

One Health Approach of Melioidosis and Gastrointestinal Parasitic Infections from *Macaca fascicularis* to Human at Kosumpee Forest Park, Maha Sarakham, Thailand

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Background and Objectives: Gastrointestinal parasitic and melioidosis infections are major causes of morbidity and mortality from infectious disease in rural areas, especially in northeastern Thailand. Both diseases are zoonotic giving rise to health problems in both long-tailed macaques and in humans. In Thailand, macaques have adapted to live and share space with humans and can spread some zoonoses to humans. Therefore, this research aimed to measure the prevalence of gastrointestinal parasitic infections and melioidosis in long-tailed macaques at Kosumpee Forest Park and measure associated risk factors of their diseases among people in this area.

Methods: This study was conducted at Kosumpee Forest Park, Maha Sarakham, Thailand. Twenty-eight blood samples and 135 fecal samples were collected from free-ranging long-tailed macaques. Blood samples were tested by indirect hemagglutination test and fecal samples were analyzed by formalin–ethyl acetate concentration technique. A cross-sectional study was conducted among 350 respondents who were involved with the Forest Park using a multi-stage stratified random sampling method and performed to measure knowledge, attitude, and practice toward the zoonoses among the respondents.

Results: It was found that seroprevalence of melioidosis was 57.1% from macaque samples. The prevalence of gastrointestinal parasites infection was 35.11% from feces samples, including *Strongyloides* spp. (15.27%), *Trichuris* spp. (22.9%), hookworm (4.58%) and *Ascarid* spp. (1.53%). KAP study indicated that the level of knowledge related to melioidosis and gastrointestinal parasites of people in the area was very low and moderate, respectively. The attitude of respondents who were aware of the diseases was at a moderate level for melioidosis and a high level for parasitic infection.

Conclusion: The study therefore emphasizes the importance of one health approach for diagnosis, surveillance and management of zoonotic diseases to promote the development of hygiene measures and to educate people in the community around Kosumpee Forest Park.

Keywords: long-tailed macaques, prevalence, melioidosis, gastrointestinal parasites, risk factors

Introduction

The long-tailed macaque (*Macaca fascicularis*) is one of the most geographically widely distributed primates. They occur mostly in Africa and the mainland or islands of Southeast Asia. The macaques have a variety of habitats such as rain-forest along rivers and mangroves.^{1,2} The macaques are the most common monkey

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in Thailand. However, they are threatened due to inbreeding and loss of habitat, from expansion of residential areas and encroaching deforestation for agriculture or communication which destroys natural habitats as a result. The macaques have adapted to live and share space with humans.³ According to some religious beliefs, monkeys are believed to represent gods or sacred things and lived in this area before humans, so the macaques are found in many religious sites. At such places, people in the area have the patience to coexist with the monkeys and take measures to protect them in temples or sacred sites.⁴ Due to macaques and people sharing the same living space, there is sometimes conflict between them, such as damage of agricultural areas, property and housing, including local people or tourists who may be harmed or contract disease caused by macaques.

At present, 75% of the emerging infectious diseases are caused by zoonotic organisms.⁵ Zoonotic diseases such as gastrointestinal (GI) parasitic infection from macaques to humans are important in Thailand and this remains a current health problem, especially in the Northeast, where rural areas lack good sanitation and hygiene practices. In both humans and animals, the infections can be obtained through eating food contaminated via the fecal-oral route, such as by eating vegetables grown with manure, eating meat that has been contaminated with bacteria and drinking water from natural sources that are not sterile.⁶ Symptoms of acute GI parasitic infections may include ground itch, cutaneous larva migrans, bronchitis and pneumonia. Adult parasites may cause gastrointestinal symptoms such as diarrhea, nausea, vomiting, loss of appetite and chronic parasitic infections cause anorexia, reducing intestinal absorption of nutrients leading to lack of essential nutrients or anemia from blood loss in the intestines.⁷ Clinical signs in macaques are similar to those in humans with anemia, tissue damage, abortion, malnutrition and death if symptoms are severe.⁸

Another important disease in the northeastern Thailand is melioidosis. This is caused by the Gram-negative bacteria, *Burkholderia pseudomallei* that can infect both humans and animals. *Burkholderia pseudomallei* is found in the soil. It is contagious through oral or aerosol routes and wounds contaminated with soil or water polluted with bacteria. They are often found in farmers because they have natural contact with soil and water. It is often not communicated from person to person or animal to person but it can arise bites from infected animal or injury causing infection through the wound. In addition, there are risk

factors that increase the likelihood of developing the disease in humans such as diabetes and alcoholism.⁹ Approximately 40–60% of people have systemic symptoms such as septicemia, pericarditis and respiratory tract symptoms such as pulmonary edema and lung abscess. About 10–33% of symptoms are in the gastrointestinal tract, liver and spleen abscesses. Urinary tract infection occurs in 14–28% causing liver abscess, acute nephritis and various symptoms such as purulent abscess in soft tissue, and arthritis.¹⁰ Clinical signs in monkeys are similar to humans, such as fever, dyspnea, neutrophilia, lung abscess and bone marrow inflammation.⁹

