Comparison of endoparasite abundance and species richness of two Roosevelt elk herds in northern California

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FULL RESEARCH ARTICLE

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Abstract

Roosevelt elk (*Cervus canadensis roosevelti*) have historically populated the Pacific Northwest from the Olympic Peninsula to the south of San Francisco Bay, and several management actions have supported restoring elk into parts of this historic range. In 1982, 17 Roosevelt elk were translocated from Gold Bluffs Beach State Park to Sinkyone Wilderness State Park. In 2020, the Sinkyone elk herd was observed to have lower body condition scores and poor coat conditions in comparison to the Gold Bluffs Beach elk herd. Therefore, the objectives of this study were to investigate the difference in health between the two herds. Fecal samples were collected (n = 20) from each herd to measure species richness and abundance of parasites. We determined there was a significant difference in species richness and abundance of parasite eggs between the two herds. The Sinkyone herd's overall higher endoparasite load may be attributed to a low immune response due to low nutrition but, causation is unknown.

Key words: abomasal parasites, California, *Cervus canadensis roosevelti*, fecal analysis, Gold Bluffs Beach, Roosevelt elk, Sinkyone Wilderness

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Introduction

Within the state of California, Roosevelt elk (*Cervus canadensis roosevelti*) inhabit portions of Humboldt, Del Norte, Mendocino, Siskiyou, and Trinity counties due to reintroduction efforts and natural range expansion (CDFW 2018). In March 1982, 17 Roosevelt elk from Gold Bluffs Beach, within Prairie Creek Redwood State Park, Humboldt County, were translocated to a similar habitat in Sinkyone Wilderness State Park in Mendocino County (CDFW 2018; California State Park 2016). This herd of elk continues to persist within the Sinkyone Wilderness State Park in the BLM King Range National Conservation Area (Wengert 2000).

Cervids can experience different effects from endoparasites, depending on the number of parasites and the species present. Gastrointestinal (GI) nematodes have been found to cause deterioration of health, weight loss in young cervids, and cause reproductive disorders in adults; however other researchers have concluded that some GI nematodes’ relations with cervids result in subclinical infections (Goossens et al. 2005). Abomasal parasites such as species within the family *Trichostrongylidae* can cause blood loss and damage to the abomasal lining, including inflammation, edema, and necrosis (Botzler and Brown 2014). These parasites can lead to diarrhea and emaciation (Botzler and Brown 2014), rough hair coat, and severe infections can result in death (Chisolm 2006). Infections of *Eimeria* spp. can be subclinical or clinical, depending on the species of parasite and age of the host, with bloody diarrhea being the main sign associated with coccidial infections (Chisolm 2006).

In 2000, Wengert found that a low percentage of the elk in Sinkyone had good body condition and identified eight species of helminths: *Trichuris* sp., *Capillaria* sp., trichostrongylids #1, #2, and #3, *Mashallagia* sp., and *Nematodirus* sp. and one species of *Eimeria* from fecal analysis. In 2020 there were additional observations of thin elk with poor coat conditions in the Sinkyone herd, especially compared to the herd at Gold Bluffs Beach. Poor coat and body conditions can be related to an elk’s overall health and immune system. Nutrition contributes to an animal’s immune response and resistance to parasites (Greer 2008). This difference in health between the two herds could be due to environmental differences such as population density (Goossens et al. 2005), inadequate macronutrients (Cook et al. 2016), or endoparasite prevalence (Greer 2008). Therefore, our objective was to investigate the difference in health between the two herds of elk using fecal analysis. Due to a difference in coat conditions and how that interferes with overall immune health, we hypothesized that the Sinkyone herd would have a higher prevalence and species richness of helminths eggs and oocysts when compared to those in the Gold Bluffs Beach herd.

Methods

Study Area

The study was conducted in two locations: Gold Bluffs Beach State Park, Humboldt County, (41.332, –124.081; **Fig. 1**) and Sinkyone Wilderness State Park, Mendocino County (39.9537, –123.9728; **Fig. 2**).

