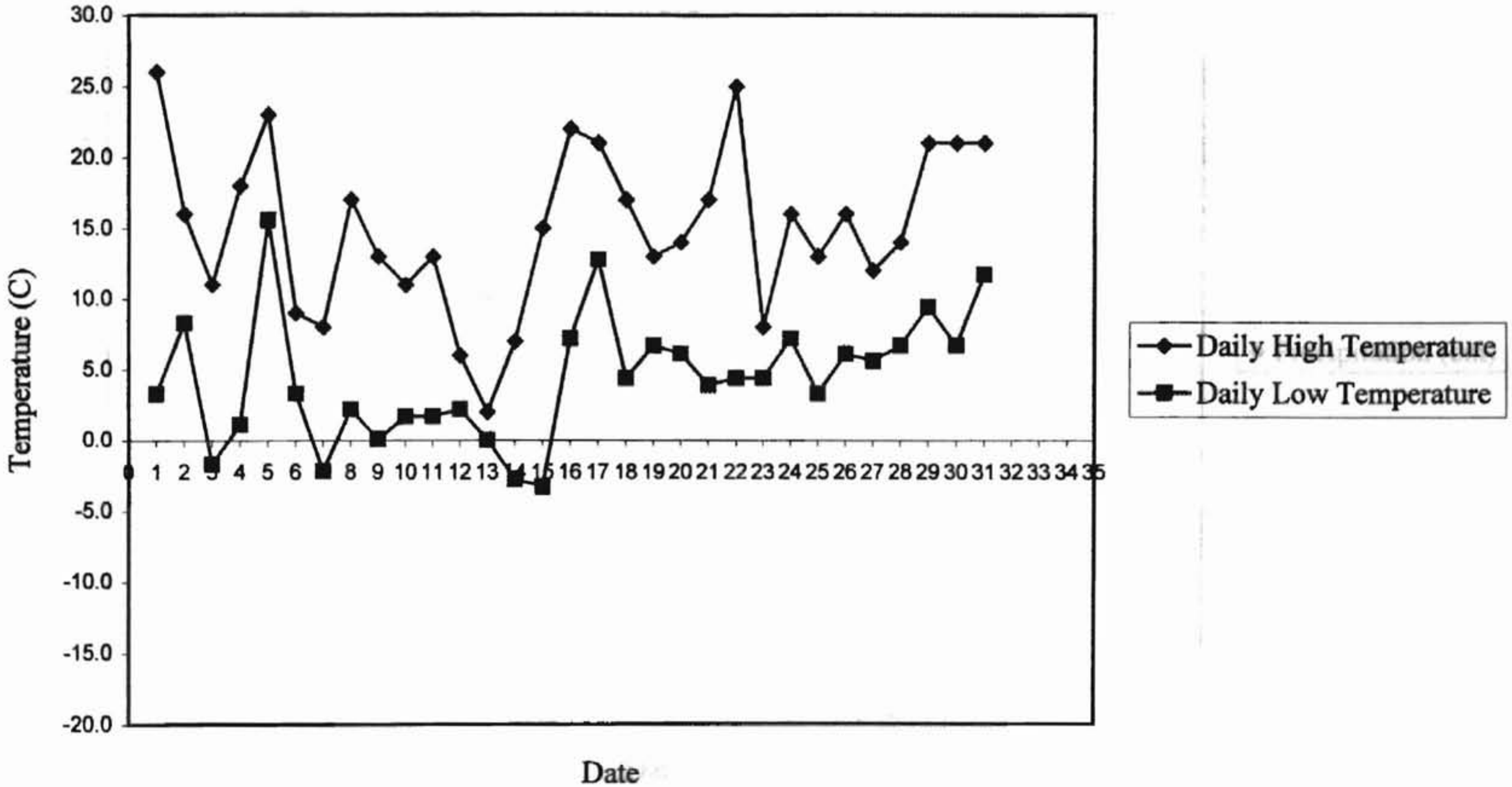


Figure 30. Tulsa March 1999
Precipitation

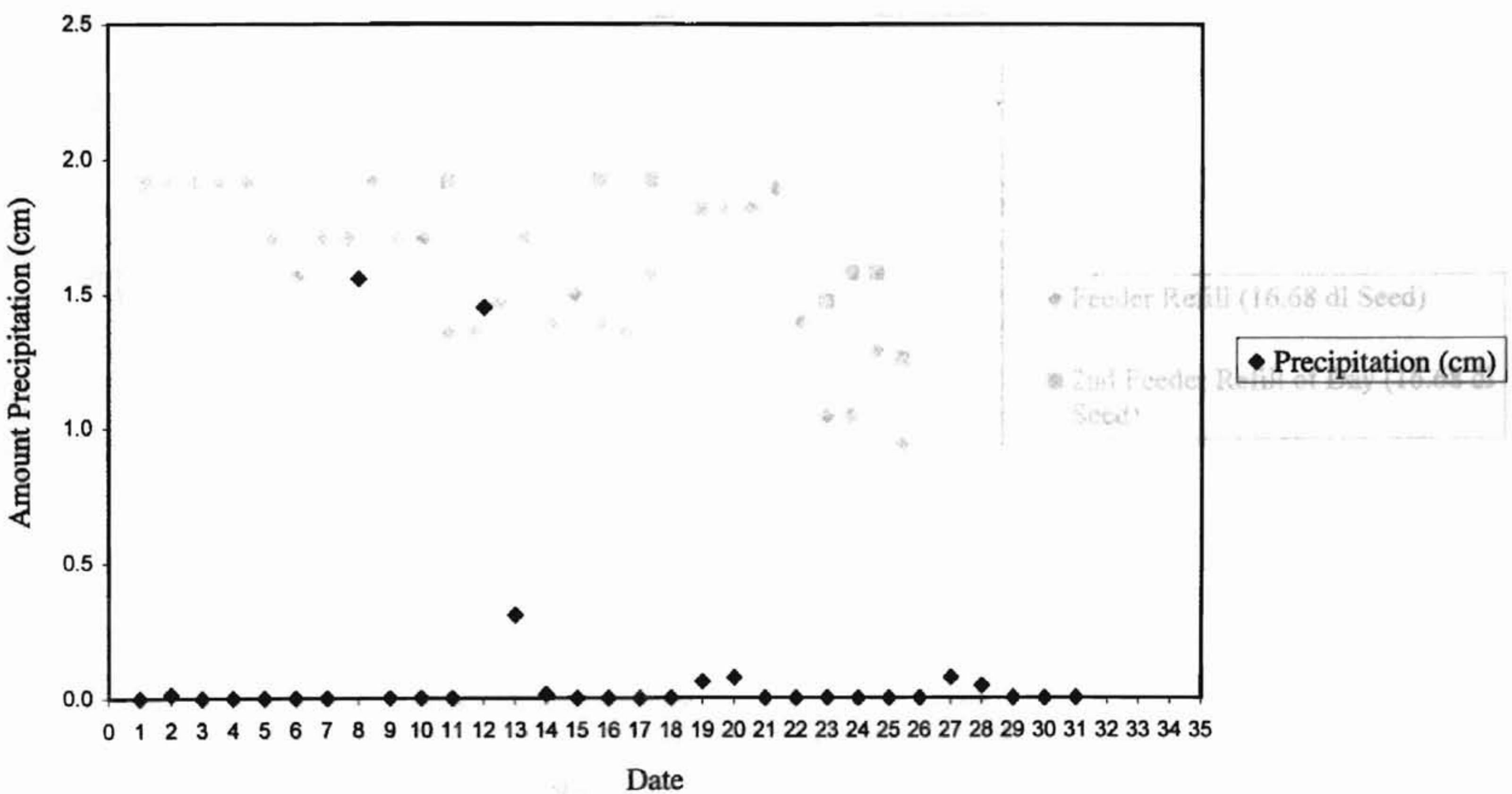


Figure 31. Tulsa March 1999
Feeder Refills

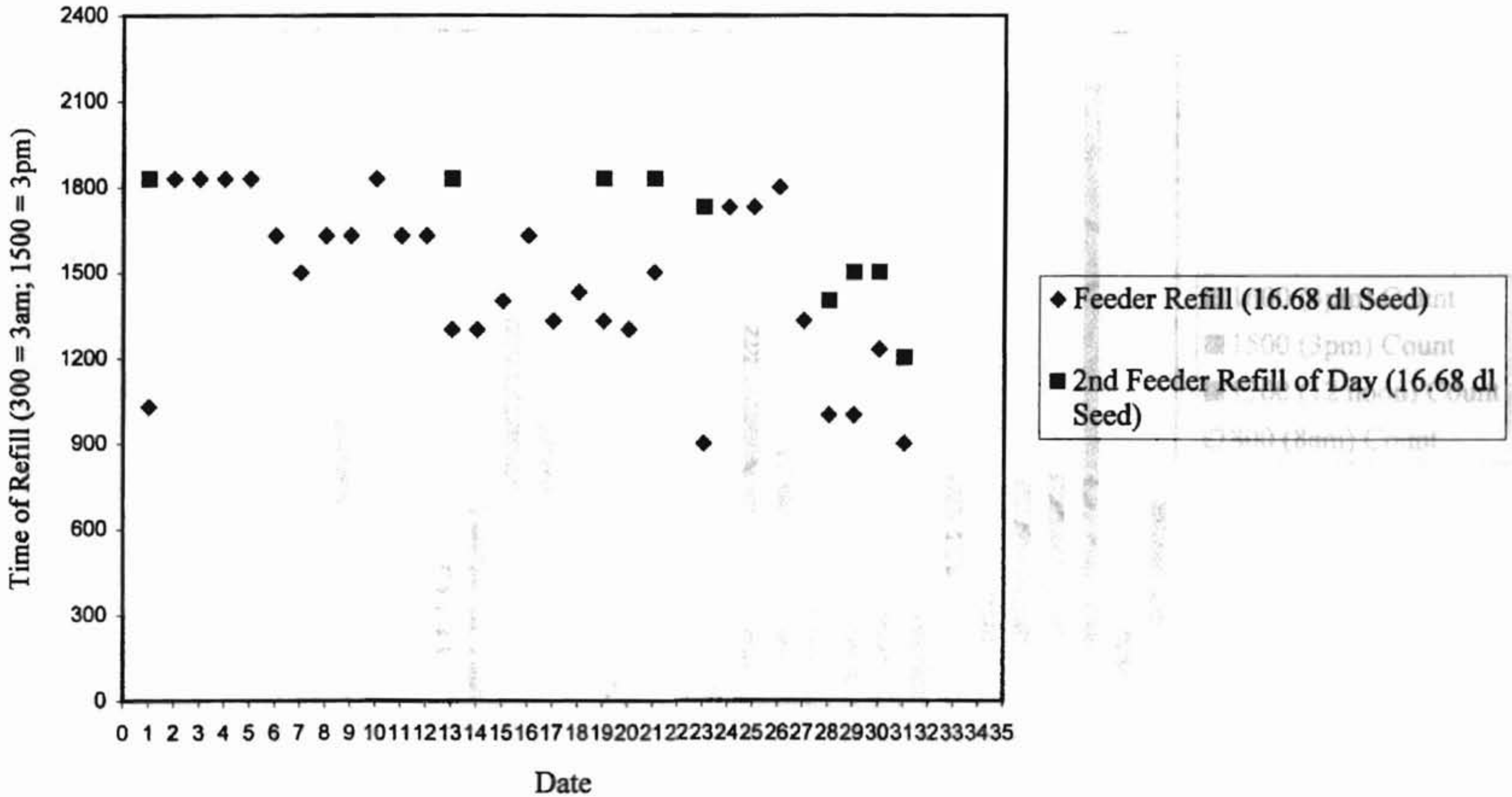
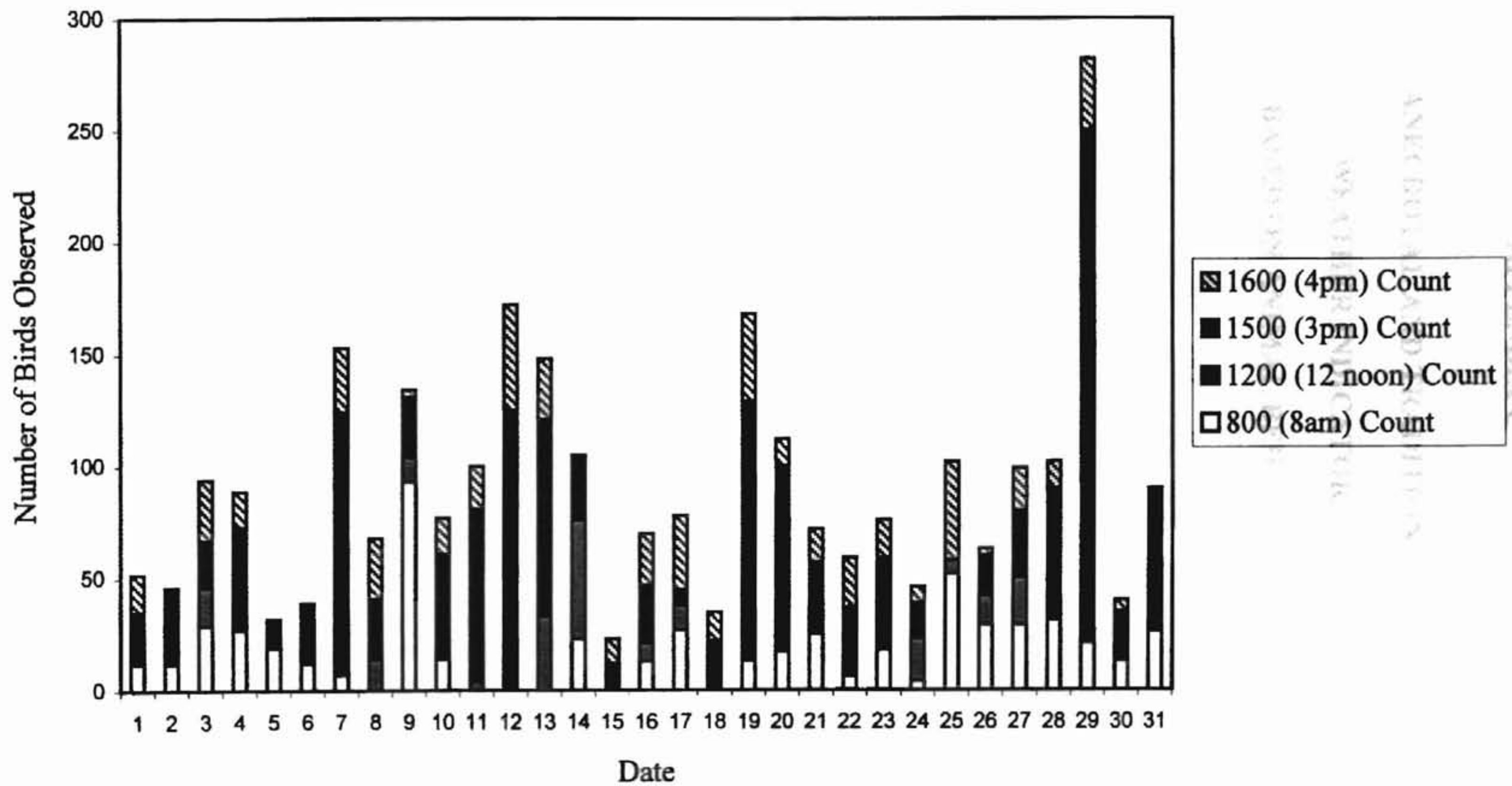


Figure 32. Tulsa March 1999
Number of Birds Observed/Time



APPENDIX C

ANECDOTAL AND TRADITIONAL
WEATHER INDICATORS
BASED ON ANIMAL BEHAVIOR

Table 7.

ANIMAL BEHAVIOR AS A WEATHER PREDICTOR

BY ANIMAL

Note: The use of common names in weather lore has necessitated the broad scientific identification in the table below.

ANIMAL	BEHAVIOR EXHIBITED	WEATHER PREDICTED	REFERENCE
ant (family Formicidae)	becomes more active	rain	Freier (1992), Garriott (1903), Houghton (1996), Lee (1998), Tributsch (1978)
ant (family Formicidae)	closes nest entrance	rain	"Animal weather prophets" (1920), Freier (1992), Watson (1993), Wigginton (1972)
ant (family Formicidae)	increases nest cone height	rain	Freier (1992), Watson (1993), Wigginton (1972)
ant (family Formicidae)	increases nest cone height	winter unusually hard	Freier (1992), Watson (1993), Wigginton (1972)
ant (family Formicidae)	moves eggs to higher ground	rain	Freier (1992), Lee (1998), Tributsch (1978), Virgil (1956)
ant (family Formicidae)	moves to higher ground	rain, heavy	Garriott (1903)
ant (family Formicidae)	travels in straight line	rain	Freier (1992), Garriott (1903), Schmid (1986)
badger (*Taxidea taxus*)	does not see shadow on February 2	winter over, early spring	Freier (1992), Watson (1993)
badger (*Taxidea taxus*)	sees shadow on February 2	winter to continue six more weeks	Freier (1992), Watson (1993)