Both these zoonotic pathogens can survive as free-living organisms in environmental niches such as water or soil and they can be transmitted to susceptible hosts including human and animal by direct and indirect contact. They are important as endemic zoonoses in the tropical area especially in the Northeast and rural areas of Thailand due to risky behaviors associated with daily activities of the people.^{11,12} Effective control, prevention or eradication of zoonotic diseases, nowadays uses a one health approach, which is a synergistic approach, with experts from all sectors involved with human health, animal health and environmental health (the One Health Triads). This approach can solve problems by designing long-term preventive measures to reduce contagious zoonotic diseases in the future.^{13,14} We studied GI parasitic infections and melioidosis and measured their prevalence in long-tailed macaques at Kosumpee Forest Park. The macaques are known wildlife reservoirs of these infections that closely interact with humans in Thailand. In addition, this study analyzed the risk factors of people in that community as the human aspect, which is considered important according to the One Health concept. The assessment of knowledge, attitude, and practice (KAP) is crucial to the prevention of GI parasites and melioidosis infection. As the prevention and control of these diseases is challenging, human behavioral approaches with proper understanding of social background and health beliefs have become a crucial measure in decreasing morbidity and mortality due to these zoonotic diseases.

Materials and Methods

Ethics Statement

All procedures were approved by Mahasarakham University for human and animal subjects research (protocol numbers 037/2016 and 0009/2016, respectively). The

questionnaire participants provided informed consent, and that this was conducted in accordance with the Declaration of Helsinki.

Fecal Sample Collection

Fecal sample collection was performed without contact with animals. Each macaques at Kosumpee Forest Park, Maha Sarakham, Northeastern Thailand (Figure 1) was assessed individually by the following method¹⁵ and using completely randomized design (CRD) to obtain representative samples from the population. Fresh stool samples were collected using gloves from 135 macaque fecal samples. Approximately 2 g of each sample was

collected into a clean plastic bag, stored at 4°C, and transported to the laboratory for GI parasites detection.

Blood Sample Collection

The investigation of melioidosis seroprevalence in the wild animals was determined via antibody titer of macaques by using blood collection. Twenty-eight macaques were temporarily caught in a soft mesh cage (4x4x1.5 m) and Tiletamine-zolazepam was administered for sedation the monkeys through the intramuscular route by the blow-pipe as show in Figure 2. The blood samples were collected from the femoral vein. Samples were collected aseptically using sterile a 5 mL syringe. All protocols