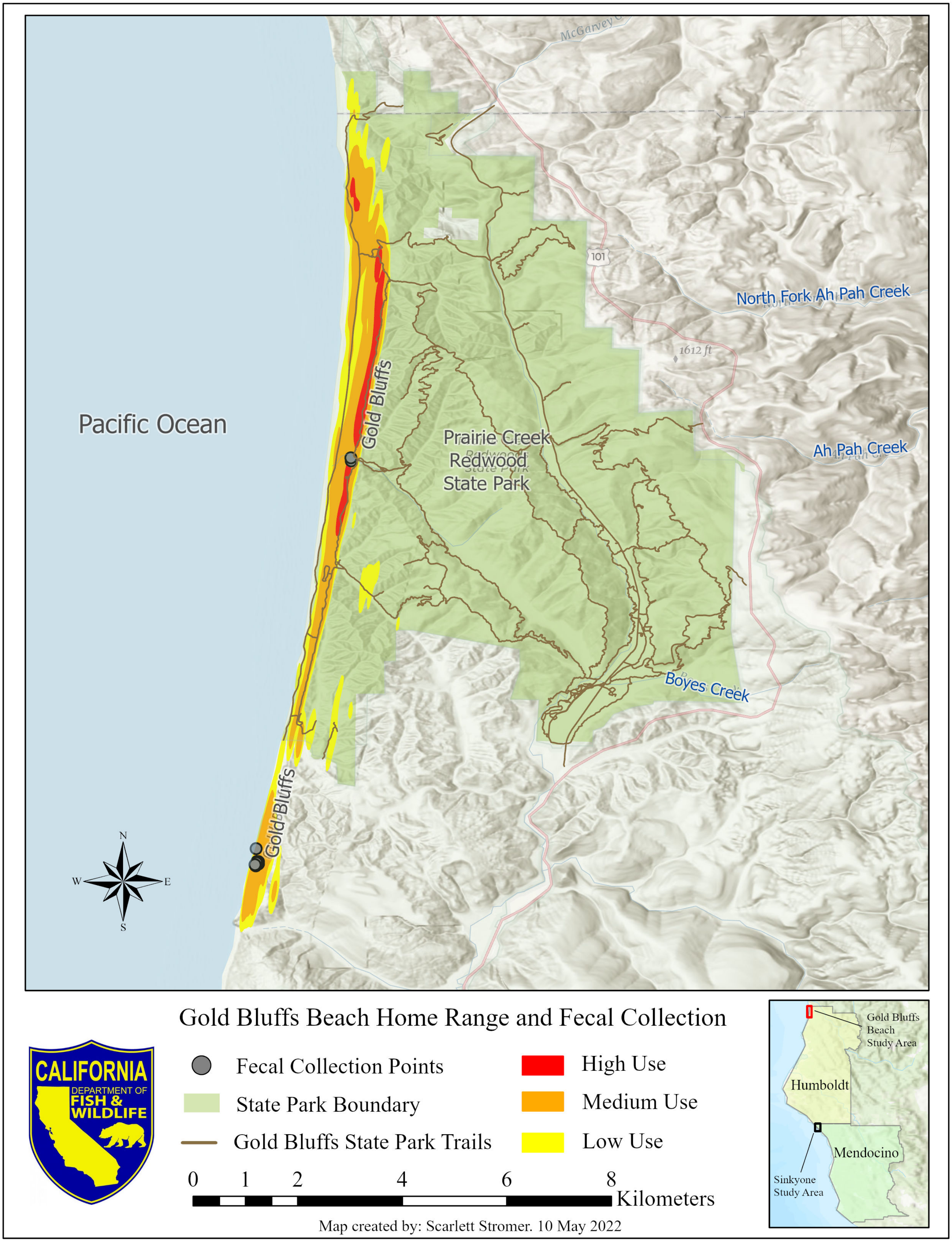

Figure 1. Location of fecal pellet sampling (n = 20) and individual observation of Roosevelt elk in Gold

Bluffs Beach State Park (Humboldt County), CA, USA, from January to February 2020. Home range derived from two collared cow Roosevelt elk, Humboldt County, CA, USA. The home range was derived using kernel utilization distribution at 99% (low use), 95% (medium use), and 50% (high use).