bat (order Chiroptera)	cries out	rain	Garriott (1903), Sattler (1978), Watson (1993)
bat (order Chiroptera)	flies late in the evening	sun	Garriott (1903)
bat (order Chiroptera)	flies low	rain	Golad (1991), Sloane (1952)
bat (order Chiroptera)	seeks shelter	rain	Sattler (1978), Watson (1993)
bear (family Ursidae)	does not see shadow on February 2	winter over, early spring	Freier (1992), Watson (1993)
bear (family Ursidae)	sees shadow on February 2	winter to continue six more weeks	Freier (1992), Garriott (1903), Watson (1993)
bear (family Ursidae)	stores up food for winter	winter unusually hard	Garriott (1903)
bear, black (*Ursus americanus*)	emerges from hibernation, returns to den	winter to continue	Reinertsen (1996)
bear, black (*Ursus americanus*)	hibernates close to the surface	winter with heavy snows	Reinertsen (1996)
bear, black (*Ursus americanus*)	hibernates deep in unusually large bed	winter cold but little snow	Reinertsen (1996)
beaver (*Castor canadensis*)	builds bigger house than usual	winter unusually hard	Wigginton (1972)
beaver (*Castor canadensis*)	builds house earlier than usual	winter to begin early, end late	Garriott (1903)
beaver (*Castor canadensis*)	builds house with most logs on north	winter unusually hard	Wigginton (1972)
beaver (*Castor canadensis*)	stores unusually large amount of brush	winter unusually hard	Watson (1993)

bighorn sheep (*Ovis canadensis*)	moves to lower elevation	rain	Tributsch (1978)
bird (nonspecific) (class Aves)	covers nest if tree-nester	storm	Tributsch (1978)
bird (nonspecific) (class Aves)	eats significantly more from bird feeders	snow	Lauritzen (1998), Walden (1997) (pers. comms)
bird (nonspecific) (class Aves)	eats up all wild berries earlier than usual	winter unusually hard	Wigginton (1972)
bird (nonspecific) (class Aves)	flies in circles, confused by shifting winds	tornado	Garriott (1903)
bird (nonspecific) (class Aves)	flies low	rain	Golad (1991)
bird (nonspecific) (class Aves)	huddles on ground with other birds	winter unusually hard	Wigginton (1972)
bird (nonspecific) (class Aves)	is silent	rain	Garriott (1903)
bird (nonspecific) (class Aves)	migrates unusually early in fall	winter unusually hard	Freier (1992), Garriott (1903)
bird (nonspecific) (class Aves)	migrates unusually late in fall	winter unusually mild	"Animal weather prophets" (1920)
bird (nonspecific) (class Aves)	oils feathers	rain	Garriott (1903)
bird (nonspecific) (class Aves)	starts singing just after rain	sun	Reinertsen (1996)

bird, sea (class Aves)	flies inland	storm at sea, very violent	Barnes (1998), Garriott (1903), Prince (1974), Tributsch (1978)
bird, shore (class Aves)	flies inland	storm at sea, very violent	Garriott (1903), Newman (1996), Prince (1974)
blackbird (family Icteridae)	sings in an unusually shrill voice	rain	Garriott (1903)
blackbird (family Icteridae)	sings more than usual in morning	rain	Garriott (1903)
blue jay (*Cyanocitta cristata)*	feeds later than usual	storm	Tributsch (1978)
blue jay (*Cyanocitta cristata)*	sits silently	storm	Wallisch (1995) (pers. obs.)
butterfly (family Papilionoidea)	gathers in air with other butterflies	winter to arrive soon	Wigginton (1972)
butterfly (family Papilionoidea)	migrates unusually early in fall	winter to begin early	Wigginton (1972)
cat (*Felis catus)*	eats grass	rain	Freier (1992)
cat (*Felis catus)*	licks fur against the grain	rain	Garriott (1903)
cat (*Felis catus)*	licks fur against the grain	snow	Garriott (1903)
cat (*Felis catus)*	licks fur more frequently	sun	Freier (1992), Garriott (1903)
cat (*Felis catus)*	sits with back to fire	snow	Freier (1992), Garriott (1903)
caterpillar, woolly (order Lepidoptera)	unusually large population in fall	winter unusually hard	Wigginton (1972)
chaffinch (*Fringilla coelebs*)	sings long/different song	rain	Tributsch (1978)

chicken (*Gallus gallus*)	oils feathers	rain	Garriott (1903)
chicken (*Gallus gallus*)	picks up pebbles and are unusually noisy	rain	Garriott (1903)
chicken (*Gallus gallus*)	rolls in dust	rain	Garriott (1903)
chicken (*Gallus gallus*)	won't go into coop	rain	Tributsch (1978)
chicken (hen) (*Gallus gallus*)	crows	storm, flooding	Watson (1993)
chicken (rooster)(*Gallus gallus*)	crows in afternoon or night	rain	Freier (1992), Garriott (1903), Schmid (1986), Watson (1993)
chipmunk (family Sciuridae)	near Lake Superior, in winter nest by Oct	winter to begin early, unusually cold	Garriott (1903)
chipmunk (family Sciuridae)	near Lake Superior, seen until Dec 1	winter unusually short, mild	Garriott (1903)
clam (order Paleoheterodonta)	more air bubbles than usual seen over bed	rain	Garriott (1903)
cockroach (family Blattidae)	becomes more active	rain	Freier (1992), Lee (1998)
cow (*Bos* sp.)	huddles with other cows	rain	Freier (1992), "Six weird ways to predict the weather" (1998)
cow (*Bos* sp.)	lays down	rain	Frier (1992), Golad (1991), Hardy (1996), Schmid (1986), "Six weird ways to predict the weather" (1998), Wigginton (1972)
cow (*Bos* sp.)	lays down early in day	rain early in day	Garriott (1903)
cow (*Bos* sp.)	lays on right side	rain	Watson (1993)
cow (*Bos* sp.)	licks forefeet	rain	Watson (1993)

cow (*Bos* sp.)	moves to lower elevation	rain	Barnes (1998), Freier (1992), Watson (1993)
cow (*Bos* sp.)	plays	rain	Pancake (1983)
cow (*Bos* sp.)	quits giving milk	rain	Watson (1993)
cow (*Bos* sp.)	sniffs air	rain	Garriott (1903), Virgil (1956), Watson (1993)
cow (*Bos* sp.)	stands in a group with tails to windward	storm	Garriott (1903)
cow (*Bos* sp.)	won't go into barn, eats more	rain	Tributsch (1978)
coyote (*Canis latrans*)	moves closer to human-occupied areas	snow	Sattler (1978)
crab (class Decapoda)	emerges on shore	rain	Freier (1992), Sattler (1978), Watson (1993)
crane (order Gruiformes)	calls loudly	rain	Garriott (1903)
crane (order Gruiformes)	flies high and quietly	sun	Garriott (1903), Tributsch (1978)
crane (order Gruiformes)	flies inland	storm	Tributsch (1978)
crane (order Gruiformes)	migrates early in autumn	winter unusually hard	Garriott (1903)
cricket (family Gryllidae)	calls loudly	sun, warmer weather	Wigginton (1972)
cricket (family Gryllidae)	calls more quickly	warmer weather	Garriott (1903)
cricket (family Gryllidae)	more active than usual	rain	Garriott (1903)
crow (*Corvus* sp.)	calls, flies in circles	rain	Freier (1992), Houghton (1996)
crow (*Corvus* sp.)	flies alone	rain	Garriott (1903)
crow (*Corvus* sp.)	flies in pairs	rain	Garriott (1903)

crow (*Corvus* sp.)	gathers in groups with other crows	winter unusually hard	Wigginton (1972)
crow (*Corvus* sp.)	migrates north in autumn	winter unusually mild	Garriott (1903)
crow (*Corvus* sp.)	migrates south in autumn	winter unusually hard	Garriott (1903)
cuckoo (family Cuculidae)	sings in highlands	sun	Garriott (1903)
cuckoo (family Cuculidae)	sings in valleys	rain	Garriott (1903)
cuttlefish (family Sepiidae)	flutters out of the water	storm	Tributsch (1978)
deer (family Cervidae)	bolts, stampedes, for no known reason	storm, violent	Reinertsen (1996)
deer (family Cervidae)	eats more than usual in fall	winter unusually hard	Marshall (1998)
deer (family Cervidae)	moves to lower elevation	rain	Barnes (1998), Freier (1992), Watson (1993)
deer (family Cervidae)	moves to lower elevation	snow	Sattler (1978)
deer, fallow (*Dama dama*)	hides in thicket	rain	Tributsch (1978)
deer, red (*Cervus elaphus*)	moves to clearing and browses in day	rain	Tributsch (1978)
deer, roe (*Capreolus capreolus*)	moves to clearing and browses in day	rain	Tributsch (1978)
deer, whitetail (*Odocoileus virginianus*)	eats throughout day, not at usual times	storm	Tinsley (1977)
dog (*Canis familiaris*)	digs holes in the ground	rain	Garriott (1903)