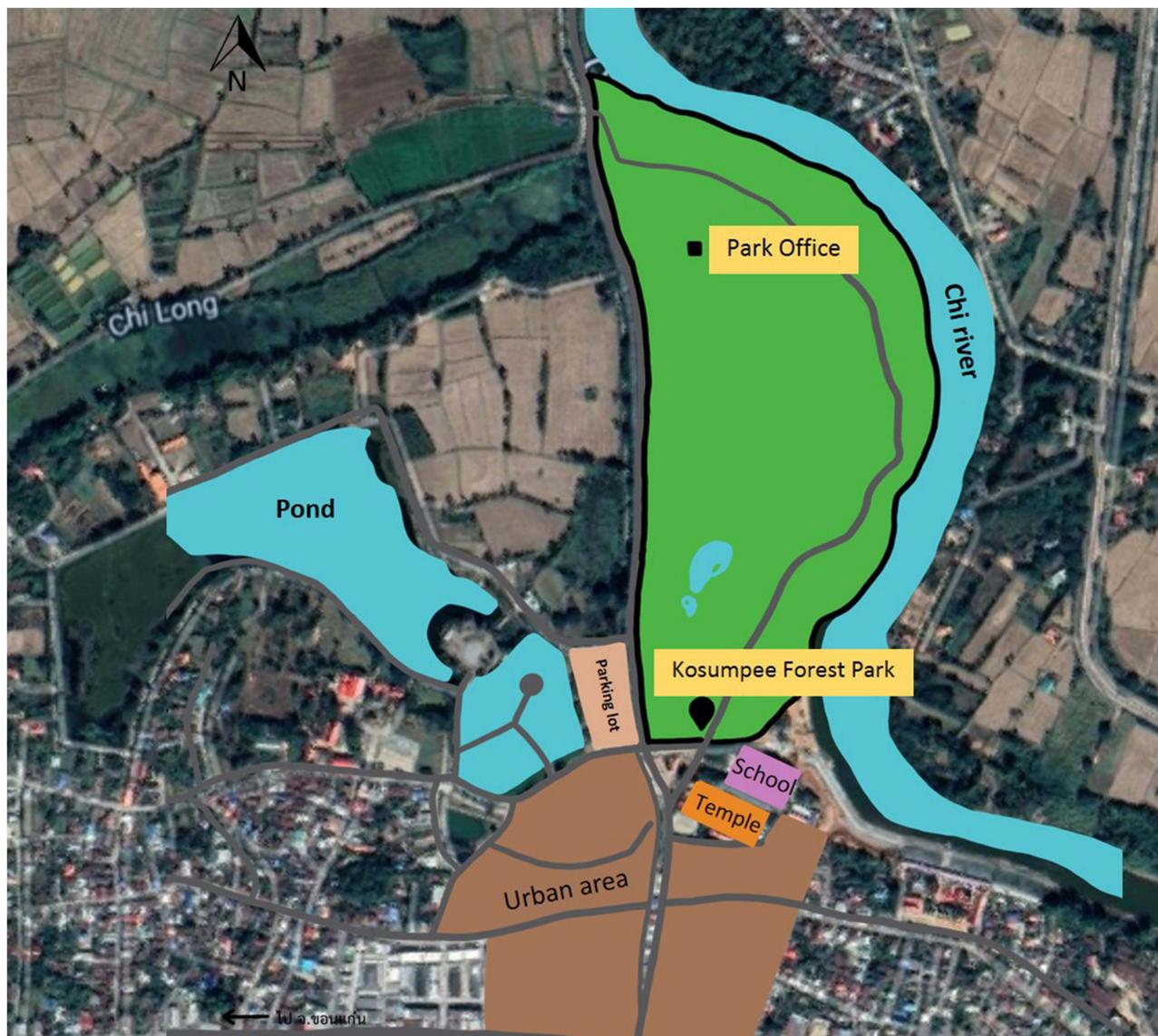


Figure 1 Geographical location of study area; Kosumpee Forest Park in Kosum Phisai district, Maha Sarakham province, Northeast Thailand (from Google Earth).



Figure 2 Long-tailed macaques were sedated by the blowpipe.

were controlled by wildlife veterinary specialists. All blood samples were stored at 4°C and taken to the Veterinary Public Health laboratory, Faculty of Veterinary Sciences, Maharakham University to separate and collect serum. Each serum sample was separated by centrifugation of blood at 3000 g for 10 minutes at room temperature. The serum samples were transferred into 1.5 mL sterile micro tube (Eppendorf) and were kept at -20 °C until further testing.

Indirect Hemagglutination Assay (IHA)

Monkey serum samples were tested for specific antibody to *B. pseudomallei* by indirect hemagglutination assay (IHA) following the IHA protocol of Mahidol-Oxford Tropical Medicine Research Unit.¹⁶ It was performed using antigen pooled from clinical *B. pseudomallei* isolates from a Springbok positive case at Khon Kaen Zoo, Thailand, following standard US CDC laboratory protocols. The optimal concentration of antigen was pooled before sensitizing with sheep red blood cells for one hour. Monkey serum samples which diluted with 2-fold serial dilutions and starting from of 1:10 dilution and heat-inactivated and then incubated with nonsensitized sheep red cells for 2 hours at room temperature and then incubated overnight at 4°C. Titers for monkey serum samples in microwell plates were analyzed, and antigen-sensitized red cells were added. The appearance of antibody was confirmed by the agglutination of red blood cells. A titer of $\geq 1:80$ was considered positive for melioidosis infection.

Formalin–Ethyl Acetate Concentration Technique

Fecal samples were processed for detecting the presence of GI parasitic eggs or larva with the formalin–ethyl acetate concentration technique (FECT), then the identification of those parasitic eggs or larva was examined under microscope. The occurrence of GI parasitic eggs or larva which related to the infection of monkeys was calculated using the descriptive statistics on MS Excel version 2013 (Microsoft, USA).

Risk Factors Assessment in Humans and Data Analysis

The KAP (knowledge, attitude, and practice) questionnaire was used as a tool in this study for assessing the risk factors in humans. The study questionnaire was administered orally in area around Kosumpee Forest Park by divided the sample into 6 groups; Forest Park staffs, students, teachers, temple dwellers, inhabitants (living around the park) and tourists. Questionnaires included close-ended and free-response questions covering the following topics: personal information about respondents, basic knowledge about the diseases (such as knowledge of signs and symptoms of these diseases in humans and animals, transmission, testing and treatment), attitude towards the diseases, behaviors that are risk factors for the disease and personal hygiene for prevention and treatment practices. The respondents received explanations and recommendations from the interviewer and all personal information was confidential.