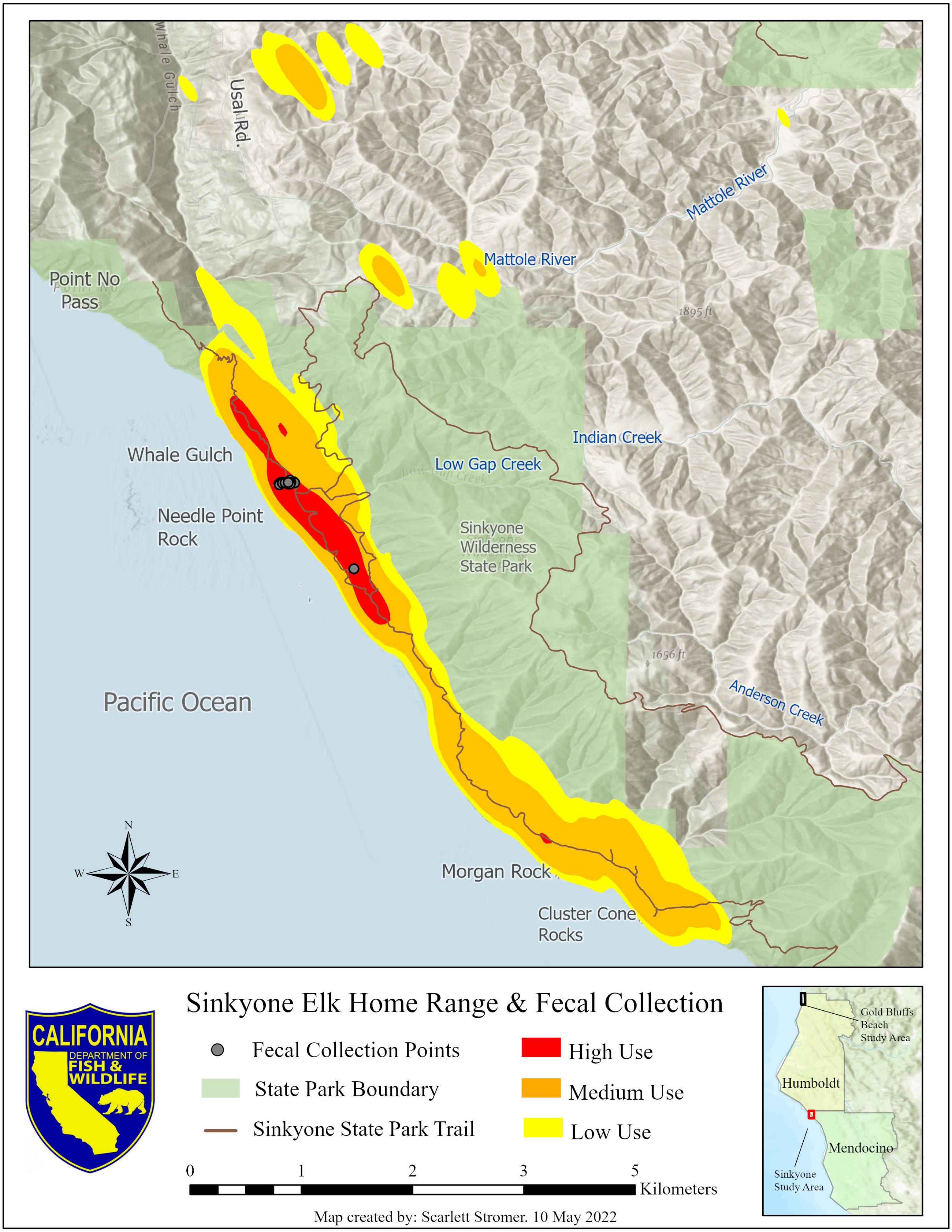

Figure 2. Location of fecal pellet sampling (n = 20) and individual observation of Roosevelt elk in

Sinkyone Wilderness State Park (Mendocino County), CA, USA, from February to March 2020. Home range derived from two collared cow Roosevelt elk, Mendocino County, CA, USA. The home range was derived using kernel utilization distribution at 99% (low use), 95% (medium use), and 50% (high use).