dog (*Canis familiaris*)	eats grass	rain	Freier (1992), Garriott (1903)
dog (*Canis familiaris*)	holds tail straight	rain	Freier (1992), Watson (1993)
dog (*Canis familiaris*)	licks fur more frequently	sun	Freier (1992)
dog (*Canis familiaris*)	refuses meat	rain	Garriott (1903)
dog (*Canis familiaris*)	rolls on back	rain	Freier (1992), Watson (1993)
dog, spaniel (*Canis familiaris*)	sleeps more than usual	rain	Schmid (1986)
dolphin (suborder Odonticeti)	splashes in waves	sun	Tributsch (1978)
dolphin (suborder Odonticeti)	swims to windward	rain	Freier (1992), Sattler (1978), Watson (1993)
donkey (*Equus asinus*)	brays more	rain	Freier (1992), Watson (1993)
donkey (*Equus asinus*)	hangs ears down and forward	rain	Freier (1992), Watson (1993)
donkey (*Equus asinus*)	rubs against walls	rain	Freier (1992), Watson (1993)
duck (family Anatidae)	unusually loud call	rain	Barnes (1998), Freier (1992), Watson (1993)
elk (*Cervus canadensis*)	bolts, stampedes, for no known reason	storm, violent	Reinertsen (1996)
elk (*Cervus canadensis*)	moves to lower elevation	rain	Barnes (1998), Freier (1992), Watson (1993)
elk (*Cervus canadensis*)	moves to lower elevation, unafraid of humans	snow, heavy; often within 24 hours	Ormond (1981)

fish (superclass Pisces)	rises to surface; bites at bait, insects	rain	Freier (1992), Garriott (1903), Golad (1991), Sattler (1978), Tributsch (1978), Watson (1993)
fish, marine (superclass Pisces)	swims up rivers	storm at sea, violent	Barnes (1998)
flea (order Siphonaptera)	bites more frequently	rain	Elliot (1996)
fly (order Diptera)	bites more frequently	rain	Garriott (1903), Golad (1991)
fly (order Diptera)	moves into buildings	rain	Freier (1992), Garriott (1903)
fly (order Diptera)	swarms	rain	Garriott (1903)
flying squirrel (*Glaucomys* sp.)	calls in midwinter	winter over, early spring	Garriott (1903)
frog (suborder Diplasiocoela)	calls very early in year	storm, flooding	Houghton (1996)
frog (suborder Diplasiocoela)	if raining, increased nighttime croaking	sun	Freier (1992), Watson (1993)
frog (suborder Diplasiocoela)	if sunny, increased croaking	rain	Freier (1992), Newman 1996), Watson (1993)
gnat (suborder Nematocera)	bites more frequently	rain	Garriott (1903)
goat (*Capra* sp.)	butts aggressively	rain	Barnes (1998), Freier (1992)
goat (*Capra* sp.)	grazes high on hills	sun	"What kind of winter will we have" (1998)
goat (*Capra* sp.)	grazes low on hills	rain	"What kind of winter will we have" (1998)
goat (*Capra* sp.)	won't enter shed, eats more	rain	Tributsch (1978)
goose (tribe Anserini)	flies high	sun	Freier (1992), Garriott (1903)
goose (tribe Anserini)	flies low	rain	Freier (1992), Garriott (1903)

goose (tribe Anserini)	roosts	rain	Sloane (1952)
goose (tribe Anserini)	unusually loud call	rain	Barnes (1998), Freier (1992), Watson (1993)
goose, wild (tribe Anserini)	flies south	cold front (freezing)	Reinertsen (1996)
goose, wild (tribe Anserini)	flies south and very high	winter unusually hard	Garriott (1903)
goose, wild (tribe Anserini)	in Kansas, flies to southeast in fall	snow, blizzard	Garriott (1903)
groundhog (*Marmota monax*)	does not see shadow on Feb 2	winter over, early spring	Freier (1992), Garriott (1903), Watson (1993)
groundhog (*Marmota monax*)	sees shadow on Feb 2	winter to continue six more weeks	Freier (1992), Garriott (1903), Watson (1993)
grouse (subfamily Tetraoninae)	drum at night	snow, heavy	Garriott (1903)
grouse (subfamily Tetraoninae)	emerges from winter hiding place	sun	Reinertsen (1996)
gull (family Laridae)	calls, flies in circles	rain	Freier (1992), Garriott (1903)
gull (family Laridae)	moves 5-15 miles inland	storm at sea, violent	Snyder (1999) (pers. comm.), Tributsch (1978), Virgil (1956)
hawk (family Accipitridae)	flies high	sun	Garriott (1903)
hawk (family Accipitridae)	flies low	rain	Garriott (1903)

hawk (family Accipitridae)	hunts in groups	rain	Sattler (1978)
heron (family Ardeidae)	flies up and down repeatedly	rain	Garriott (1903), Virgil (1956)
herring (*Clupea* sp.)	school more rapidly	rain	Garriott (1903)
honey bee (subfamily Apinae)	stays close to hive	rain	Freier (1992), Garriott (1903), Golad (1991), Schmid (1986), Watson (1993)
hornet (subfamily Vespinae)	heavier than usual nest construction	winter unusually hard	Wigginton (1972)
hornet (subfamily Vespinae)	nest built close to ground	winter unusually hard	Kauffman (1998), Wigginton (1972)
hornet (subfamily Vespinae)	nest built higher than usual	snow, heavy	Golad (1991)
horse (*Equus caballus*)	shies for no reason	rain	Barnes (1998), Freier (1992) , Garriott (1903)
horse (*Equus caballus*)	sniffs air	rain	Garriott (1903)
iguana (family Iguanidae)	hides in vegetation, among rocks+B200	rain	Banuelos Connell (1999) (pers. comm.)
junco (*Junco* sp.)	feeds in tree rather than on ground	winter unusually hard	Wigginton (1972)
katydid (suborder Ensifera)	first sings three month before frost	frost, season's first killing	Wigginton (1972)
lark (family Alaudidae)	flies high	sun	Freier (1992)
lark (family Alaudidae)	flies low	rain	Freier (1992)

lark (family Alaudidae)	roosts	rain	Sloane (1952)
martin (family Hirundinidae)	flies low	rain	Garriott (1903)
martin (family Hirundinidae)	seen in spring	winter over	Garriott (1903)
mosquito (family Culicidae)	bites more frequently	rain	"Six weird ways to predict the weather" (1998), Watson (1993)
mouse (order Rodentia)	becomes more active	rain	Freier (1992), Sattler (1978)
mouse (order Rodentia)	migrates into house earlier than usual	winter unusually hard	Golad (1991)
mule (*Equus* sp.)	unusual behavior, e.g. ears laid back	storm, violent	Crooks(1999) (pers. comm.)
muskrat (*Ondatra zibethica*)	builds bigger house than usual	winter unusually hard	Wigginton (1972)
opossum (*Didelphis marsupialis*)	moves to higher ground	rain	Sattler (1978)
owl (families Tytonidae, Strigidae)	if raining, loud calls	sun	Barnes (1998), Freier (1992), Tributsch (1978), Watson (1993)
owl (families Tytonidae, Strigidae)	if sunny, loud calls	rain	Barnes (1998), Freier (1992), Tributsch (1978), Watson (1993)
owl (families Tytonidae,	unusually loud call	rain	Barnes (1998), Freier (1992), Watson
owl, "arctic"(families Tytonidae, Strigidae)	seen further south than usual	winter unusually hard	Watson (1993)
owl, hoot (families Tytonidae, Strigidae)	calls late in fall	winter unusually hard	Wigginton (1972)

owl, screech (*Otus* sp.)	call sounds like a woman crying	winter unusually hard	Wigginton (1972)
ox (*Bos taurus*)	sniffs air	storm	Tributsch (1978)
parrot (order Psittaciformes)	unusually loud call	rain	Barnes (1998), Freier (1992), Garriott (1903), Watson (1993)
peafowl (cock) (*Pavo* sp.)	unusually loud call	rain	Barnes (1998), Freier (1992), Garriott (1903), Watson (1993)
pheasant, Chinese (family Phasianidae)	crows repeatedly	rain	Reinertsen (1996)
pig (familiy Suidae)	carries straw for nest	rain	Freier (1992), Garriott (1903), Tributsch (1978), Virgil (1956), Watson !993)
pig, wild (family Suidae)	gathers straw, sticks, etc., for nest	winter unusually hard	Wigginton (1972)
pigeon (*Columba* sp.)	returns to nest or coop	rain	Garriott (1903)
pike (fish) (family Esocidae)	lies on bottom of stream	rain	Garriott (1903)
porpoise (*Phocaena* sp.)	more active than usual	rain	Freier (1992), Garriott (1903), Sattler (1978), Watson (1993)
porpoise (*Phocaena* sp.)	swims up rivers	storm at sea, violent	Barnes (1998)
prairie dog (*Cynomys* sp.)	covers burrow entrance with grass	rain	Barnes (1998)
rabbit (family Leporidae)	becomes more active	rain	Freier (1992), Sattler (1978)