Data Analysis

The melioidosis seroprevalence and GI parasitic infection in long-tailed macaques were analyzed by using descriptive statistics in the SPSS statistics program version 16.0 (IBM, Armonk, NY, USA). Questionnaire data was also entered and analyzed using the IBM Statistics for Social Sciences (SPSS) version 16 software for Windows (IBM, Armonk, NY, USA). Data were checked and cleaned. Chi square tests and the Fisher tests were performed to determine the associated factors for good KAP toward melioidosis and GI parasitic infection among the respondents. P-values ≤ 0.05 was considered to be statistically significant. Frequency and percentage were calculated for all variables.

Results

Prevalence of Melioidosis in Long-Tailed Macaques

A total of 28 serum samples of free ranging long-tailed macaques were collected and tested by IHA. Sixteen (57.14%) samples were positive by using a cut-off value of 1:80 as suggested by Mekaprateep and team,¹⁷ while, 12 samples (42.86%) were negative as shown in Table 1. Estimation of the population prevalence at 95% CI was calculated from the formula of $p \pm 1.96 * SE$ resulting in a prevalence of 56.97% to 57.31%.

Long-Tailed Macaque Fecal Analysis

Individual fecal samples from 131 macaques were tested by FECT. Overall, 35.11% (46 of 131) of macaques were infected with one or more gastrointestinal parasites including *Strongyloides* spp., *Trichuris* spp., *Ascaris* spp., and hookworm as shown in Table 2. The result revealed the highest prevalence of *Trichuris* infection in long-tailed macaques followed by *Strongyloides* infection. *Ascaris* spp. was the least prevalent of GI parasitic infections in long-tailed macaques. Interestingly, rhabditiform larvae were identified under microscope from 8 fecal samples which detected as positive samples of *Strongyloides* sp. infection.

Human Survey

A total of 370 and 362 respondents participated in the questionnaire regarding KAP analysis for melioidosis and gastrointestinal parasitic infections, respectively. According to the sociodemographic characteristics of the respondents in the questionnaire of melioidosis infection,

Table 1 Frequencies of Melioidosis IHA Serum Titers of Long-Tailed Macaques at Kosumpee Forest Park, Maha Sarakham Province, Thailand

| Titer | No. Positive | % |
|---------------|--------------|--------|
| <1:10 | 0 | 0 |
| 1:10 | 4 | 14.29 |
| 1:20 | 5 | 17.86 |
| 1:40 | 3 | 10.71 |
| 1:80 | 8 | 28.57 |
| >1:80 | 8 | 28.57 |
| Total samples | 28 | 100.00 |

Table 2 Prevalence of GI Parasites in Long-Tailed Macaques in Kosumpee Forest Park, Maha Sarakham Province, Thailand

| No. Sample | GI Parasitic Egg | Positive (% Prevalence) |
|-------------------|---------------------------|-------------------------|
| 131 fecal samples | <i>Strongyloides</i> spp. | 20 (15.27) |
| | <i>Trichuris</i> spp. | 30 (22.90) |
| | Hookworm | 6 (4.58) |
| | <i>Ascarid</i> spp. | 2 (1.53) |
| | Total | 46 (35.11) |

all respondents were Thai, and females (59.46%) outnumbered the males (40.54%). The age range with the greatest number of respondents was 7 to 14 years (38.65% preliminary students) while ages ranged from 35 to 44 years (4.86%) is the least respondent population. For the gastrointestinal parasitic infections questionnaire, all respondents were Thai, and females (58.29%) outnumbered the males (47.71%). The age range with the greatest number of respondents was 7 to 14 years (38.12% preliminary students) while ages ranged up to 65 years (3.59%) is the least respondent population. The mean scores for respondent's knowledge, attitudes, and practices of melioidosis and gastrointestinal parasitic infections were compared among the different groups as shown in Tables 3 and 4, respectively. The knowledge, attitudes, and practices scores varied significantly by the group of people which relevant to those macaques. It is very interesting that all group of people had very low knowledge about melioidosis (<30% of all groups), while, they had a good knowledge about GI parasitic infection (>50% of all groups). Forest Park staff, students and tourists tended to have a better attitude with concern about melioidosis and all groups were greatly concerned about GI parasitic infection. This research revealed that basic self-protection practices to protect them from melioidosis infection were minimal, while, they had a good level of self-protection practices from GI parasitic infection except in the case of temple dwellers.

Discussion

Based on the IHA results, 56.97% to 57.31% melioidosis seroprevalence was determined for the studied free ranging population of long-tailed macaques. There have been no other investigations in macaques in Thailand. Previous study of melioidosis seroprevalence from livestock in Thailand reported a seroprevalence of 8135 animals in 2005–2006 consisting of cattle (2.56%), goats (0.33%),