Both locations' climate varies considerably, with high precipitation and moderate temperatures averaging from 7–9°C in the months of February to March 2020 (NOAA 2022). The coastal provinces receive more rainfall than any other part of California, sustaining a diverse ecosystem of flora and fauna (CDFW 2015; California State Park 2021). Gold Bluffs Beach is a 10 mile stretch of coastline ranging from sea level to 180 meters in elevation, surrounded by soft serpentine soil and sandy beaches, with grass-covered dunes, groves of red alder (*Alnus rubra*), old-growth coastal redwoods (*Sequoia sempervirens*), and mixed conifer forests (Bowyer 1981; CDFW 2015; Humboldt California's Redwood Coast 2019). The Sinkyone Wilderness State Park is a 60-mile stretch of coastline ranging from sea level to 425 m in elevation and is mostly composed of shrubs and grassland interspersed with Douglas fir (*Pseudotsuga menziesii*). Both locations support terrestrial communities of Roosevelt elk, black-tailed deer (*Odocoileus hemionus*), black bear (*Ursus americanus*), mountain lions (*Pumas concolor*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*) (CDFW 2015). Within the Sinkyone Wilderness State Park, marine mammals can be spotted along the shoreline, such as Northern elephant seals (*Phoca leonine*), California sea lions (*Zalophus californianus*), and harbor seals (*Phoca vitulina*) (California State Parks 2021).

Locating the Elk

California Department of Fish and Wildlife (CDFW) personnel fitted GPS collars on two cow elk in Sinkyone (on 24 January 2019) and two cow elk at Gold Bluffs Beach (on 9 March 2017 and 20 November 2019). These capture efforts were found to be ethical and approved by Institutional Animal Care and Use Committee (IACUC) (15/16.W.96-A). We located elk with GPS location data from the collars paired with radio telemetry. Once the elk were located, all observations of elk defecating were performed with an unaided eye or by using 10×42 binoculars at 5–100 m (Bowyer 1981).

Fecal Collection

This research was approved by CDFW and IACUC (16/17.W.46-E). We conducted the study from 24 January to 20 March 2020, during which fecal samples from 20 individuals were obtained from each herd over the course of two visits per location (Figs. 1 and 2). To ensure that samples were fresh and from different elk, five samples (4 females and 1 calf) from individual elk in the Gold Bluffs Beach herd and nine samples (7 females, 1 male, and 1 calf) from individual elk in the Sinkyone herd were collected after observing the elk defecating. All other samples were collected opportunistically with an internal temperature above 10°C and were at least three or more meters distant from another sample (Turner and Getz 2010). Fecal samples were examined visually for parasites, blood, and mucous before being placed in their own individual sterile 4-oz Whirl Pak bag with the air removed to preserve the parasites (Zajac and Conboy 2006). Each fecal sample was placed on ice to prevent helminth eggs from hatching (Nielsen et al. 2010).

Fecal Smear and Floatation

Samples were refrigerated at the Cal Poly, Humboldt Wildlife Disease Lab in Arcata, CA, USA, for immediate testing. Fecal floats were performed using ~1.0 g of feces in a Fecalyzer® (Vétoquinol USA

Inc., Buena, NJ, USA). Fecal smears were performed by placing a direct smear of feces and several drops of Fecasol® (Sodium nitrate solution, Vétoquinol USA Inc., Buena, NJ, USA) onto a glass slide with a coverslip (Zajac and Conboy 2006). Helminths and oocysts were identified using a compound microscope (Zajac and Conboy 2006) and measured using a micrometer (González-Ruiz and Bendall 1995). All identifications were confirmed by R. Brown.

Data Analysis

Due to eggs being difficult to differentiate to species without molecular methods, we used scatter plots to distinguish the difference in the size of eggs we were finding. The size of *Eimeria* oocysts ranged from 20 µm to 48 µm. We were able to categorize *Eimeria* spp. oocysts into five different species groups (**Fig. 3**).