rabbit (family Leporidae)	more rabbits caught in traps	rain	"Animal weather prophets" (1920)
raccoon (*Procyon lotor*)	moves to higher ground	rain	Sattler (1978)
raven (*Corvus* sp.)	unusually loud call	rain	Barnes (1998), Freier (1992), Watson (1993)
migratorisus; Eurasian *Erithacus rubecula*)	appears in spring	winter over	Garriott (1903)
robin (American *Turdus migratorisus*; Eurasian	sings from treetop	rain	Freier (1992), Garriott (1903)
migratorisus; Eurasian *Erithacus rubecula*)	sings long/different song	rain	Cooke (1998) (pers. comm.), Garriott (1903)
rook (*Corvus frugilegus*)	flies high	sun	Freier (1998)
rook (*Corvus frugilegus*)	flies low	rain	Freier (1998), Garriott (1903)
rook (*Corvus frugilegus*)	roosts	rain	Sloane (1952)
sea urchin (class Echinoidea)	adheres to rock	storm	Tributsch (1978)
(*Lobodon carcinophagus*)	early migration from Antarctic	winter to begin early, unusually cold	Hurley (1919)
sheep (*Ovis* sp.)	becomes more active and playful	rain	Barnes (1998), Freier (1992), Garriott (1903), Tributsch (1978)

sheep (*Ovis* sp.)	moves to lower elevation	rain	Barnes (1998), Freier (1992), Watson (1993)
sparrow (families Passeridae, Emberizidae)	unusually loud call	rain	Barnes (1998), Freier (1992), Watson (1993)
spider (order Araneida)	crawls on web during rain	rain, light, short duration	Garriott (1903), Lee (1998)
spider (order Araneida)	enlarges, repairs web	rain	Freier (1992), Garriott (1903)
spider (order Araneida)	spins web	sun	Lee (1998)
spider (order Araneida)	unusually large population in fall	winter unusually hard	Wigginton (1972)
spider (order Araneida)	web built close to other webs	winter unusually hard	Kauffman (1998)
squirrel (family Sciuridae)	becomes more active	rain	Freier (1992), Sattler (1978)
squirrel (family Sciuridae)	builds nest low in tree	winter unusually hard	Wigginton (1972)
squirrel (family Sciuridae)	few sighted in fall	winter unusually hard	Freier (1992), Garriott (1903)
squirrel (family Sciuridae)	gathers nuts unusually early in fall	winter unusually hard	Wigginton (1972)
squirrel (family Sciuridae)	gathers unusually large number of nuts	winter unusually hard	(1992), Garriott (1903), Golad (1991), Marshall (1998)
squirrel (family Sciuridae)	patches, reinforces nest	rain	Sattler (1978)

squirrel (family Sciuridae)	seen in winter	winter over, early spring	Garriott (1903)
squirrel (family Sciuridae)	stores nuts high in trees	winter unusually hard	Freier (1992)
stormy petrel (family Hydrobatidae)	gathers in flock in ship's wake	storm	Garriott (1903)
swallow (family Hirundinidae)	calls, flies in circles	rain	Freier (1992)
swallow (family Hirundinidae)	flies high	sun	"Animal weather prophets" (1920), Freier (1992), Garriott (1903)
swallow (family Hirundinidae)	flies low	rain	"Animal weather prophets" (1920), Freier (1992), Garriott (1903), Sloane (1952)
swallow (family Hirundinidae)	roosts	rain	Sloane (1952)
swan (*Cygnus* sp.)	builds nest high	storm, flooding	Garriott (1903)
swan (*Cygnus* sp.)	flies against wind	storm (hurricane within 24 hours)	Watson (1993)
titmouse (*Parus* sp.)	sings long/different song	rain	Tributsch (1978)
tortoise, desert (*Gopherus agassizii*)	emerges from underground burrows	rain	Hawk (1999) (pers. comm.)
trout (family Salmonidae)	jumps rapidly	rain	Garriott (1903)

turkey (*Meleagris* sp.)	perches in tree; refuses to descend	snow	Hardy (1996)
wasp (superfamily Ichneumonoidea)	nest built in sheltered area	winter unusually hard	Garriott (1903)
woodpecker (family Picidae)	pecks low on trees	sun	Garriott (1903)
worm (Phylum Annelida)	found in buildings in fall	winter unusually hard	Wigginton (1972)
worm, earth (class Oligochaeta)	emerges from ground	rain	Houghton (1996), Tributsch (1978), Wigginton (1972)
wren (family Troglodytidae)	seen in winter	snow	Garriott (1903)

ANIMAL BEHAVIOR AS A WEATHER PREDICTOR

BY WEATHER PREDICTED

Note: The use of common names in weather lore has necessitated the broad scientific identification in the table below.

WEATHER PREDICTED	ANIMAL	BEHAVIOR EXHIBITED	REFERENCE
cold front (freezing)	goose, wild (tribe Anserini)	flies south	Reinertsen (1996)
frost, season's first killing	katydid (suborder Ensifera)	first sings three month before frost	Wigginton (1972)
rain	ant (family Formicidae)	becomes more active	Freier (1992), Garriott (1903), Houghton (1996), Lee (1998), Tributsch (1978)
rain	ant (family Formicidae)	closes nest entrance	"Animal weather prophets" (1920), Freier (1992), Watson (1993), Wigginton (1972)
rain	ant (family Formicidae)	increases nest cone height	Freier (1992), Watson (1993), Wigginton (1972)
rain	ant (family Formicidae)	moves eggs to higher	Freier (1992), Lee (1998), Tributsch
rain	ant (family Formicidae)	travels in straight line	Freier (1992), Garriott (1903), Schmid (1986)
rain	bat (order Chiroptera)	cries out	Garriott (1903), Sattler (1978), Watson (1993)
rain	bat (order Chiroptera)	flies low	Golad (1991), Sloane (1952)
rain	bat (order Chiroptera)	seeks shelter	Sattler (1978), Watson (1993)

rain	bighorn sheep (*Ovis canadensis*)	moves to lower elevation	Tributsch (1978)
rain	bird (nonspecific) (class Aves)	is silent	Garriott (1903)
rain	bird (nonspecific) (class Aves)	flies low	Golad (1991)
rain	bird (nonspecific) (class Aves)	oils feathers	Garriott (1903)
rain	blackbird (family Icteridae)	sings in an unusually shrill voice	Garriott (1903)
rain	blackbird (family Icteridae)	sings more than usual in morning	Garriott (1903)
rain	cat (*Felis catus)*	eats grass	Freier (1992)
rain	cat (*Felis catus)*	licks fur against the grain	Garriott (1903)
rain	chaffinch (*Fringilla coelebs*)	sings long/different song	Tributsch (1978)
rain	chicken (*Gallus gallus*)	oils feathers	Garriott (1903)
rain	chicken (*Gallus gallus*)	picks up pebbles and are unusually noisy	Garriott (1903)
rain	chicken (*Gallus gallus*)	rolls in dust	Garriott (1903)
rain	chicken (*Gallus gallus*)	won't go into coop	Tributsch (1978)
rain	chicken (rooster)(*Gallus gallus*)	crows in afternoon or night	Freier (1992), Garriott (1903), Schmid (1986), Watson (1993)
rain	clam (order Paleoheterodonta)	more air bubbles than usual seen over bed	Garriott (1903)

rain	cockroach (family Blattidae)	becomes more active	Freier (1992), Lee (1998)
rain	cow (*Bos* sp.)	huddles with other cows	Freier (1992), "Six weird ways to predict the weather" (1998)
rain	cow (*Bos* sp.)	lays down	Frier (1992), Golad (1991), Hardy (1996), Schmid (1986), "Six weird ways to predict the weather" (1998), Wigginton (1972)
rain	cow (*Bos* sp.)	lays on right side	Watson (1993)
rain	cow (*Bos* sp.)	licks forefeet	Watson (1993)
rain	cow (*Bos* sp.)	moves to lower elevation	(1993)
rain	cow (*Bos* sp.)	quits giving milk	Watson (1993)
rain	cow (*Bos* sp.)	sniffs air	(1993)
rain	cow (*Bos* sp.)	plays	Pancake (1983)
rain	cow (*Bos* sp.)	won't go into barn, eats more	Tributsch (1978)
rain	crab (class Decapoda)	emerges on shore	(1993)
rain	crane (order Gruiformes)	calls loudly	Garriott (1903)
rain	cricket (family Gryllidae)	more active than usual	Garriott (1903)
rain	crow (*Corvus* sp.)	calls, flies in circles	Freier (1992), Houghton (1996)
rain	crow (*Corvus* sp.)	flies alone	Garriott (1903)
rain	crow (*Corvus* sp.)	flies in pairs	Garriott (1903)
rain	cuckoo (family Cuculidae)	sings in valleys	Garriott (1903)
rain	deer (family Cervidae)	moves to lower elevation	(1993)