Table 3 Respondents' knowledge, Attitude and Practices of melioidosis

| Variables | Forest Park Staff (n=10) | Students (n=158) | Teachers (n=11) | Temple Dwellers (n=9) | Local Participants (n=90) | Tourists (n=92) | P-value |
|--|--------------------------|------------------|-----------------|-----------------------|---------------------------|-----------------|---------|
| Knowledges | | | | | | | |
| Knowledge about melioidosis | | | | | | | 0.015 |
| Yes | 0 (-) | 23 (14.56) | 2 (18.18) | 0 (-) | 4 (4.44) | 19 (20.65) | |
| No | 10 (100) | 135 (85.44) | 9 (81.82) | 9 (100) | 86 (95.56) | 73 (79.35) | |
| Knowledge of the symptoms of melioidosis | | | | | | | 0.229 |
| Yes | 0 (-) | 22 (13.92) | 2 (18.18) | 0 (-) | 9 (10.00) | 18 (19.56) | |
| No | 10 (100.00) | 136 (86.08) | 9 (81.82) | 9 (100.00) | 81 (90.00) | 74 (80.44) | |
| Knowledge that melioidosis caused by bacteria | | | | | | | <0.001 |
| Yes | 2 (20.00) | 56 (35.44) | 2 (18.18) | 0 (-) | 6 (6.67) | 29 (31.52) | |
| No | 8 (80.00) | 102 (64.56) | 9 (81.82) | 9 (100.00) | 84 (93.33) | 63 (68.48) | |
| Knowledge about prevention of melioidosis | | | | | | | 0.087 |
| Yes | 0 (-) | 29 (18.35) | 2 (18.18) | 0 (-) | 9 (10.00) | 21 (22.83) | |
| No | 10 (100.00) | 129 (81.65) | 9 (81.82) | 9 (100.00) | 81(90.00) | 71 (77.17) | |
| Attitudes | | | | | | | |
| Concerned about melioidosis | | | | | | | <0.001 |
| Yes | 7 (70.00) | 100 (63.29) | 5 (45.45) | 1 (11.11) | 23 (25.56) | 48 (52.17) | |
| No | 3 (30.00) | 58 (36.7) | 6 (54.55) | 8 (89.89) | 67 (74.44) | 44 (47.83) | |
| Concerned about using protective measures | | | | | | | <0.001 |
| Yes | 8 (80.00) | 101 (63.92) | 7 (63.64) | 0 (-) | 36 (40.00) | 59 (64.13) | |
| No | 2 (20.00) | 57 (36.08) | 4 (36.36) | 9 (100.00) | 54 (60.00) | 33 (35.87) | |
| Seek a medical consultation when needed | | | | | | | <0.001 |
| Yes | 6 (60.00) | 119 (75.32) | 4 (36.36) | 1 (11.11) | 33 (36.67) | 57 (61.96) | |
| No | 4 (40.00) | 39 (24.68) | 7 (63.64) | 8 (89.89) | 57 (63.33) | 35 (38.04) | |
| You believe everyone have risk of infection | | | | | | | <0.001 |
| Yes | 8 (80.00) | 123 (77.85) | 9 (81.82) | 3 (33.33) | 52 (57.78) | 76 (82.61) | |
| No | 2 (20.00) | 35 (22.15) | 2 (18.18) | 6 (66.67) | 38 (42.22) | 16 (17.39) | |
| Practices | | | | | | | |
| Clean the body after visiting forest park | | | | | | | <0.001 |
| Yes | 7 (70.00) | 46 (29.11) | 3 (27.27) | 6 (66.67) | 54 (60.00) | 49 (53.26) | |
| No | 3 (30.00) | 112 (70.89) | 8 (72.73) | 3 (33.33) | 36 (40.00) | 43 (46.74) | |
| You put any soil or herbs on the wound | | | | | | | 0.064 |
| Yes | 6 (60.00) | 29 (18.35) | 3 (27.27) | 3 (33.33) | 21 (23.33) | 21 (22.83) | |
| No | 4 (40.00) | 129 (81.65) | 8 (72.73) | 6 (66.67) | 69 (76.67) | 71 (77.17) | |
| Walking barefoot in stable and agricultural area | | | | | | | <0.001 |
| Yes | 7 (70.00) | 35 (22.15) | 3 (27.27) | 9 (100.00) | 35 (38.89) | 33 (35.87) | |
| No | 3 (30.00) | 123 (77.85) | 8 (72.73) | 0 (-) | 55 (61.11) | 59 (64.13) | |
| Have you ever been swimming in natural water resources | | | | | | | 0.002 |
| Yes | 10 (100.00) | 108 (68.35) | 8 (72.73) | 8 (88.89) | 47 (52.22) | 69 (75.00) | |
| No | 0 (-) | 50 (31.65) | 3 (27.27) | 1 (11.11) | 43 (47.78) | 23 (25.00) | |

(Continued)

Table 3 (Continued).

