Tools to study and manage grazing behavior at multiple scales to enhance the sustainability of livestock production systems

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Key points

- A “single tool” for studying free-ranging animal behavior on complex landscapes does not exist.
- Today’s tools require competent multiple disciplinary teams beginning with the planning and design of experiments on through to applying the results within a practical management framework.
- Research that involves instrumenting animals must be conducted in a human manner that accurately measures and or manages the phenomenon in question.
- Using innate animal behaviors to accomplish management goals by melding biology with electronics to optimize ecological and labor efficiency is the future and virtual fencing will soon be one of the tools.

Key words: bio-logging, telemetry, gps, virtual fencing

Introduction

Tracking animals is not new, early hunters practiced it for survival (Liebenberg, 2006); however, today it is practiced in the name of science and what the future holds will be new (Etc^{group}., 2004). The phrase “if you can measure it, you can manage it” may have first been used in the health care industry (Kinex IHA Corp., 2000). Nevertheless, this axiom is pivotal to range animal ecology involving measuring and managing free-ranging animal distribution, a central tenant of grazing management (Bailey and Brown, 2011). Free-ranging livestock neither use all the space made available to them (Anderson et al., 2003; Rinella et al., 2011) nor do they use it in a random manner (Anderson et al, 2011a). Over 68 factors (Anderson, 2010) including magnetism (Begall et al., 2008) appear to impact landscape use by free-ranging animals. Thus understanding the process of foraging is challenging and may require research programs that de-emphasize traditional methods (Laca, 2009).

In the beginning

Early scientific monitoring of animal behavior relied solely on visually obtained written records (Cory, 1927; Johnstone-Wallace and Kennedy, 1944). Later, written records were augmented with aerial photographs (Nelson and Furr, 1966) or pasture maps (Arnold and Dudzinski, 1978). Observation should always form the basis of animal behavior studies (Lehner, 1979; Williams et al., 2010) because it embraces man’s power to reason. One of the earliest cattle studies involving 24 hour observation may have been the research of Dwyer (1961). Observational data are largely limited to daylight hours (Hughes and Reid, 1951; Reppert, 1960) though night-vision technologies are now available (Allison and Destefano, 2006).

Whenever we “peer” into an animal’s world the first question we should ask is: “how are we, as observers, influencing the observation we are attempting to document?” Bio-logging devices are known to modify behaviors (Ropert-Coudert and Wilson, 2004) and often turn simplicity into complexity. Small items such as improperly fitted equipment packages can negatively influence an animal’s behavior (Krausman et al., 2004). Matsui et al. (1990) reported that improperly fitted equipment may cause large (46%) discrepancies between what was observed and what the equipment recorded. Equipment harnesses must be appropriate (Gwynne and Kingaby, 1976; Zucco and Mourão, 2009) and the animal that will carry the equipment must not be adversely impacted by its presence (Hulbert et al., 1998). Withey et al. (2001) suggest equipment packages should not exceed 3% of the animal’s total body mass, while Murray and Fuller (2000) suggest the mass be < 5%. Kenward (2001) states adverse effects tend to emerge if collars exceed 3% of body mass and for harness-mounted tags or implants the mass should not exceed 4% to 5%. Schlecht et al. (2004) reported that equipment packages equal to 2.1% of cattle body mass did not appear to negatively impact cattle.   The author’ personal experience suggests harness design may be as critical as mass requirements in not negatively impacting free-ranging animal behavior.

Automated recording of animal walking predates considering travel in a spatial context (Canaway et al., 1955). Early behavior studies focused on monitoring total travel without knowing precisely where on the landscape it occurred (Rook et al., 2004). Cresswell’s (1957) range meter may have been the first mechanical device to measure animal travel. The animal wore a harness that pulled a wheel; the revolutions of which determined distance traveled. Obviously landscape and topography limited its widespread application. Pedometers attached to a sheep’s legs were used to monitor activity (Liddell, 1923) many years before they were used to successfully monitor travel of cattle on brush infested rangeland (Anderson and Urquhart, 1986).