rain	deer, fallow (*Dama dama*)	hides in thicket	Tributsch (1978)
rain	deer, red (*Cervus elaphus*)	moves to clearing and browses in day	Tributsch (1978)
rain	deer, roe (*Capreolus capreolus*)	moves to clearing and browses in day	Tributsch (1978)
rain	dog (*Canis familiaris*)	eats grass	Freier (1992), Garriott (1903)
rain	dog (*Canis familiaris*)	digs holes in the ground	Garriott (1903)
rain	dog (*Canis familiaris*)	holds tail straight	Freier (1992), Watson (1993)
rain	dog (*Canis familiaris*)	refuses meat	Garriott (1903)
rain	dog (*Canis familiaris*)	rolls on back	Freier (1992), Watson (1993)
rain	dog, spaniel (*Canis familiaris*)	sleeps more than usual	Schmid (1986)
rain	dolphin (suborder Odonticeti)	swims to windward	Freier (1992), Sattler (1978), Watson (1993)
rain	donkey (*Equus asinus*)	brays more	Freier (1992), Watson (1993)
rain	donkey (*Equus asinus*)	hangs ears down and forward	Freier (1992), Watson (1993)
rain	donkey (*Equus asinus*)	rubs against walls	Freier (1992), Watson (1993)
rain	duck (family Anatidae)	unusually loud call	(1993)
rain	elk (*Cervus canadensis*)	moves to lower elevation	Barnes (1998), Freier (1992), Watson (1993)
rain	fish (superclass Pisces)	rises to surface; bites at bait, insects	Freier (1992), Garriott (1903), Golad (1991), Sattler (1978), Tributsch (1978), Watson (1993)

rain	flea (order Siphonaptera)	bites more frequently	Elliot (1996)
rain	fly (order Diptera)	bites more frequently	Garriott (1903), Golad (1991)
rain	fly (order Diptera)	moves into buildings	Freier (1992), Garriott (1903)
rain	fly (order Diptera)	swarms	Garriott (1903)
rain	frog (suborder Diplasiocoela)	if sunny, increased croaking	Freier (1992), Newman 1996), Watson (1993)
rain	gnat (suborder Nematocera)	bites more frequently	Garriott (1903)
rain	goat (*Capra* sp.)	butts aggressively	Barnes (1998), Freier (1992)
rain	goat (*Capra* sp.)	grazes low on hills	"What kind of winter will we have" (1998)
rain	goat (*Capra* sp.)	won't enter shed, eats more	Tributsch (1978)
rain	goose (tribe Anserini)	flies low	Freier (1992), Garriott (1903)
rain	goose (tribe Anserini)	roosts	Sloane (1952)
rain	goose (tribe Anserini)	unusually loud call	(1993)
rain	gull (family Laridae)	calls, flies in circles	Freier (1992), Garriott (1903)
rain	hawk (family Accipitridae)	hunts in groups	Sattler (1978)
rain	hawk (family Accipitridae)	flies low	Garriott (1903)
rain	heron (family Ardeidae)	flies up and down repeatedly	Garriott (1903), Virgil (1956)
rain	herring (*Clupea* sp.)	school more rapidly	Garriott (1903)
rain	honey bee (subfamily Apinae)	stays close to hive	Freier (1992), Garriott (1903), Golad (1991), Schmid (1986), Watson (1993)

rain	horse (*Equus caballus*)	shies for no reason	(1903)
rain	horse (*Equus caballus*)	sniffs air	Garriott (1903)
rain	iguana (family Iguanidae)	hides in vegetation, among rocks+B200	Banuelos Connell (1999) (pers. comm.)
rain	lark (family Alaudidae)	flies low	Freier (1992)
rain	lark (family Alaudidae)	roosts	Sloane (1952)
rain	martin (family Hirundinidae)	flies low	Garriott (1903)
rain	mosquito (family Culicidae)	bites more frequently	"Six weird ways to predict the weather" (1998), Watson (1993)
rain	mouse (order Rodentia)	becomes more active	Freier (1992), Sattler (1978)
rain	opossum (*Didelphis marsupialis*)	moves to higher ground	Sattler (1978)
rain	owl (families Tytonidae, Strigidae)	if sunny, loud calls	Barnes (1998), Freier (1992), Tributsch (1978), Watson (1993)
rain	owl (families Tytonidae, Strigidae)	unusually loud call	Barnes (1998), Freier (1992), Watson (1993)
rain	parrot (order Psittaciformes)	unusually loud call	Barnes (1998), Freier (1992), Garriott (1903), Watson (1993)
rain	peafowl (cock) (*Pavo* sp.)	unusually loud call	Barnes (1998), Freier (1992), Garriott (1903), Watson (1993)
rain	pheasant, Chinese (family Phasianidae)	crows repeatedly	Reinertsen (1996)
rain	pig (familiy Suidae)	carries straw for nest	Freier (1992), Garriott (1903), Tributsch (1978), Virgil (1956), Watson !993)
rain	pigeon (*Columba* sp.)	returns to nest or coop	Garriott (1903)

rain	pike (fish) (family Esocidae)	lies on bottom of stream	Garriott (1903)
rain	porpoise (*Phocaena* sp.)	more active than usual	Freier (1992), Garriott (1903), Sattler (1978), Watson (1993)
rain	prairie dog (*Cynomys* sp.)	covers burrow entrance with grass	Barnes (1998)
rain	rabbit (family Leporidae)	becomes more active	Freier (1992), Sattler (1978)
rain	rabbit (family Leporidae)	more rabbits caught in traps	"Animal weather prophets" (1920)
rain	raccoon (*Procyon lotor*)	moves to higher ground	Sattler (1978)
rain	raven (*Corvus* sp.)	unusually loud call	(1993)
rain	robin (American *Turdus migratorisus*; Eurasian *Erithacus rubecula*)	sings from treetop	Freier (1992), Garriott (1903)
rain	robin (American *Turdus migratorisus*; Eurasian *Erithacus rubecula*)	sings long/different song	Cooke (1998) (pers. comm.), Garriott (1903)
rain	rook (*Corvus frugilegus*)	flies low	Freier (1998), Garriott (1903)
rain	rook (*Corvus frugilegus*)	roosts	Sloane (1952)
rain	sheep (*Ovis* sp.)	becomes more active and playful	Barnes (1998), Freier (1992), Garriott (1903), Tributsch (1978)
rain	sheep (*Ovis* sp.)	moves to lower elevation	Barnes (1998), Freier (1992), Watson (1993)

rain	sparrow (families Passeridae, Emberizidae)	unusually loud call	Barnes (1998), Freier (1992), Watson (1993)
rain	spider (order Araneida)	enlarges, repairs web	Freier (1992), Garriott (1903)
rain	squirrel (family Sciuridae)	becomes more active	Freier (1992), Sattler (1978)
rain	squirrel (family Sciuridae)	patches, reinforces nest	Sattler (1978)
rain	swallow (family Hirundinidae)	calls, flies in circles	Freier (1992)
rain	swallow (family Hirundinidae)	flies low	"Animal weather prophets" (1920), Freier (1992), Garriott (1903), Sloane (1952)
rain	swallow (family Hirundinidae)	roosts	Sloane (1952)
rain	titmouse (*Parus* sp.)	sings long/different song	Tributsch (1978)
rain	tortoise, desert (*Gopherus agassizii*)	emerges from underground burrows	Hawk (1999) (pers. comm.)
rain	Salmonidae)	jumps rapidly	Garriott (1903)
rain	worm, earth (class Oligochaeta)	emerges from ground	Houghton (1996), Tributsch (1978), Wigginton (1972)
rain early in day	cow (*Bos* sp.)	lays down early in day	Garriott (1903)
rain, heavy	ant (family Formicidae)	moves to higher ground	Garriott (1903)
rain, light, short duration	spider (order Araneida)	crawls on web during rain	Garriott (1903), Lee (1998)
snow	bird (nonspecific) (class Aves)	eats significantly more from bird feeders	Lauritzen (1998), Walden (1997) (pers. comms)
snow	cat (*Felis catus)*	licks fur against the grain	Garriott (1903)