| Variables | Forest Park Staff (n=10) | Students (n=158) | Teachers (n=11) | Temple Dwellers (n=9) | Local Participants (n=90) | Tourists (n=92) | P-value |
|---|--------------------------|------------------|-----------------|-----------------------|---------------------------|-----------------|---------|
| Have you ever touched a monkey or its feces | | | | | | | <0.001 |
| Yes | 8 (80.00) | 113 (71.52) | 9 (81.82) | 7 (77.78) | 36 (40.00) | 53 (57.61) | |
| No | 2 (20.00) | 45 (28.48) | 2 (18.18) | 2 (22.22) | 54 (60.00) | 39 (42.39) | |

Note: Values are presented as number (%).

sheep (7.23%), swine (7.23%) and deer (1.61%).¹⁸ The seroprevalence of melioidosis in macaques in Kosumpee Forest Park in this study was higher than in all other animals studied. This is due to significantly higher environmental contamination in soils¹⁹ such as paddy fields, open fields, plantations, forests and ponds.^{20–22} Characteristics of the environment within and around Kosumpee Forest Park resulted in the high risk and incidence of melioidosis in the macaque population.

The prevalence of GI parasitic infection in macaque from this study was 35.11%. Overall, 35.11% (36 of 131) of macaques were infected with one or more GI parasites; *Strongyloides* spp. (15.27%, 20 of 131) *Trichuris* spp. (22.90%, 30 of 131), Hookworm (4.58%, 6 of 131) and *Ascarid* spp. (1.53, 2 of 131). The prevalence of all parasitic infections in macaques at Kosumpee Forest Park was lower than previous report by Pumipuntu in 2018 (62.6%)²³ but was approximately identical to that reported by Schurer and team in 2019 (44%).²⁴ *Trichuris* spp. tended to increase while *Strongyloides* spp. decreased in 2019 and increased in this study. Hookworm tended to decrease and *Ascarid* spp. was not found in 2018, but it was detected in 2019 and during this study. Interestingly, this research found rhabditiform larvae of *Strongyloides* sp. in 8 out of 20 fecal samples from the monkeys which amounts to 40% of all *Strongyloides* infection. The rhabditiform larvae can be excreted from the feces of long-tailed macaques, survive within the environment such as soil or water, and act as soil-transmitted helminths which can cause reinfection to animal and human via the environmental sources as their reservoirs.²³ This finding implies the significance of this GI pathogen in the perspective of “One Health” that needs to be emphasized. Recording the ongoing prevalence and the diversity of parasitic species in detail will help to understand the relationship between the parasite and human knowledge, awareness and social behavior.^{23,25} The prevalence of both melioidosis and GI

parasitic infection in this study emphasizes and highlights the presence of zoonotic potential diseases which can transmit infection between wildlife to humans as animal reservoirs. It implies the current dynamics and consequences of their infections in wildlife, especially in free ranging long-tailed macaques which have coexistence with humans thus bringing them in closer proximity to one another.

More than that, this study indicated the knowledge level associated with melioidosis among the local population sample was at low level (12.97%), consistent with another study in Thailand (7%)²⁶ and GI parasitic infections were at moderate level (68.78%), consistent with previous study in Thailand (68.50%).²⁷ Awareness of melioidosis, accounted for 49.72% of the sample and was at moderate level and GI parasitic infections was at high level (87.56%).

Practices that are risk factors for melioidosis that were statistically significant were (i) cleaning the body after visiting the Forest Park ($P < 0.001$), (ii) walking barefoot in stables and agricultural areas ($P < 0.001$), (iii) having ever been into a natural water resource ($P = 0.002$) and (iv) having ever touched the body or stools of animals ($P < 0.001$). More than 95.14% of the sample had visited the Forest Park. If people touched animals or their manure without cleaning and protective contact, there was a risk of infections. Because the pathogens may be transmitted from the animal through breathing, feces, urine and secretions into the environment, when people enter an environment in which the animal lives, they can easily become infected.²⁸

Practices that are statistically significant risk factors for GI parasitic infections were consisting of (i) level of personal hygiene ($P < 0.001$), (ii) eating uncooked vegetables ($P < 0.001$), (iii) eating uncooked fish ($P = 0.003$), (iv) wearing shoes when leaving the house ($P = 0.001$) and (v) housing near the community littering area ($P =$

Table 4 Respondents' knowledge, Attitude and Practices of Gastrointestinal Parasitic Infections