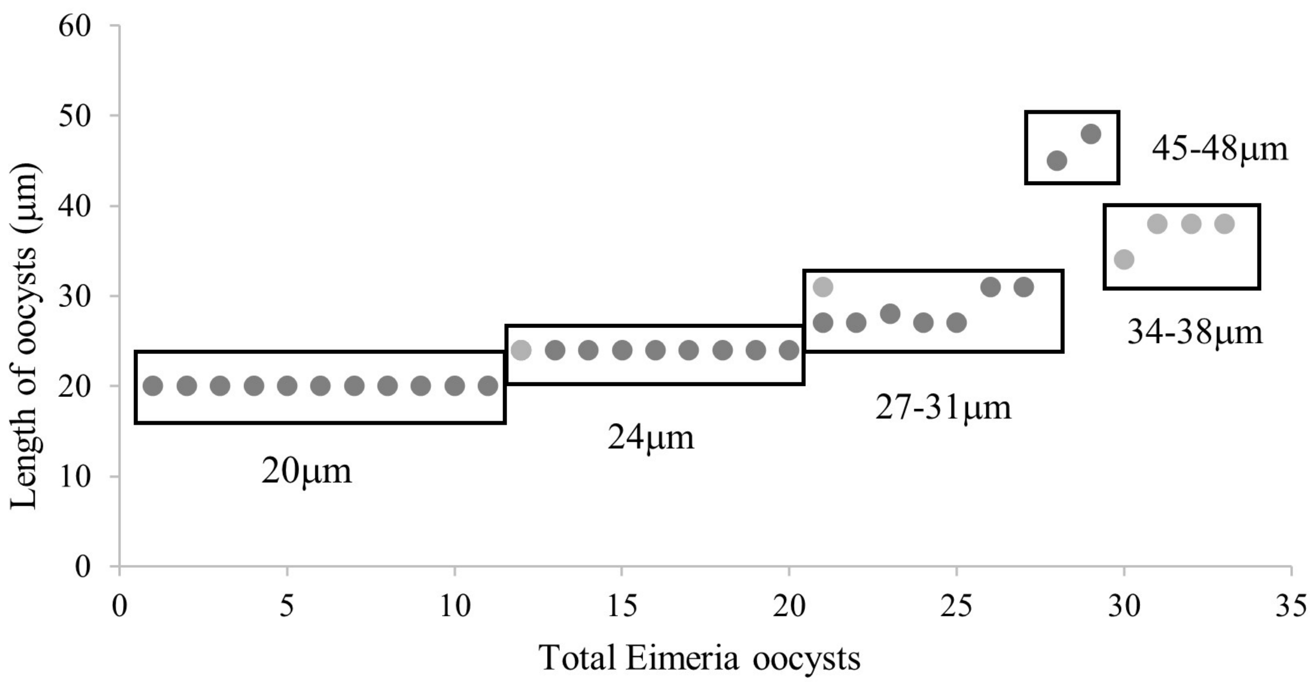

Figure 3. *Eimeria* spp. size chart from fecal samples collected from Sinkyone Roosevelt elk (dark grey) and Gold Bluffs Beach elk (grey). *Eimeria* sp. #1 (20 µm) *Eimeria* sp. #2 (24 µm) *Eimeria* sp. #3 (27–31 µm) and *Eimeria* sp. #4 (45–48 µm), *Eimeria* sp. #5 (34–38 µm). All samples were collected from Sinkyone Wilderness State Park, CA, USA, and Gold Bluffs Beach State Park, CA, USA, from January to March 2020.

Similarly, *Strongylid* spp. helminths size ranged from 31 µm to 100 µm. We categorized *Strongylid* spp. helminths into five species groups (**Fig. 4**).