snow	cat (*Felis catus)*	sits with back to fire	Freier (1992), Garriott (1903)
snow	coyote (*Canis latrans*)	moves closer to human-occupied areas	Sattler (1978)
snow	deer (family Cervidae)	moves to lower elevation	Sattler (1978)
snow	turkey (*Meleagris* sp.)	perches in tree; refuses to descend	Hardy (1996)
snow	wren (family Troglodytidae)	seen in winter	Garriott (1903)
snow, blizzard	goose, wild (tribe Anserini)	in Kansas, flies to southeast in fall	Garriott (1903)
snow, heavy	grouse (subfamily Tetraoninae)	drum at night	Garriott (1903)
snow, heavy	hornet (subfamily Vespinae)	nest built higher than usual	Golad (1991)
snow, heavy; often within 24 hours	elk (*Cervus canadensis*)	moves to lower elevation, unafraid of humans	Ormond (1981)
storm	bird (nonspecific) (class Aves)	covers nest if tree-nester	Tributsch (1978)
storm	blue jay (*Cyanocitta cristata)*	feeds later than usual	Tributsch (1978)
storm	blue jay (*Cyanocitta cristata)*	sits silently	Wallisch (1995) (pers. obs.)
storm	cow (*Bos* sp.)	stands in a group with tails to windward	Garriott (1903)
storm	crane (order Gruiformes)	flies inland	Tributsch (1978)

storm	cuttlefish (family Sepiidae)	flutters out of the water	Tributsch (1978)
storm	deer, whitetail (*Odocoileus virginianus*)	eats throughout day, not at usual times	Tinsley (1977)
storm	ox (*Bos taurus*)	sniffs air	Tributsch (1978)
storm	sea urchin (class Echinoidea)	adheres to rock	Tributsch (1978)
storm	stormy petrel (family Hydrobatidae)	gathers in flock in ship's wake	Garriott (1903)
storm (hurricane within 24 hours)	swan (*Cygnus* sp.)	flies against wind	Watson (1993)
storm at sea, very violent	bird, sea (class Aves)	flies inland	Barnes (1998), Garriott (1903), Prince (1974), Tributsch (1978)
storm at sea, very violent	bird, shore (class Aves)	flies inland	Garriott (1903), Newman (1996), Prince (1974)
storm at sea, violent	fish, marine (superclass Pisces)	swims up rivers	Barnes (1998)
storm at sea, violent	gull (family Laridae)	moves 5-15 miles inland	Snyder (1999) (pers. comm.), Tributsch (1978), Virgil (1956)
storm at sea, violent	porpoise (*Phocaena* sp.)	swims up rivers	Barnes (1998)
storm, flooding	chicken (hen) (*Gallus gallus*)	crows	Watson (1993)

storm, flooding	frog (suborder Diplasiocoela)	calls very early in year	Houghton (1996)
storm, flooding	swan (*Cygnus* sp.)	builds nest high	Garriott (1903)
storm, violent	deer (family Cervidae)	bolts, stampedes, for no known reason	Reinertsen (1996)
storm, violent	elk (*Cervus canadensis*)	bolts, stampedes, for no known reason	Reinertsen (1996)
storm, violent	mule (*Equus* sp.)	unusual behavior, e.g. ears laid back	Crooks(1999) (pers. comm.)
sun	bat (order Chiroptera)	flies late in the evening	Garriott (1903)
sun	bird (nonspecific) (class Aves)	starts singing just after rain	Reinertsen (1996)
sun	cat (*Felis catus)*	licks fur more frequently	Freier (1992), Garriott (1903)
sun	crane (order Gruiformes)	flies high and quietly	Garriott (1903), Tributsch (1978)
sun	cuckoo (family Cuculidae)	sings in highlands	Garriott (1903)
sun	dog (*Canis familiaris*)	licks fur more frequently	Freier (1992)
sun	dolphin (suborder Odonticeti)	splashes in waves	Tributsch (1978)
sun	frog (suborder Diplasiocoela)	if raining, increased nighttime croaking	Freier (1992), Watson (1993)
sun	goat (*Capra* sp.)	grazes high on hills	"What kind of winter will we have" (1998)
sun	goose (tribe Anserini)	flies high	Freier (1992), Garriott (1903)
sun	grouse (subfamily Tetraoninae)	emerges from winter hiding place	Reinertsen (1996)

sun	hawk (family Accipitridae)	flies high	Garriott (1903)
sun	lark (family Alaudidae)	flies high	Freier (1992)
sun	owl (families Tytonidae, Strigidae)	if raining, loud calls	Barnes (1998), Freier (1992), Tributsch (1978), Watson (1993)
sun	rook (*Corvus frugilegus*)	flies high	Freier (1998)
sun	spider (order Araneida)	spins web	Lee (1998)
sun	swallow (family Hirundinidae)	flies high	"Animal weather prophets" (1920), Freier (1992), Garriott (1903)
sun	woodpecker (family Picidae)	pecks low on trees	Garriott (1903)
sun, warmer weather	cricket (family Gryllidae)	calls loudly	Wigginton (1972)
tornado	bird (nonspecific) (class Aves)	flies in circles, confused by shifting winds	Garriott (1903)
warmer weather	cricket (family Gryllidae)	calls more quickly	Garriott (1903)
winter cold but little snow	bear, black (*Ursus americanus*)	hibernates deep in unusually large bed	Reinertsen (1996)
winter over	martin (family Hirundinidae)	seen in spring	Garriott (1903)
winter over	robin (American *Turdus migratorisus*; Eurasian *Erithacus rubecula*)	appears in spring	Garriott (1903)
winter over, early spring	badger (*Taxidea taxus*)	does not see shadow on February 2	Freier (1992), Watson (1993)

winter over, early spring	bear (family Ursidae)	does not see shadow on February 2	Freier (1992), Watson (1993)
winter over, early spring	flying squirrel (*Glaucomys* sp.)	calls in midwinter	Garriott (1903)
winter over, early spring	groundhog (*Marmota monax*)	does not see shadow on Feb 2	Freier (1992), Garriott (1903), Watson (1993)
winter over, early spring	squirrel (family Sciuridae)	seen in winter	Garriott (1903)
winter to arrive soon	butterfly (family Papilionoidea)	gathers in air with other butterflies	Wigginton (1972)
winter to begin early	butterfly (family Papilionoidea)	migrates unusually early in fall	Wigginton (1972)
winter to begin early, end late	beaver (*Castor canadensis*)	builds house earlier than usual	Garriott (1903)
winter to begin early, unusually cold	chipmunk (family Sciuridae)	near Lake Superior, in winter nest by Oct	Garriott (1903)
winter to begin early, unusually cold	seal, crab-eater (*Lobodon carcinophagus*)	early migration from Antarctic	Hurley (1919)
winter to continue	bear, black (*Ursus americanus*)	emerges from hibernation, returns to den	Reinertsen (1996)
winter to continue six more weeks	badger (*Taxidea taxus*)	sees shadow on February 2	Freier (1992), Watson (1993)
winter to continue six more weeks	bear (family Ursidae)	sees shadow on February 2	Freier (1992), Garriott (1903), Watson (1993)

winter to continue six more weeks	groundhog (*Marmota monax*)	sees shadow on Feb 2	Freier (1992), Garriott (1903), Watson (1993)
winter unusually hard	ant (family Formicidae)	increases nest cone height	Freier (1992), Watson (1993), Wigginton (1972)
winter unusually hard	bear (family Ursidae)	stores up food for winter	Garriott (1903)
winter unusually hard	beaver (*Castor canadensis*)	builds bigger house than usual	Wigginton (1972)
winter unusually hard	beaver (*Castor canadensis*)	builds house with most logs on north	Wigginton (1972)
winter unusually hard	beaver (*Castor canadensis*)	stores unusually large amount of brush	Watson (1993)
winter unusually hard	bird (nonspecific) (class Aves)	eats up all wild berries earlier than usual	Wigginton (1972)
winter unusually hard	bird (nonspecific) (class Aves)	huddles on ground with other birds	Wigginton (1972)
winter unusually hard	bird (nonspecific) (class Aves)	migrates unusually early in fall	Freier (1992), Garriott (1903)
winter unusually hard	caterpillar, woolly (order Lepidoptera)	unusually large population in fall	Wigginton (1972)
winter unusually hard	crane (order Gruiformes)	migrates early in autumn	Garriott (1903)
winter unusually hard	crow (*Corvus* sp.)	gathers in groups with other crows	Wigginton (1972)
winter unusually hard	crow (*Corvus* sp.)	migrates south in autumn	Garriott (1903)
winter unusually hard	deer (family Cervidae)	eats more than usual in fall	Marshall (1998)