| Variables | Forest Park Staff (n=10) | Students (n=157) | Teachers (n=18) | Temple Dwellers (n=10) | Local Participants (n=47) | Tourists (n=120) | P value |
|---|--------------------------|------------------|-----------------|------------------------|---------------------------|------------------|---------|
| Knowledges | | | | | | | |
| Knowledge about GI parasitic infections | | | | | | | 0.220 |
| Yes | 5 (50.00) | 99 (63.06) | 13 (72.22) | 7 (70.00) | 35 (74.47) | 90 (75.00) | |
| No | 5 (50.00) | 58 (36.94) | 5 (27.78) | 3 (30.00) | 12 (25.53) | 30 (25.00) | |
| Knowledge that only children and the elderly can infected GI parasites | | | | | | | 0.201 |
| Yes | 2 (20.00) | 41 (26.11) | 7 (38.89) | 4 (40.00) | 19 (40.43) | 28 (23.33) | |
| No | 8 (80.00) | 116 (73.89) | 11 (61.11) | 6 (60.00) | 28 (59.57) | 92 (76.67) | |
| Knowledge that whipworm and threadworm are GI parasites | | | | | | | <0.001 |
| Yes | 4 (40.00) | 81 (51.59) | 13 (72.22) | 1 (10.00) | 36 (76.60) | 82 (68.33) | |
| No | 6 (60.00) | 76 (48.41) | 5 (27.78) | 9 (90.00) | 11 (23.40) | 38 (31.67) | |
| Knowledge that eating or drinking contaminated with animal feces can infected parasites | | | | | | | <0.001 |
| Yes | 7 (70.00) | 115 (73.25) | 13 (72.22) | 3 (30.00) | 41 (87.23) | 107 (89.17) | |
| No | 3 (30.00) | 42 (26.75) | 5 (27.78) | 7 (70.00) | 6 (12.77) | 13 (10.83) | |
| Knowledge that lime can be used instead of heat in cooking | | | | | | | 0.193 |
| Yes | 4 (40.00) | 62 (39.49) | 6 (33.33) | 2 (20.00) | 13 (27.66) | 31 (25.83) | |
| No | 6 (60.00) | 95 (60.51) | 12 (66.67) | 8 (80.00) | 34 (72.34) | 89 (74.17) | |
| Attitudes | | | | | | | |
| Be aware of the dangers of parasites in the digestive system | | | | | | | 0.035 |
| Yes | 6 (60.00) | 136 (86.62) | 16 (88.89) | 7 (70.00) | 42 (89.36) | 110 (91.67) | |
| No | 4 (40.00) | 21 (13.38) | 2 (11.11) | 3 (30.00) | 5 (10.64) | 10 (8.33) | |
| You believe that anthelmintic drug taken after eating raw meat or fish can prevent parasitic infections | | | | | | | <0.001 |
| Yes | 8 (80.00) | 84 (53.50) | 12 (66.67) | 3 (30.00) | 24 (51.06) | 30 (25.00) | |
| No | 2 (20.00) | 73 (46.50) | 6 (33.33) | 7 (70.00) | 23 (48.94) | 90 (75.00) | |
| Be aware of suspected symptom will see a doctor | | | | | | | <0.001 |
| Yes | 10 (100.00) | 123 (78.34) | 17 (94.44) | 4 (40.00) | 36 (76.60) | 108 (90.00) | |
| No | 0 (-) | 34 (21.66) | 1 (5.56) | 6 (60.00) | 11 (23.40) | 12 (10.00) | |
| You believe dried manure can be used in vegetable fields because it is free from parasites | | | | | | | 0.250 |
| Yes | 6 (60.00) | 83 (52.87) | 12 (66.67) | 3 (30.00) | 23 (48.94) | 52 (43.33) | |
| No | 4 (40.00) | 74 (47.13) | 6 (33.33) | 7 (70.00) | 24 (51.06) | 68 (56.67) | |
| Practices | | | | | | | |
| You have personal hygiene | | | | | | | <0.001 |
| Yes | 10 (100.00) | 129 (82.17) | 18 (100.00) | 4 (40.00) | 47 (100.00) | 109 (90.83) | |
| No | 0 (-) | 28 (17.83) | 0 (-) | 6 (60.00) | 0 (-) | 11 (9.17) | |
| Eating uncooked vegetables | | | | | | | <0.001 |
| Yes | 10 (100.00) | 89 (56.69) | 15 (83.33) | 1 (10.00) | 40 (85.11) | 112 (93.33) | |
| No | 0 (-) | 68 (43.31) | 3 (16.67) | 9 (90.00) | 7 (14.89) | 8 (6.67) | |

(Continued)

Table 4 (Continued).