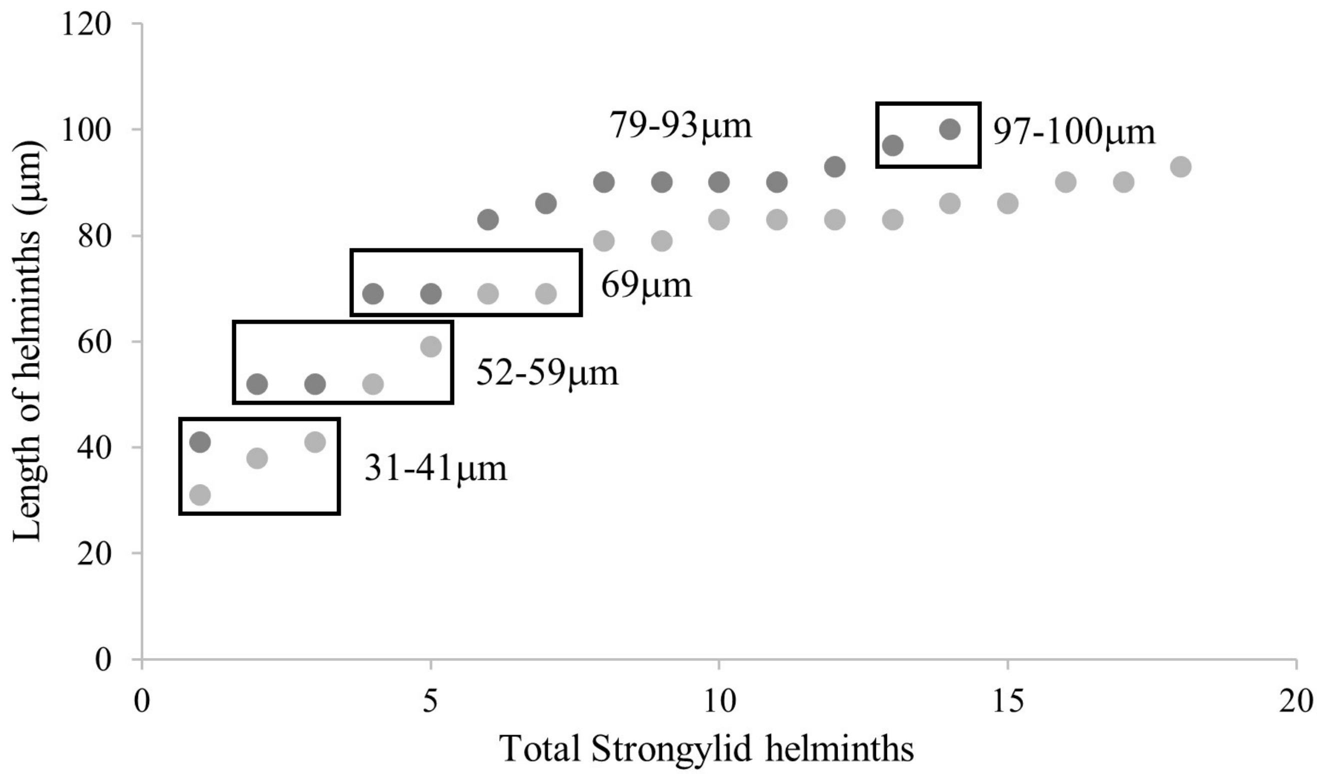

Figure 4. *Strongylid* spp. egg size chart from fecal samples collected from *Sinkyone* Roosevelt elk (dark grey) and Gold Bluffs Beach elk (grey): *Strongylid* sp. #1 (31–41 µm), *Strongylid* sp. #2 (52–59 µm), *Strongylid* sp. #3 (69 µm), *Strongylid* sp. #4 (79–93 µm), and *Strongylid* sp. #5 (97–100 µm). All samples were collected from Sinkyone Wilderness State Park, CA, USA, and Gold Bluffs Beach State Park, CA, USA, from January to March 2020.

A Mann-Whitney U test was used to evaluate the medians of the abundance of helminth eggs and *Eimeria* spp. oocysts, and to compare species richness between each herd of elk. Finally, we calculated the prevalence of each parasite by dividing the number of infected elk by the total sampled, and the parasite genera per elk were calculated by dividing elk infected by 0, 1, 2, 3, or 4 genera by the total sampled.

Results

Parasites

Overall, 13 species of parasites were identified from the Sinkyone herd, including four species of *Eimeria*, eight nematodes, and one species of fluke. The Gold Bluffs Beach herd had 10 species of parasites present, including three species of *Eimeria* spp. and seven species of nematodes. The Sinkyone herd had a greater species richness than the Gold Bluffs Beach herd (U = 123, P = 0.033).

The abundance of parasites was higher in the Sinkyone herd than in the Gold Bluffs Beach herd (U = 88.5, P = 0.003); 275 eggs or oocysts were found in samples from the Sinkyone herd, and 66 eggs or oocysts were found in samples from the Gold Bluffs Beach herd. However, one cow from the Sinkyone herd was an outlier with 138 helminth eggs counted, and her sample was omitted from the analysis of abundance.