winter unusually hard	goose, wild (tribe Anserini)	flies south and very high	Garriott (1903)
winter unusually hard	hornet (subfamily Vespinae)	nest built close to ground	Kauffman (1998), Wigginton (1972)
winter unusually hard	hornet (subfamily Vespinae)	heavier than usual nest construction	Wigginton (1972)
winter unusually hard	junco (*Junco* sp.)	feeds in tree rather than on ground	Wigginton (1972)
winter unusually hard	mouse (order Rodentia)	migrates into house earlier than usual	Golad (1991)
winter unusually hard	muskrat (*Ondatra zibethica*)	builds bigger house than usual	Wigginton (1972)
winter unusually hard	owl, "arctic"(families Tytonidae, Strigidae)	seen further south than usual	Watson (1993)
winter unusually hard	owl, hoot (families Tytonidae, Strigidae)	calls late in fall	Wigginton (1972)
winter unusually hard	owl, screech (*Otus* sp.)	call sounds like a woman crying	Wigginton (1972)
winter unusually hard	pig, wild (family Suidae)	gathers straw, sticks, etc., for nest	Wigginton (1972)
winter unusually hard	spider (order Araneida)	unusually large population in fall	Wigginton (1972)
winter unusually hard	spider (order Araneida)	web built close to other webs	Kauffman (1998)

winter unusually hard	squirrel (family Sciuridae)	builds nest low in tree	Wigginton (1972)
winter unusually hard	squirrel (family Sciuridae)	few sighted in fall	Freier (1992), Garriott (1903)
winter unusually hard	squirrel (family Sciuridae)	gathers nuts unusually early in fall	Wigginton (1972)
winter unusually hard	squirrel (family Sciuridae)	gathers unusually large number of nuts	"Animal weather prophets" (1920), Freier (1992), Garriott (1903), Golad (1991), Marshall (1998)
winter unusually hard	squirrel (family Sciuridae)	stores nuts high in trees	Freier (1992)
winter unusually hard	wasp (superfamily Ichneumonoidea)	nest built in sheltered area	Garriott (1903)
winter unusually hard	worm (Phylum Annelida)	found in buildings in fall	Wigginton (1972)
winter unusually mild	bird (nonspecific) (class Aves)	migrates unusually late in fall	"Animal weather prophets" (1920)
winter unusually mild	crow (*Corvus* sp.)	migrates north in autumn	Garriott (1903)
winter unusually short, mild	chipmunk (family Sciuridae)	near Lake Superior, seen until Dec 1	Garriott (1903)
winter with heavy snows	bear, black (*Ursus americanus*)	hibernates close to the surface	Reinertsen (1996)

APPENDIX D

MODEL STUDIES

OF ANIMAL BEHAVIOR

AS A WEATHER PREDICTOR:

EARTHWORM BEHAVIOR AS A RAIN INDICATOR;

WRITING A STUDY TO EXAMINE ANIMAL BEHAVIOR

AS A WEATHER INDICATOR

APPENDIX D

EARTHWORM BEHAVIOR AS A RAIN INDICATOR

Introduction

According to Houghton (1996), Tributsch (1978), and Wigginton (1972), a traditional, nonscientific way to predict rain is that earthworms emerge from underground. This study provides guidance to examine this tradition by simple observations and record-keeping.

Background

Earthworms (class Oligochaeta) are segmented worms representing over 4000 species living in a variety of habitats (Conniff, 1996; Grzimek, 1974). Traditional lore states that earthworms emerge from the ground before a rain. An important point for any observer studying this supposed phenomenon is to determine whether earthworms emerge before, during or after a rain. Some observations suggest that it is the vibrations caused in the earth by falling rain, rather than the rain itself, that encourages earthworms to emerge. Gulls and turtles have been seen stamping on the ground and feeding on the earthworms that then emerged from the ground (Conniff, 1996).

Conducting the Study

Materials needed to conduct the study are:

- An area where earthworms have been seen and can easily be observed and counted. The study area could be a sidewalk, yard, garden, etc. The study area should be simple to define; for example, a definable area could be a specific sidewalk square or a section of yard marked off by boards or string.
- A precipitation gauge. The gauge can be a commercially available gauge or an empty tin can or plastic cup or bowl.
- A calendar on which to record rain and earthworm counts.
- A pen or pencil for recording on the calendar.
- A clock or watch for accurate information on time of observations.

The study procedure is as follows:

- Choose the study area.
- Place the gauge in the study area.
- Choose a time (or times) to examine the study area and empty the precipitation gauge every day.

At least once a day during the period of the study:

- Examine the study area and count the number of earthworms visible on top of the ground.
- Record the number of earthworms counted on the appropriate day on the calendar.

- Check the precipitation gauge. Record on the calendar whether precipitation fell on the study area (amount and kind of precipitation may also be recorded). If the gauge contains any precipitation, empty it and return it to its place.
- Record the time of the observation.
- If possible, record the time at which precipitation began and ended. If this is unknown, record known information. For example, "8am 6 worms, 0 precipitation in gauge. Left study area; returned at 9:30am in heavy rain; 17 worms." Record any information that might indicate whether worms emerged from underground before precipitation or because of it.

Points to consider when conducting the study include:

- Length of study. The more days on which observations are recorded, the more data will be gathered, and the more likely it will be that patterns and relationships will be seen. The study should be conducted for at least 30 days to provide sufficient information to compare earthworm counts on days with and without precipitation.
- Timing of study. The study period should cover a period that provides a good opportunity for days with and without precipitation.
- Time of observations. Since earthworms often emerge from underground at night, comparing observations made at night and during daylight may provide interesting data.

- Recording information that will allow a determination to be made whether earthworms emerged before, after or during precipitation (see above).
- Possible explanations for earthworm behavior. It may be useful to record any disturbances near the study area such as heavy vehicular traffic, underground activities by other animals such as gophers, etc. Atmospheric pressure readings may also provide interesting data.
- Different ways of presenting and interpreting recorded data. For example, study results can be examined as a comparison between numbers of earthworms seen on days with and without precipitation. If precipitation amounts are recorded, earthworm numbers could be examined in relationship to daily precipitation.

WRITING A STUDY
TO EXAMINE ANIMAL BEHAVIOR
AS A WEATHER INDICATOR

Introduction

For thousands of years in a variety of cultures, humans observed and interpreted the behavior of animals to predict the weather ("Animal weather prophets," 1920). With the development of such tools as the barometer, using animal behavior to indicate future weather patterns gradually became relegated to folk tradition (Heninger, 1968). Few scientific studies have examined the possibility that animal behavior might be influenced by impending weather; given the weight of tradition, this possibility seems to be a problem deserving further attention.

In light of the useful information gathered by amateur observers for the programs of the National Audubon Society and the Cornell Laboratory of Ornithology and since relatively simple studies could be conducted, this problem seems to be one that could profitably be investigated by people from outside the traditional scientific community. Many people have access to animals for observation and to official weather forecasts and reports for meteorological data. Not only could interesting data be gathered by amateurs, but participating in a study could also encourage a more intimate connection with the natural world and more interest in scientific processes.

Designing a Study

Designing a study to examine animal behavior as a weather indicator requires careful thought and background research. Appendix C provides tables of anecdotal and traditional weather indicators based on animal behavior; the tables are arranged by animal and by weather predicted. These tables provide many possibilities for observation and data recording.

Points to consider when choosing an animal behavior to observe include:

- Easy access to the chosen animal.
- Frequency of weather event chosen.
- Time frame required for the study. A study should last at least 30 days. The study period should cover a period that provides a good opportunity for various types of weather.
- Familiarity with the usual behavior of the chosen animal. The animal's patterns of behavior should be known so exceptions can be noted accurately.
- Choosing an easily identifiable and measurable behavior to observe. "Birds fly low" is a traditional indicator of rain, but defining and measuring the height of "low" may be difficult.

Points to consider when choosing what data to record include:

- Timing of observations is crucial. Knowledge of an animal's habits is crucial when determining times of observations. Factors such as other demands on observer's time should also be considered.

- Ability to record information that may reveal relationships between animal behavior and future weather. Temperature changes and precipitation totals may be relatively easy to obtain. Hourly records of barometric pressure may be more difficult to obtain. As a general rule, obtaining as much weather data as possible will provide the best chance of seeing patterns or relationships.
- Ability to record information that will allow the observer to determine whether animal behavior preceded, occurred during, or followed weather changes.

Drawing Conclusions from a Study

Analyzing data and drawing conclusions from it requires caution. A 30-day observation of behavior exhibited by a few animals may be extremely interesting, but it will probably not answer most of the questions regarding the accuracy of animal behavior as a weather indicator.

Points to consider when drawing conclusions from a study include:

- Scientific explanations for animal behavior that appears to indicate weather changes. Explanations could include behavior resulting from physiological responses to changes in atmospheric pressure, thunder too faint to be audible to humans but audible to some animals, etc. A plausible scientific reason for a behavior will lend credibility to apparent relationships between animal behavior and weather.

- Careful examination of relationships between various sets of data. For example, a particular behavior may be exhibited before any precipitation, before precipitation greater than a certain amount, or before precipitation combined with a decrease or increase in temperature.

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