The present and future

Wildlife scientists were the first to use electronic devices (radio transmitters) to monitor animal behavior (LeMunyan et al., 1959). Even though the first devices provided only coarse (± 300 m; Britten et al., 1999) resolution. LeMunyan's devices cost approximately $25 (excluding labor to build them), weighed 122.5 g with a volume of 7.5 cm x 4.0 cm x 1.4 cm and had an interrogation range of up to ~ 23 m.

Mench (1983), and more recently Millspaugh and Marzluff (2001) discuss Very High Frequency (VHF) electronic approaches for tracking wildlife. Beginning in the 1970's the Argos Satellite System operated by CLS Argos (CLS, 2008) led in tracking terrestrial wildlife species. More recently, the Argos system has been used in conjunction with the global positioning system (GPS; Herring, 1996) for wildlife tracking studies (Soutullo et al., 2007). The spatial accuracy of Argos has always been challenging (Hays et al., 2001) and may be one reason it was not widely used by range animal ecologists to track livestock.

One of the earliest electronic based protocols to track free-ranging cattle suggested the use of ground based towers (Petrusevics and Davidson, 1975). Though VHF has accuracy limitations for estimating spatial location (Samuel and Fuller, 1994) it remains a viable option for tracking. Wyckoff et al. (2007) provide an example using 10 animals wearing VHF equipment to record 1000 locations for one month. He estimated the cost at ~$300 per animal and ~300 hours of field labor. In contrast, using GPS equipment to conduct the same study would cost ~$2,500 per animal even though field labor would be negligible. Insufficient data collection can be a problem in radio-tracking studies (Harris et al., 1990). However, accuracy comes at a cost and this can severely limit the sample size of instrumented animals a research scientist has available (Clark et al., 2006).

Though other tracking technologies have been attempted, including the use of lasers (Fehmi and Laca, 2001), access control systems (Swain et al., 2003), video systems (Moll et al., 2009), video systems combined with GPS (Harris et al., 2007), and cell phones (Naik, 2011); GPS remains the premier satellite based tracking system since its commercial development in the early 1990's for tracking wildlife (Moen et al., 1996; Rodgers, 2001). With GPS, sub-centimeter accuracies are possible (Leick, 1995) using differential correction (DGPS; Moen et al., 1997). Karsky (2004) has determined that post-processing GPS data is the most accurate method when compared to procedures that operate in real time. Umstatter (personal communication) found that 90% of memory storage can be lost applying DGPS in real time.

GPS positional accuracy without differential correction can be ± 5 m (Rodgers et al. 1996) which is well within the 20 m range Huircán et al. (2010) suggests is acceptable with free-ranging cattle. However, accuracy requirements depend on the question being asked. Swain et al. (2008) reported the capability of recording GPS fix rates of 4 per second. With such data recording frequently autocorrelation can be a problem (Otis and White, 1999). Juang et al. (2002) suggested that a three minute interval between samples was adequate to record independent behavior using ZebraNet. Even with the capabilities GPS offers it is not the "perfect tool" for range-animal ecologists (Johnson et al., 2002). Wildlife researchers using GPS/VHF telemetry systems have experienced as much as a 50+% failure rate in equipment (Wyckoff et al., 2007). Hiroyuki et al. (2002), Hebblewhite et al. (2007), and Buerkert and Schlecht (2009) found positional accuracies can vary among commercial devices. Wyckoff et al. (2007) found canopy type may not effect acquisition locations yet D'Eon (2003) reported a "small" (27%) negative effect of canopy cover on fix rate success even though under optimum placement and conditions his collars only had an 80% fix rate success. Resting animals may give a lower fix rate than moving animals (Bourgoin et al., 2009). Hilly terrain (Rutter et al., 1997) and the ionosphere (Jensen and Mitchell, 2011) can also negatively impact GPS reception.