Prevalence for each type of parasite was determined for all samples (n = 20 from each herd). Sinkyone had a higher prevalence of seven species: *Eimeria* sp. #1, #2, #3, and #4, *Toxocara* sp., *strongylid* sp. #5., and *Fasciola hepatica*. Gold Bluffs Beach had a higher prevalence of four species: *Eimeria* sp. #5, *strongylid* sp. #1 and #4, and *Nematodirus* sp. Elk at both locations had a similar prevalence of *Capillaria* sp. and *strongylid* sp. #2 and #3 (**Fig. 5**).

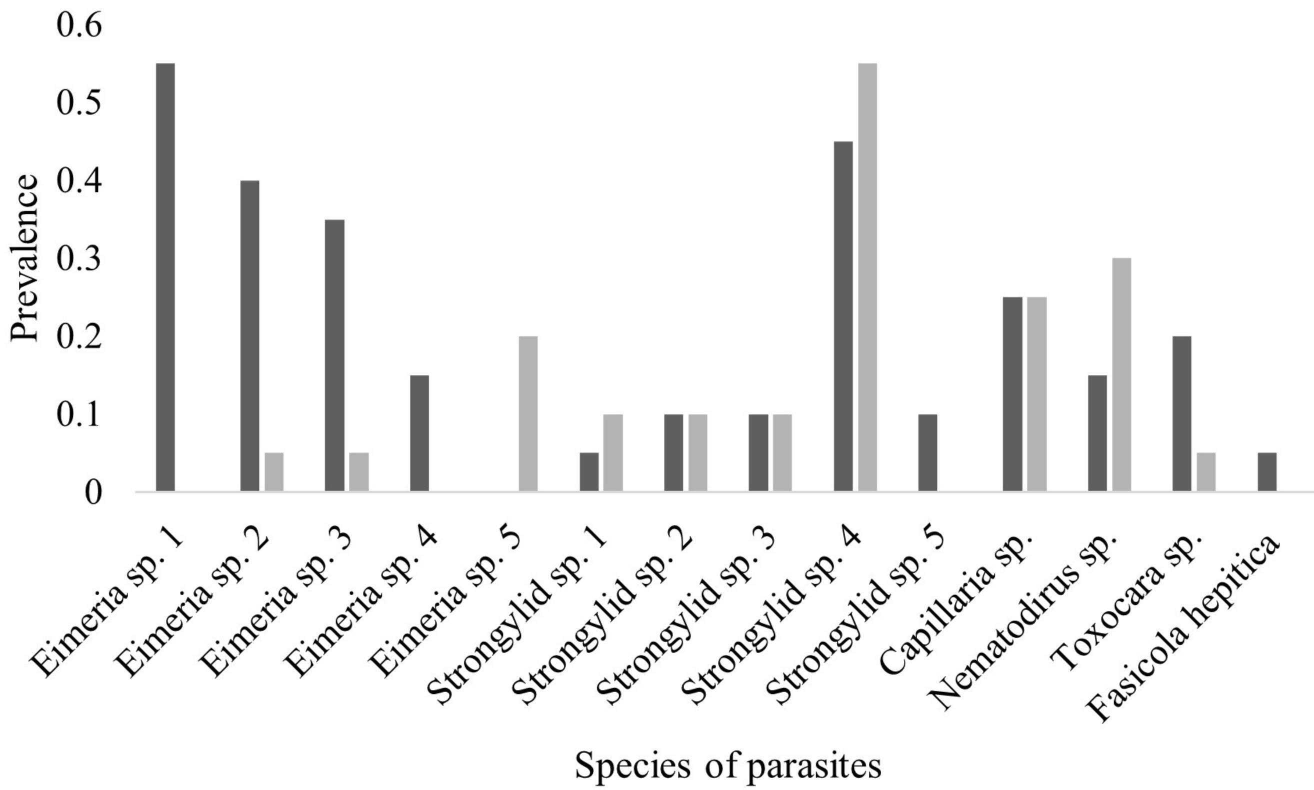

Figure 5. Figure 5. Prevalence of parasites estimated from forty Roosevelt elk fecal samples collected from Sinkyone Wilderness State Park, Mendocino County, CA, USA, (n = 20) (black lines), and Gold Bluffs Beach State Park, Humboldt County, CA, USA, (n = 20) (gray lines).