| Variables | Forest Park Staff (n=10) | Students (n=157) | Teachers (n=18) | Temple Dwellers (n=10) | Local Participants (n=47) | Tourists (n=120) | P value |
|--|--------------------------|------------------|-----------------|------------------------|---------------------------|------------------|---------|
| Eating uncooked fish | | | | | | | 0.003 |
| Yes | 9 (90.00) | 58 (36.94) | 10 (55.56) | 3 (30.00) | 18 (38.30) | 64 (53.33) | |
| No | 1 (10.00) | 99 (63.06) | 8 (44.44) | 7 (70.00) | 29 (61.70) | 56 (46.67) | |
| Clean the body after touch animal body/stool | | | | | | | 0.232 |
| Yes | 9 (90.00) | 126 (80.25) | 16 (88.89) | 7 (70.00) | 43 (91.49) | 105 (87.50) | |
| No | 1 (10.00) | 31 (19.75) | 2 (11.11) | 3 (30.00) | 4 (8.51) | 15 (12.50) | |
| Wearing shoes when leaving the house | | | | | | | 0.001 |
| Yes | 10 (100.00) | 125 (79.62) | 17 (94.44) | 5 (50.00) | 44 (93.62) | 106 (88.33) | |
| No | 0 (-) | 32 (20.38) | 1 (5.56) | 5 (50.00) | 3 (6.38) | 4 (11.67) | |
| Housing near the community littering area | | | | | | | 0.031 |
| Yes | 0 (-) | 21 (13.38) | 6 (33.33) | 3 (30.00) | 3 (6.38) | 15 (12.50) | |
| No | 10 (100.00) | 136 (86.62) | 12 (66.67) | 7 (70.00) | 44 (93.62) | 105 (87.50) | |

Note: Values are presented as number (%).

0.031). An environment where people and humans live together provides opportunity for contact with the monkey's body or feces and was a risk factor for human parasite infection.²⁴ The result is related to a previous study which reported that there was a statistically significant association between eating uncooked food as food culture and GI parasitic infections of Thai people in rural areas.²⁷ More than that, lack of systematic waste management, knowledge and understanding of animal reservoirs and their role of the people, especially in old ages, are the important factors which promotes infection.²⁹ In addition, not wearing shoes while leaving the house had a statistically significant association with GI parasitic infections.^{27,30}

This finding revealed the significance of melioidosis and GI parasitic infection which are some of the most sylvatic infectious disease in wildlife. In addition, they could be potentially important zoonotic pathogens, with macaques playing an important role as animal reservoirs of zoonotic infections in this area. Interestingly, those zoonotic diseases are the essential problem of "One Health" issues which at present which involve human, animal and environmental health. Melioidosis and GI parasitic infection are potential zoonotic diseases in which animals are reservoirs that can contaminate the environment and cause re-infections.^{23,24,31,32} Although transmission of infection from animals to humans is

difficult and needs suitable factors for spillover, it cannot be ignored.^{33,34} Animal excretion or secretions can carry various pathogens and shed them into the environment around human communities as natural reservoirs that harbor infectious zoonotic pathogens outside the bodies of animal reservoirs. Climate change, such as rainfall in the rainy season, will increase the risk of exposure or infection from natural reservoirs to human.²⁸

Kosumpee Forest Park is an obvious coexistence model of humans and wildlife in the same environment. It is an eco-tourism destination, thus increasing the opportunity for infection. There should be surveillance measures and reduction of the risk factors for infections through interdisciplinary cooperation to share knowledge, attitudes and tools between the government, the private sector and the people. This is a study of knowledge, attitudes and practices related to zoonotic infection to assist in directing policy in the provision of unique resources that meet local needs, which is necessary for operating suitable preventive and control programs, improving personal sanitation, educating about zoonotic diseases to increase risk awareness of people in this area.

Conclusion

This study provides an obvious evidence that there is a high prevalence of melioidosis and GI parasitic infections in long-tailed macaques at Kosumpee Forest Park.

The long-tailed macaque seems to be the important reservoir hosts for zoonotic melioidosis and GI parasites found in the study area including *Strongyloides* spp., *Ascaris* spp., *Trichuris* spp. and hookworms. These all have sylvatic cycles among free-ranging wildlife hosts and lead a potential risk to health from zoonotic diseases of people living and working near the Forest Park. People's occupation had an effect on risk factors of knowledge, attitudes and practices of both infectious diseases and can help identify the cause and design measures or solutions for future problems in areas of wildlife and human community coexistence. There also needs to be a continuous assessment of knowledge, attitudes and practices of people in vulnerable areas and to educate and understand effects on behavioral modification to reduce risk factors and prevent infections to promote human, animal and environmental health.

Acknowledgments

This research project was financially supported by Mahasarakham University. We would like to thank Prof. Dr. Randall Kyes, Departments of Psychology and Global Health, Center for Global Field Study, Washington National Primate Research Center, University of Washington, Seattle, Washington, USA and all staff at Kosumpee Forest Park for guidance and assistance at the sampling field. We really feel thankful to Dr. Panyupha Thammawat, Faculty of Humanities and Social Sciences, Khon Kaen University for her valuable advice in the questionnaire design. We are grateful to Faculty of Veterinary Sciences, Mahasarakham University for diagnostic laboratory and Wildlife hospital, Khon Kaen Zoo for melioidosis diagnostic laboratory. We also thank the Wildlife and Exotic Friends Club, MSU and students from Faculty of Environmental and Resource Studies for the assistance with animal and human sampling. Finally, we really feel thank to Department of National Parks Wildlife and Plant Conservation (DNP), Thailand for permission to work in the area.

Disclosure

The authors declare that there is no conflicts of interest in this work.

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