Studies employing GPS need to balance storage memory, power (battery) requirements and logging interval (Putfarken et al., 2008). Battery requirements remain a primary challenge (Andersen et al., 2005; Hooker et al., 2008) due mainly to GPS receivers, even though the units may only weigh 24 g (Witte and Wilson 2004). Tomkins and O'Reagain (2007) found that alkaline batteries when used at ambient air temperature of > 36°C may have been responsible for internal corrosion and poor functioning of almost 50% of their GPS devices in Queensland, Australia. One exciting new technology application involves devices for converting mechanical energy into electrical energy to power electronic packages worn by animals. Nadimi et al. (2010) reported that miniature electromechanical generators having only a 25% conversion efficiency could produce 214 ± 25 mW of electrical energy per second using the up and down movement of a sheep's head.

Virtual fencing promises unique spatial and temporal management opportunities

Virtual fencing is a 1970's methodology designed for controlling pets (Anderson, 2001). Sensory stimulation, other than sight, without conventional fences (physical boundaries) control the spatial and temporal distribution of animals. By combining Richard Peck's original concept with 21st century electronics, including GPS, free-ranging animal management is being catapulted from reactionary management into potentially pro-active management with the opportunity for positive stewardship of the plant/animal landscapes globally. Though not a panacea, it promises to be a key methodology for providing revolutionary ecological and economic benefits for those managing free-ranging animals. When commercially available it will likely replace conventional fencing as the preferred tool for improving free-ranging animal distribution on extensive landscapes.

Several static virtual fencing approaches have been tried on livestock beginning with controlling goats (Fay, 1989) and later cows (Tiedemann et al. 1999; Butler et al., 2006; Swain, 2009) ; however, Anderson (2006) was the first to manage the spatial and temporal movement of cows across a landscape using virtual fencing. It is the flexible feature of virtual fencing that holds the greatest potential for implementing optimum ecological management at the plant-animal interface. Anderson (2007) and Umstatter (2011) present some of the challenges facing this method of managing free-ranging animals. A major question this methodology has yet to answer is, what percentage of an animal group will require instrumentation in order for the entire group to be controlled? Furthermore, additional research will be required on how sensory cues may stress animals. Preliminary research suggests that audio cues appear to alter a cow's heart rate less than environmental cues (Anderson et al., 2011b).

The future without unwanted surprises

In the 1950's Tribe (1950) asked a relevant question in his critical review of free-ranging animal behavior that bears repeating: "are present techniques the best that can be employed in our study of animal behavior?" The goal for range animal ecologists must be integrated monitoring systems that combine sensors, mathematical models and knowledge bases in a way that can be interpreted to produce the maximum amount of useful information (Frost et al., 1997). When melding our human capabilities with machines great advances in our understanding become possible (Norman, 1993). Before beginning a research project using electronic data gathering devices, it is critical to have a coherent team and funding securely in place. Range animal ecologists should use wildlife scientists, biologists, ethologists, electronics engineers, hardware and software engineers, spatial statisticians and modeling experts who "want to" work together when teams are being assembled. Competent teams that function in harmony are often easier to assemble in theory than in reality (Burns, 2006). Electronic tools employed in range animal ecology will likely have been developed within highly advanced industries where profit is immediately realized from "inexpensive" mass production; innovators will then adapt these devices to production agriculture and its underlying science (Lawton, 2003).

A standardized protocol needs to be developed for analyzing animal movement data (Patterson et al., 2007). Also standardizing how accuracy among GPS devices is reported is needed (Trotter et al., 2009). Until then researchers who purchase commercial equipment would be wise to contact those already using the devices to determine if there are limitations to the equipment not readily acknowledged. Finally, be aware how your research will impact the animal rights (Sunstein and Nusssbaum, 2004) and animal well-welfare (Fraser, 2008) communities, both of which will continue to impact the future use of devices worn by free-ranging animals.

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Note: Other key references not cited herein may be found in the literature section of the above listed references.