There was a higher percentage of samples from Sinkyone with multiple species of parasites; 50% of the samples yielded 2–3 parasite species, 4 species were identified in 20%, and 5 species were identified in 10% of samples. In comparison, only 1–2 species of parasites were found in 70% of the samples from Gold Bluffs Beach, and no individual was found with more than 4 species (**Table 1**).

Table 1. The percentage of Roosevelt elk with evidence of intestinal parasitism and the number of species detected from fecal pellets collected from Sinkyone Wilderness State Park (n = 20), Mendocino County, CA, USA, and Gold Bluffs Beach State Park (n = 20), Humboldt County, CA, USA from January to March 2020.

Table 1a. Sinkyone Herd

# of species	# of elk infected	% of herd
0	1	5%

# of species	# of elk infected	% of herd
1	3	15%
2	5	25%
3	5	25%
4	4	20%
5	2	10%

Table 1b. Gold Bluffs Beach Herd

# of species	# of elk infected	% of herd
0	2	10%
1	6	30%
2	8	40%
3	2	10%
4	2	10%
5	0	0%

Discussion

We determined that the Sinkyone herd had a higher species richness and parasite abundance when compared to the Gold Bluffs Beach herd, which supports our hypothesis. Other variables such as habitat use, nutrition, and density of the population could be a factor in the difference of abundance and species richness of parasites found, but causation is unknown.

Sinkyone elk had a higher prevalence of helminth eggs and *Eimeria* spp. oocysts, with one additional species of *strongylid*, compared to Gold Bluffs Beach. Wengert (2000) found a total of eight species of parasites in the Sinkyone herd: including *Trichuris* sp. and *Marshallagia* sp., which were not identified in this study. She reported a few genera of parasites found were no cause for alarm; however, parasitism of various helminths could affect population growth and herd health over the long term (Wengert 2000).

Comparing our findings to Wengert's, we found 7 more parasite species than she did. This difference could be due to many environmental factors, such as the elk population in Sinkyone has grown since 2000, allowing for easier disease transmission, or perhaps climate change is creating favourable conditions for the parasites. These probable changes could be investigated in the future.

Wengert (2000) also found low body scores from the Sinkyone herd. Body condition can be affected by many variables, including parasites and herd size relative to carrying capacity; high abomasal parasite counts have been used to indicate that white-tailed deer herds are beyond their carrying capacity (Eve and Kellogg 1977). Other factors also affect body condition, and no correlation was found between abomasal parasite load and body condition of black-tailed deer from three locations in coastal and inland Humboldt County (Botlzer 1979). Recent studies show that northern ungulate species are reliant on summer nutrition and nitrogen rich plants, which provide a digestible protein, and energy which can result in a higher fecundity rate and higher lean body mass (Cook et al. 2016, Rowland et al. 2018, and McArt et al. 2009).

More work is needed to determine which factors, including population density relative to carrying capacity, macronutrients, climate change, endoparasites, or other diseases, may be contributing to the health differences of these elk herds. Our sample size was small, making it likely that some parasites were missed. Helminth eggs are not shed consistently by individuals throughout the day, so we recommend collection of fecal samples in the morning when ungulates are active and grazing, which will increase the sample size of unique individuals. Additionally, parasites are shed inconsistently through the seasons and are typically more prevalent in the summer, and fall months (Eve and Kellogg 1977). We recommend testing parasite loads with a larger fecal sample size collected during the ideal time and seasons, performing necropsies with abomasal parasite counts to quantify parasite loads, and use of molecular methods to clarify the identification of parasites found.

Management Implications

Herd health should be considered when managing populations of elk. Factors that increase overall endoparasite egg abundance, and species richness should be addressed, and management actions should be taken when necessary. Many factors affecting herd health and disease transmission are density-dependent, but, in locations without harvest, a reduction of herd size or an increase in available habitat should be considered a mechanism to decrease disease transmission.

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